WORCESTER POLYTECHNIC INSTITUTE

KILBY GARDNER HAMMOND RENEWABLE ENERGY CASE STUDY

Interactive Qualifying Project

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5/4/2010

A feasibility study for a photovoltaic energy plant in the Kilby Gardner Hammond Neighborhood of Worcester, Mass.

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INTRODUCTION

Currently, the world is facing a time of large scale industrialization and modernization. Industrious populations are using more energy to power their factories and supply their technologically equipped residents at the same time as third world countries are increasing their industrial capabilities and power consumption. The two main problems with a heavy reliance on fossil fuels and other non-renewable energy is the costs of production and the amount of pollutants being produced each year. Energy prices continue to rise with higher demands for ever decreasing stocks of fossil fuels. Population sizes continue to increase, creating rising pollution production and greater health risks. In many areas this is causing major negative environmental impacts. The need for renewable clean energy sources is critical to supplying the growing global energy demands cleanly and responsibly.

Even on a small scale, the benefits of using clean energy sources are plentiful. For local communities, renewable energy sources, despite a sizeable initial investment, provide long term inexpensive clean energy. Arguably the biggest economic benefit of self owned renewable energy is isolation from the rising costs of energy from large distributers. In communities where the cost of living is already too high, rising energy costs can push residents into financial trouble. Our project will investigate the process, feasibility and effectiveness of integrating a solar powered power plant in a small Kilby Gardner Hammond (KGH) neighborhood of Worcester, Mass.

The KGH neighborhood has recently begun the slow process of revitalization following years of disregard after the manufacturing plants in the area shut their doors. Much of this revitalization has been the work of the Main South Community Development Corporation (MSCDC) in an attempt to increase property values and quality of life for the residents. The MSCDC is a non-profit housing development organization located in Worcester. Through the extensive use of state and federal funding the MSCDC has used their expertise in project management to facilitate the creation of low income housing and the renovation of derelict commercial spaces.

The MSCDC works with public and private entities to raise funding for their projects and administers 1-3 million dollars annually for the redevelopment of the neighborhood. The MSCDC specializes in developing housing units; over the past couple decades, the MSCDC has renovated and built dozens of properties and made them available at low cost, some of them with integrated renewable solar energy. The MSCDC relies on strong partnership from the Boys and Girls Club and Clark University, who have made development in the area much more possible.

The MSCDC is constantly working on many projects throughout the KGH neighborhood. One of their publicized projects is at 1 Wyman Street where the MSCDC is working to rehabilitate two commercial units and six residential units. This is a classic example of the type of work completed by the MSCDC as they brought storefront properties to 1 Wyman Street and created six condominiums on the property. It is hoped that the MSCDC will continue to push towards their goals with the KGH neighborhood by assisting this proposed installation of a solar power plant.

Many of the people living in the KGH neighborhood are members of low income families with limited financial resources for a renewable energy plant and would benefit greatly from the reduced energy bills, increased property values and reduced negative environmental impact that would result from such a plant. Due to the low income status of many of the residents, the financing of this project will be an extremely large and difficult barrier of implementation. In order to ease the financial strain on the community and those involved in the project, we researched many financial subsidies and grants offered by both the state and federal government. With state and federal aid, this project could be feasible for the KGH neighborhood and has the potential to help many members of the community.

To bring a solar power plant to the KGH neighborhood there are many things that must be investigated in order to move forward with the project. To begin the process of planning a community oriented renewable energy source, we had to find a property location for the plant, the types of solar panels to be used, the total energy output and the projected payback period that results from all of these factors. These four investigations became the goals of our project in the process of moving towards the final objective of implementing a solar power plant in the KGH neighborhood, adding further financial stability and integrating green energy to the community.

Each step of the process is required for the project as a whole to succeed. These intermediary goals have become the basis for the remainder of this paper, leaving the remaining steps to be investigated further. The research that we have done for these steps of the process is quite extensive and encompasses many of the variables that could be accounted for. In this section we will explain the importance of each goal, along with a brief overview of how we were able to collect pertinent information and make decisions based on our growing knowledge.

BACKGROUND

As communities across the country and throughout the world move away from large centralized power plants towards smaller localized renewable energy plants they must also take into account a broader community wide sustainable energy plan. The goal of a community wide energy plan is to eliminate as much excess energy use and material waste as possible. This can be achieved through actions such as creating public awareness programs, recycling programs and renewable power plants.

The KGH neighborhood has the opportunity to continue moving forward with their community wide energy plan by building a solar power plant in the KGH neighborhood. The goals of this KGH Renewable Energy Case Study focus on the process of bringing this power plant to fruition. In the rest of this section we will explain the importance of each of our four goals, how they will impact the community as a whole and how they will contribute to the community wide green energy plan.

PROPERTY LOCATION

The location of the plant was the first thing that we investigated; many characteristics about the location can have a major effect on the overall efficiency and effectiveness of the solar plant. In the process of determining the best properties, we used many criteria, most notably, size, location and topography. The other criteria that we looked at were important but did not have as great an effect on the overall energy production of the location. (For a complete description of our criteria please reference Appendix B.)

SIZE

The size of a lot is a major selling point for the feasibility of a photovoltaic plant. Because solar panels must be laid with no obstruction of direct sunlight, they cannot be built in layers or positions that allow their solar cells' solar exposure to overlap. The size of a lot directly relates to the number of panels that may be installed, thus affecting the maximum power potential of the entire system. Also, given the zoning conditions of a lot, it may be against the local zoning ordinances to build structures close to the edge of a property, so free space may be a requirement of a lot. On the other side, choosing a very large lot could prove to be a waste of developable space. A good way to deal with an oversized lot is simply to break the lot into smaller lots and sell the unused space.

LOCATION

Given the goals of this project, the location of the property is extremely important. The chosen location must be able to support a large solar installation with minimal negative impact to the surrounding neighborhood as well as being well suited for solar generation. Residents may not like the sight of a large power plant installed in their backyard. Keeping this in mind it still has to be located in a manner that lends to easy power distribution to the community. In addition to aesthetic and distribution concerns, it must also be noted that there must be plenty of solar exposure and limited chance that a large structure will be built that blocks such exposure.

TOPOGRAPHY

Lot topography can become the deciding point for the feasibility of any structure, whether it is a building or a power plant. In the case of photovoltaic arrays, lot topography is especially important. An uneven topography could cause large construction costs to level or resurface the property. Because of the particular latitude of New England, the property's solar exposure could be greatly reduced if it slopes downhill in a direction other than directly south. In the case that the land is poorly exposed, either a considerably sized structure must be built or the surface must be altered to compensate. These added costs can make the payback period of a photovoltaic array much longer.

TYPES OF SOLAR PANELS

As solar power continues to become in higher demand, many companies are coming out with their own technology. In order to sort through all of the major companies and the many product lines of solar panels, we had to decide on the best method to determine the appropriate solar panels for the KGH neighborhood. The most important factors in the decision are cost, total output and size.

COST

The direct cost of a panel is not a good representation of the resultant cost of installation for a solar power plant. Given the different properties of different solar systems a relative cost analysis must be completed. In regards to solar power, the most important number in regards to cost is the number of watts (energy output) per dollar. The lower the cost per watt the more power output that can be gained by the same initial investment. The issues that may arise with lower cost panels, however, is that these panels typically will lose their functionality sooner, are less durable then higher priced models and often feature a lower efficiency.

EFFICIENCY

The efficiency of the plant is the total amount of energy that can be generated per square meter of solar panels. Efficiency considerations should be made for plots of land that do not have an abundance of space. Given the total output and the size, we are able to determine the energy output per square meter. Depending on the size of the lot and the desired total output of the project, this can be a large part of the decision process. Panels with a lower efficiency tend to be cheaper and if space is not an issue, then these cheaper panels definitely are worth the extra space that is used, likewise if the amount of available space is not in excess this can become an issue.

COST VS. EFFICIENCY

Cost and efficiency alone cannot become the deciding factor when it comes to solar panels. They must be balanced with each other in a manner that best fits the location and desires of the community. It often comes down to the amount of available space, but in a project such as this one where there is not a required output level, the community may decide that getting the most output for the investment is the only important factor. This becomes a simple question of the goals of the community and how much they are willing on spending to have more efficient panels.

TOTAL ENERGY OUTPUT

The total energy output of a solar power plant is dependent on the rated output of the plant and the amount of solar energy that reaches the plant on any given day. The rated output of a plant is the amount of power that could be generated by a plant if all the panels were receiving direct sunlight. A plant will often not output its total rated output, as the sun may be blocked by clouds, and will output almost nothing during night hours. Total rated output of a plant is a decision of the KGH neighborhood and depends on the size of the investment that they intend to make.

Solar exposure is a major factor in the total energy output of a solar power plant. It is well known that depending on the location, a plot of land may receive more or less sun throughout the year. For example, the equator has much more solar energy than northern latitudes, such as Massachusetts. In order to find the expected total energy output of a solar power plant, the amount of energy that is expected to be present is needed. The expected solar energy can have a major effect on the feasibility of a project and if there isn't enough solar potential, the project will not be able to move forward as it is not economically viable.

PAYBACK PERIOD

From a financial investment point of view, the payback period of any project is most important consideration. We will be using the cost analysis information from both the property and the technology along with the expected energy output to calculate the expected long term payback period for this project. This will allow the KGH neighborhood to understand how long it will take for their solar power plant to start creating an income for the residents and the community as a whole.

BACKGROUND CONCLUSION

Each of our four goals, finding a property location, types of solar panels to be used, the total energy output and the projected payback period of the project are extremely important to the success of a solar power plant in the KGH neighborhood of Worcester, Mass. Now that we have laid out the importance of each of these steps, we can move forward to the process that we used to meet our goals.

METHODS

For each of our four goals we stepped through an organized process of finding the required information, thus allowing us to come to appropriate conclusions. Each goal required slightly different methods of acquiring information; the methods we used are laid out here.

LOCATION

We started our search for the best location with the general topography of the area to get a sense of what we were dealing with by using Google Maps and local zoning maps. We then proceeded to visit the neighborhood to get a hands-on view of the area we were dealing with. Once we were able to get a good idea of which properties we were interested in, we contacted the City of Worcester Assessor's Office for property values and other financial information about the properties. It was also important to take a look at the utilities available to the property and the Brownfield status for more government funding. Lastly, once we had all of the desired information, we created a set of criteria to judge each of the properties against each other and come up with the best possible solution for the KGH neighborhood.

MAPS - GEOGRAPHY

Google Maps was extremely helpful in the early stages of planning to allow for an overview of the area. We were able to get a general idea of the topography and size of the different plots as well as view the existing structures on the property. This allowed us to immediately eliminate areas that were clearly not suitable for our needs due various issues such as railroads or active businesses. We also were able eliminate parcels that were too small or had adjourning buildings that would block sunlight from the location. In addition to a general overview of the area, we looked at how the area was built to see where businesses, industrial and residential areas met to determine locations where it made sense to integrate into the community. We attempted to avoid selecting locations that would displease close residents and business owners as solar plants are large and not very discrete entities.

When we reached the limit of the accuracy and lack of information present with Google Maps, we contacted the city of Worcester for a copy of the zoning maps in the area. These gave us a lot more information about the area and allowed for us to get an understanding of what parcels were zoned for solar arrays and renewable energy plants, thus eliminating more areas that were not suitable to our needs and constricting our search to the remaining parcels. At this point, we had reached the end of the aide we could get from maps without seeing the area for ourselves.

GETTING OUT THERE

The Main South area of Worcester has experienced a period of economic decline due to inactivity in the factories and lack of production in the area. Many of the parcels of land we investigated are unused and uncared for. This can cause maps to be out of date, not portraying the real current state of the area. For more accurate information of the area, we had to visit the areas and see for ourselves what was available and how each of the parcels compared to each.

One of our biggest concerns was the neighborhood layout and how that would affect our efforts of a renewable energy initiative in the area. It was important that we survey the land to make sure that the areas of interest were within the neighborhood but not in the way of possible future revitalization efforts. This caused us to look away from currently populous areas and busy sectors of the neighborhood and lean towards the more industrial areas of Main South.

Through researching the maps, we were able to determine a limited number of areas that had to be scoped out, as each parcel had to be examined for accuracy of records and solar potential. The main factors we looked at in this regard were, view of the southern sky throughout the day, development status, condition of the property and general positioning of the location and its fit for a solar system. The view of the southern sky is extremely important for a solar power plant as in this area of the world; a majority of the energy from the sun comes from a southern direction. Due to other revitalization efforts in the area, it was important to determine which properties already had development plans that would get in the way of a solar power plant. The onsite land analysis of the property condition was extremely important as this information was not readily available from other sources and was not current. Many of the properties had abandoned vehicles and other waste that would have to be cleaned and removed before moving forward with the project.

As previously stated, much of the information we had on the properties was old and out of date. For example, some records may have a building on a property that was demolished and removed without the records being updated. The Google Maps aerial photographs were not always accurate and were a few years old, giving a misrepresentation of the state of the properties. Due to the nature of the power plant it was also very important to survey the possible connection to the grid and the availability of relatively new power lines to the area.

CITY OF WORCESTER ASSESSOR'S OFFICE

With all of our research into the available properties and their physical characteristics, there was a large amount of information that we were unable to glean from the maps and onsite analysis. An extremely important set of data from the Assessors' Office included the property values of each of the parcels along with their past and current values and how those values were expected to change. The actual financial aspect of the land and the implications involved with the acquisition of the land became a large portion of the project and with the help of the Assessor's Office, we were able to acquire the required data. From the Assessor's large database, we were able to extract the size, shape, cost and existing owner of each plot of land. This was invaluable information for cutting down the number of proposed plots. We then looked further into the land's economic history and examined the liquidity of the land and any recent value changes that had taken place to determine how desirable the land was to potential buyers.

UTILITIES

Though this study is of the installation of a solar power plant with limited need for utilities, there is still the need of electrical hookup to the grid and sewer for drainage of the land. With the aid of the Worcester Public Works Office, we were able to determine that all of the feasible sites had adequate sewer access. National Grid did not cooperate in the investigation and we were unable to find definitive data on the existence or cost of install for high power transmission lines; National Grid did not wish to disseminate this information, likely to protect the integrity of the grid against possible terrorism.

BROWNFIELDS

One of the important aspects to the installation of a solar power plant in this area is the possibility of building the plant on a brownfield. The properties deemed brownfields are eligible to receive more federal government funding to develop the area and install green energy solutions. We researched the brownfield status of the feasible sites through the EPA Brownfields database and incorporated that into the scoring of the properties. This was complicated further by the fact that many brownfield sites' status is not made public for the economic protection of the land owner.

CRITERIA

Now that we had a large spreadsheet of all of the pieces of land and their respective values, we created a set of criteria to determine a raw score of each of the parcels.

Attribute	Reason	Scale Type
Size	Area of lot determines the possible number of panels that can be placed and in turn the maximum power output.	In units
Location	The lot location is important because it must be in a location that is suitable for a photovoltaic module. Important factors include what surrounds the lot, accessibility of the lot and aesthetic considerations.	Scale
Topography	The lot must be in an advantageous position to receive maximum solar flux. If the lot is on a hill facing North, construction costs to displace the soil may be large or the task may be impossible.	Scale
Brownfield Status	If the lot has Brownfield status, it may be eligible for EPA funding for development.	Boolean
Zoning	If the lot is zoned in a specific manner it may require specific zoning for a PV system.	Value
Buildability	If the lot has development issues such as bad soil, existing conditions that make it unbuildable or other issues, it may not be developable and a solar farm may be an attractive idea.	Scale
Grid Connection	If the lot has multiple grid connections, there are more options for connecting. Also, construction costs change with different connection types.	Number/Scale
Current Structures	If there are significant clean up costs or existing buildings, a property may not be worth it. However, development grants must be considered.	Scale

TABLE 1: CRITERIA FOR PLANT LOCATION

See Appendix B for a complete explanation of these criteria.

SOLAR MODULES

Many of the available solar modules are very similar in quality and price. The exact panels that are purchased tend to be picked by the installer depending on what they are comfortable with. This said, knowledge of the available panels is important information for the KGH neighborhood. We researched the available panels and tried to get the wholesale prices for the panels as this installation would be large enough to buy panels in bulk. Many manufacturers did not readily make the prices of the panels available since transactions tend to take place through a middle man, typically the solar installer. Through direct contact with the manufacturers, we were able to gather the desired data. In order to give a comprehensive analysis of the panels, we looked at cost, power output, warranty, efficiency, size and weight. All of these variables are extremely important and can affect the final feasibility of the project. Depending on the location and the required specifications of the power plant some of these variables become more important than others. Because of the fact that we had found so many panels with so many different sets of characteristics, we created a large dataset of all of the available panels and cut that down to the top eight panels seen in the findings chapter.

OTHER SOLAR SITES

In our quest for a greater understanding of the process of implementing a solar power plant, we looked at other such plants that currently existed around the country. By looking at the size, location, power generation, technology and monetary value of these plants, we were able to judge the relative feasibility of a plant in the KGH Neighborhood. A major consideration for power plants is the public perception of the plant and solar is no different. By looking at previous plants we were able to get an idea how past communities had accepted the power plant into their community. These sites are not as highly publicized as we thought and we spent a considerable amount of time searching through news articles, blogs, government sites and private publications to come up with a small list of existing plants.

TOTAL ENERGY OUTPUT

The last part of our research led us to the energy generation of the power plant and how it would pay itself off in the long run. In order to find this information, we needed accurate solar irradiance data for this area of Massachusetts. The Army/Navy did an extensive sun study in Worcester that analyzes the amount of sun energy throughout the year on differently angled panels. This data is extremely helpful because it gives an accurate representation of the amount of sun energy that is expected to be available throughout different times of the year.

Along with figuring out the amount of energy that we could generate, we also had to look at the amount of money that could be made off of that energy. Electrical energy continues to be worth more money as the cost of oil and gas increase and these trends are an important consideration in the long term analysis of a power plant. By talking directly with N-Star, we were able to check current power prices for both wholesale and residential/commercial retail and project our monetary values once the plant was up and running.

PAYBACK PERIOD

To find the payback period of the project we did not need to do any more research. We had already found all the required information in previous sections and it was just a matter of using that information. The payback period of a solar power plant project such as this is dependent on a few different variables, the initial total investment, the expected amount of energy generated and the profit from that energy. For each of our different plots the initial investment was different due to the price of the land and the amount of available solar space. The expected energy output is a result of the total size of the plant and the expected amount of sun. In this area of Massachusetts, the average number of Sun Hours per day is 4.5. An example solar array of 500kW would have the following expected output per year:

$$Total\ Energy = 4.5\ Sun\ Hours * 365\ days * 500kW = 821{,}250kWh$$

Given this total output we can solve for the expected yearly profit by using the estimate of $0.12/kWh:

$$Yearly\ Profit = \$0.12\ *\ 821{,}250kWh = \$98{,}550$$

Now to continue our example we'll estimate the initial investment of this project to be $4/W for a total initial investment of $2 Million. By dividing this number by the expected yearly payback we get the estimated total payback period for the project:

$$Payback\ Period = \frac{\$2{,}000{,}000}{\$98{,}550} = 20.29\ years$$

This value of about 20 years is the average payback period for solar panel installations in Worcester. We stepped through these calculations for each of the proposed properties in order to figure out the specific payback period for those properties.

FINDINGS

Now we will delve into the specific locations within the KGH community along with the technology, irradiation measurements and costs associated with each of these sites. There are many more sites available in the KGH neighborhood then can be included in the write-up of the study but we have picked what we believe to be the top five best locations and included the many others that we have investigated in Appendix C. Throughout this section we will be explaining the importance of each of the variables we investigated and how we were able to narrow down the options to the best possible solution.

LOCATIONS

There are many available plots in the KGH Neighborhood that offer the required assets for a renewable energy location. In order to choose the best locations for this type of project, we came up with a set of criteria and scored each of the parcels. This allowed us to come up with a numerical representation of the available properties and distinguish the ones with the highest value for such a project.

PROPERTY

After studying many of the locations throughout the area, we were able to come up with five major locations that fit the criteria we laid out as seen in Appendix B. These five parcels stood out from the rest and are listed below in order from lowest raw score to highest. Each property has its pros and cons and depending on the final goals of the project they could all be potential locations for a solar installation. The initial raw score is a rough estimate of the value of the property for use as a renewable energy plant. In the next section, we will look deeper into each of the parcels and how they relate to each other in regards to renewable energy.

LOCATION:	33 KILBY ST	92 GRAND ST	0 TAINTER ST	49 CANTERBURY ST	55 TAINTER ST
Land Value:	$105,100	$264,900	$232,800	$247,100	$292,400
Lot Size (sq ft):	33,413	95,157	34,602	75,707	130,652
Max Power Size (W):	413000	1176000	428000	935000	1614000
Panel Only Cost:	$1,743,000	$4,963,000	$1,806,000	$3,946,000	$6,811,000
Total Cost:	$1,848,100	$5,227,900	$2,038,800	$4,193,100	$7,103,400
Payback Period (yrs):	22.7	22.6	24.2	22.8	22.3
Profit/Month:	$7,000	$19,000	$7,000	$15,000	$26,000
Raw Score:	**37**	**39**	**40**	**42**	**42**

TABLE 2: PLANT LOCATION DATA (CITY OF WORCESTER, MASSACHUSETTS, 2009)

COMPARISON

The raw score shown above is a rough estimate of the property feasibility and more analysis of the values must be looked at. One of the biggest factors in picking a renewable energy location is the return on investment of a certain location. With this in mind we looked at the comparison between property values, cost of install and total panel space. By plotting these together we can show:

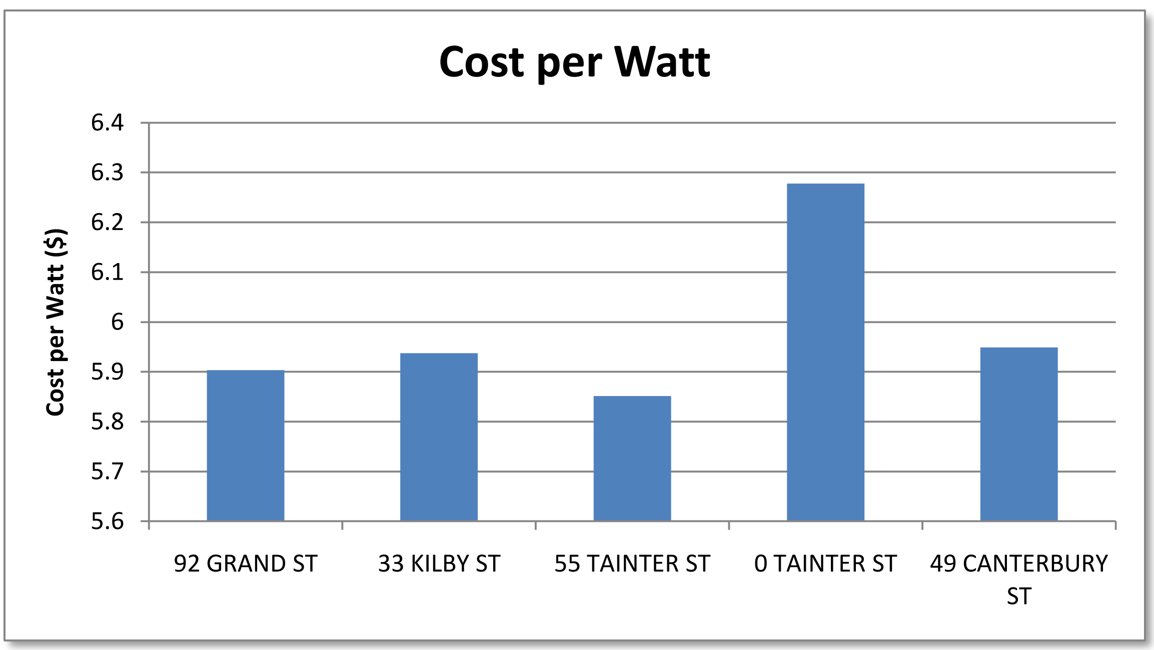

CHART 1: COST PER WATT COMPARISON

The cost per watt analysis shows that, though both 55 Tainter St. and 49 Canterbury St. had the same raw score, the cost per watt to install solar at the Canterbury site would be almost $0.10/watt more. This can have a substantial impact in the long term payback of an installation. 0 Tainter St. is much more expensive per watt; this will make continuing with any project at this location much more costly with a long payback period. With this in mind we must look at the total cost of installation because though 55 Tainter St. is the cheapest per watt it is also the biggest project overall.

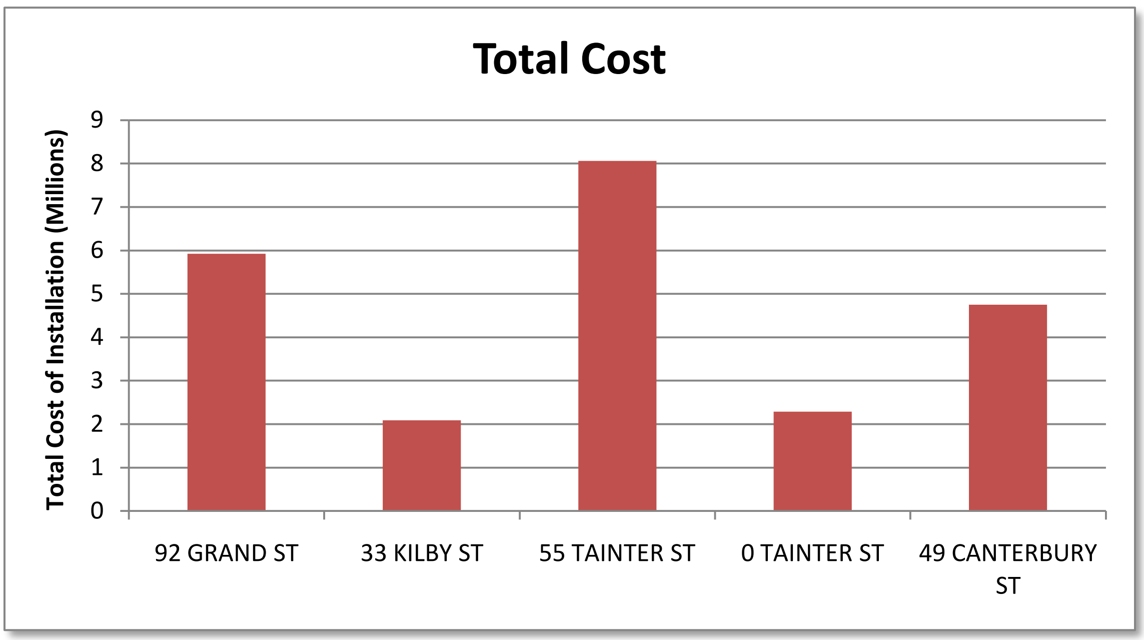

CHART 2: TOTAL COST COMPARISON

Depending on the size of the investment for the project, some locations may be eliminated due to excessive costs above what is feasible for the KGH Community. From our other analysis, 55 Tainter St. is the best location for installing solar with an unlimited budget but the install cost is estimated to be just above $8 million dollars where 33 Kilby St. is about $2 million.

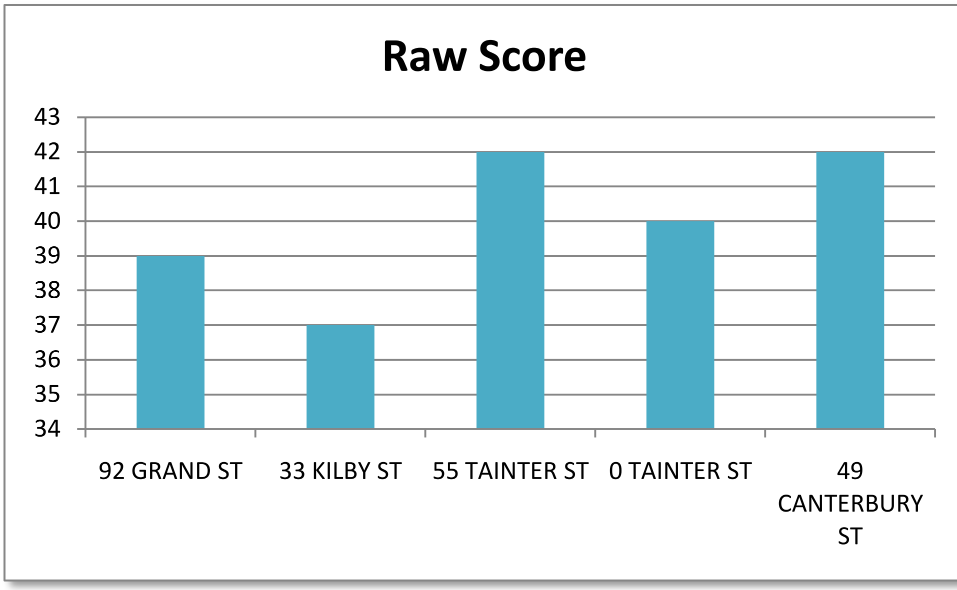

CHART 3: RAW SCORES

It is easy to see that with an unlimited budget, 55 Tainter St. is the best option for a renewable energy project but given the excessive costs involved with the location the solution becomes much more complicated. 33 Kilby St. is very good when it comes to cost per watt and total cost, but did not score quite as well on the raw scoring of the location due to a cement structure and surrounding obstacles. Each of the five locations presented here has its respective benefits and depending on the available funds for installation the decision will be easy to make.

SOLAR PANELS

There are many available solar solutions that come at different costs per watt and watts per meter. These are both extremely important aspects in picking a solar panel since both variables effect the final production, payback and installation cost. If space is a limiting factor, then the number of watts that can be generated per area is important and if space is less of an issue, then the cost of each watt may be the deciding factor. The KGH community has an excess of land and no direct energy requirements so the most obvious deciding factor in the decision of which solar panel to use would be the return on investment in the project.

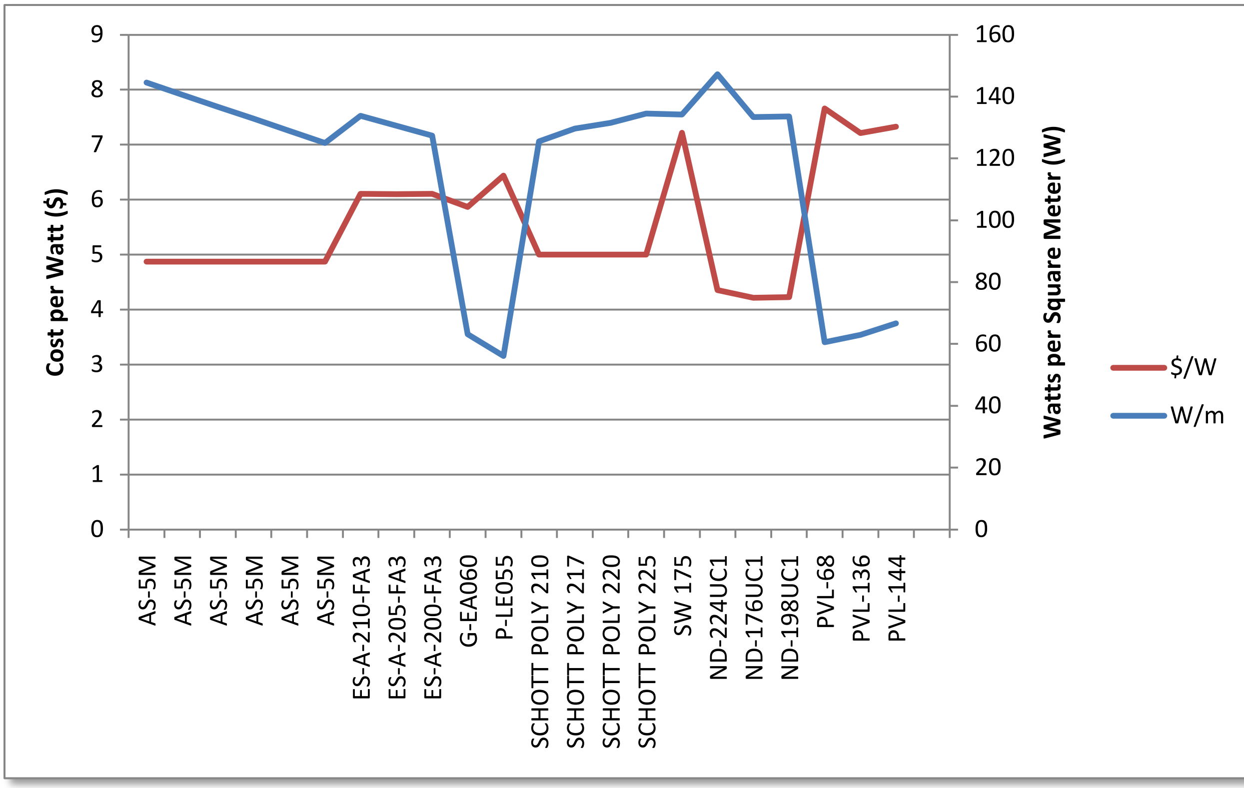

CHART 4: COST PER WATT AND WATT PER METER

It can be seen in Chart 4 that the Amerisolar AS series and the Sharp Electronics ND series panels have the highest watt/meter rating and the lowest cost per watt rating. For a low cost project like this, the ND series would be the best option for lowest cost of installation. Each particular panel has its pros and cons to every situation but these eight panels are the best of the ones we studied.

	AS	AS	AS	AS	AS	AS	Sharp	Sharp	Sharp
Model	AS-5M	AS-5M	AS-5M	AS-5M	AS-5M	AS-5M	ND-224UC1	ND-176UC1	ND-198UC1
Output (W)	185	180	175	170	165	160	240	176	198
MSRP ($)	$902	$878	$853	$829	$804	$780	$1,045	$742	$837
W/m	145	141	137	133	129	125	147	133	134
$/W	$4.88	$4.88	$4.88	$4.88	$4.88	$4.88	$4.35	$4.22	$4.23

TABLE 3: TOP EIGHT PANELS (SEE APPENDIX C)

We will use these values in the findings section to give an overall decision on what panels to use with each parcel of land in the study.

PAYBACK PERIOD

The payback period of any investment is extremely important to the interested investors. Due to the ever changing political environment of renewable energy, the government funding is extremely difficult to pin down to a specific amount. With this in mind, we did our payback period analysis assuming no government funding and worst case scenario for the project.

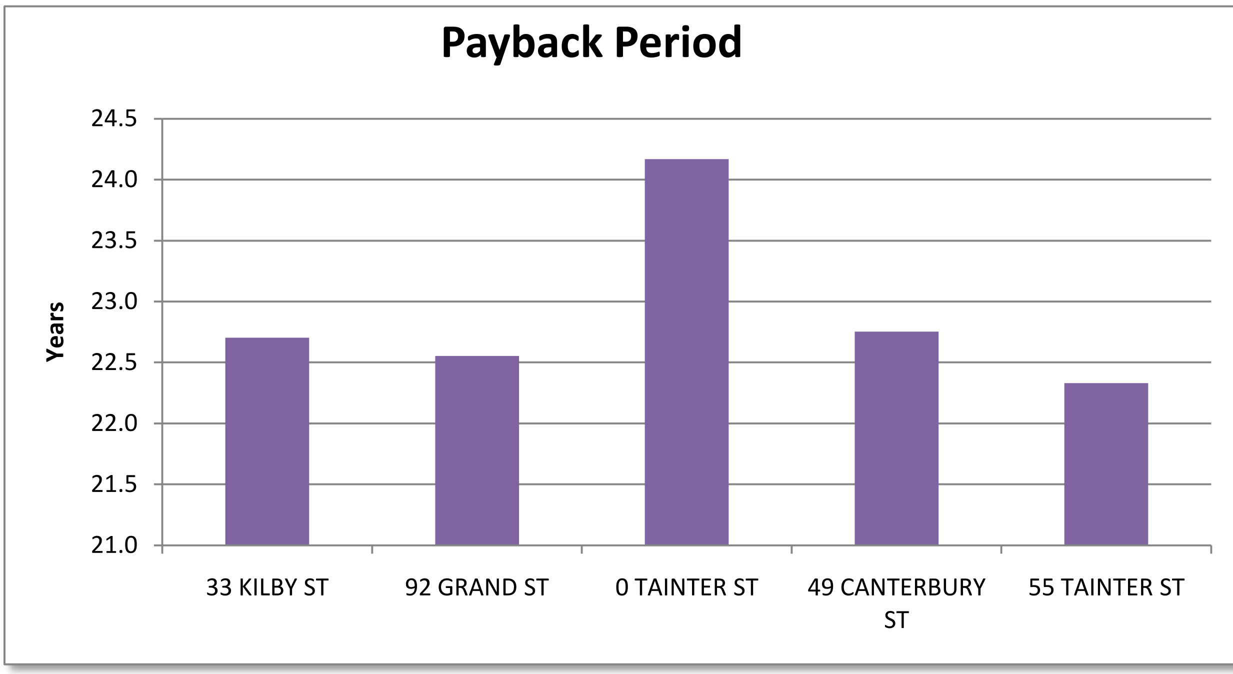

CHART 5: PAYBACK PERIOD

All five locations have a payback period of about 22 years with 0 Tainter St. standing out at over 24 years. This is a relatively common payback period for solar panel installations and any government incentive will only work to bring this number down. Once the panels have paid themselves off, they will continue to generate electricity, yielding a pure profit for the Main South Community minus mostly government subsidized property taxes.

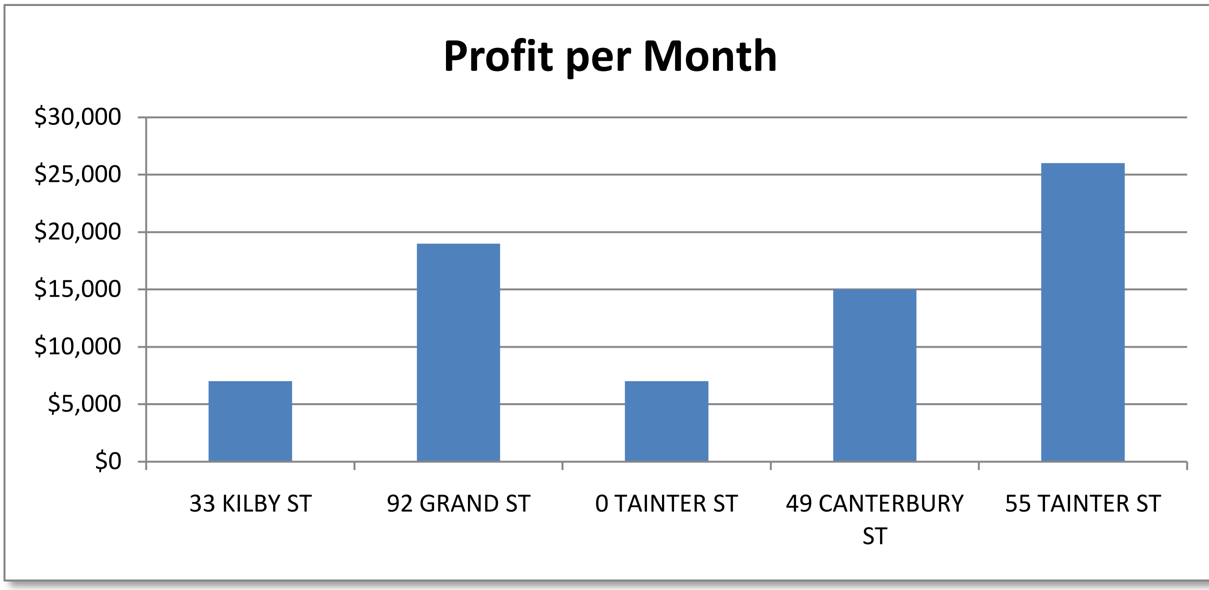

CHART 6: PROFIT PER MONTH

IRRADIATION MEASUREMENTS

One of the most important factors of solar power generation is the amount of sun that is received at a certain location throughout the year. This, combined with the positioning of the solar panels, determines the total amount of energy that can be harvested from a particular piece of property. The Navy did a long study of the amount of sunlight received at a location outside of Worcester. This study took into account many different variables including the degree tilt of solar panels and whether or not the panels follow the sun (mechanically align themselves to face the sun). We looked into both of these systems for the KGH neighborhood to analyze which would be most beneficial to the area.

FIXED POSITION

First we looked at panels mounted in a south facing fixed position with varying tilts relative to the horizon. Chart 4 shows these values for 0°, 27.27° and 42.27°.

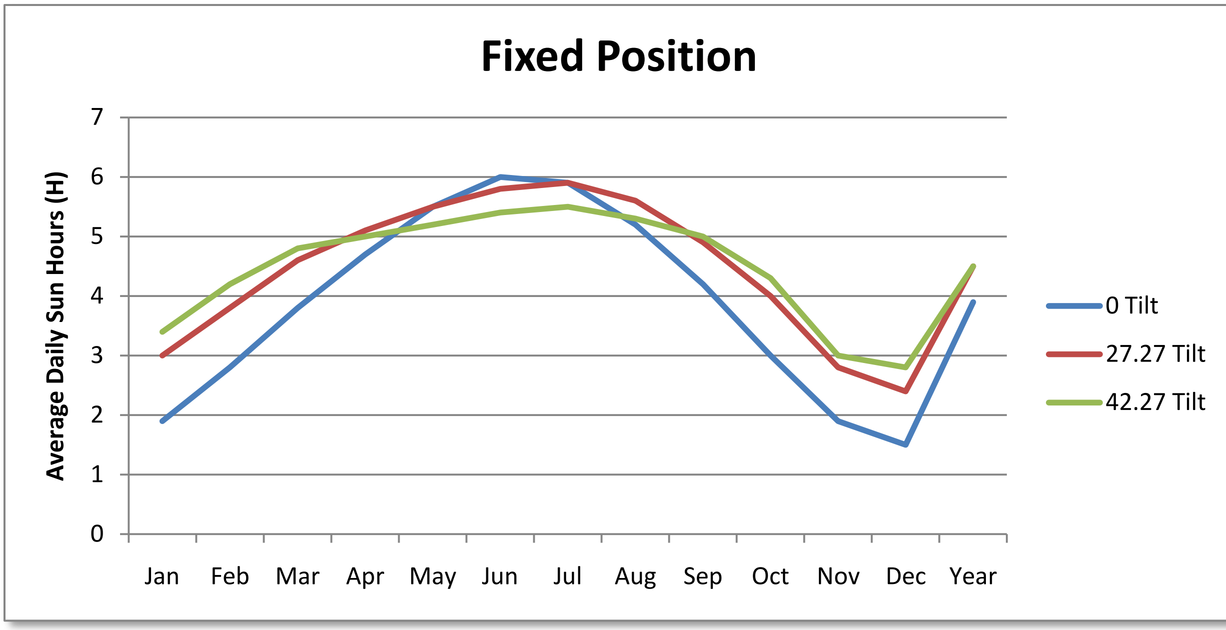

CHART 7: PIXED POSITION IRRADIATION (NATIONAL RENEWABLE ENERGY LABORATORY, 2008)

It can be seen in Chart 4 that both the 27.27° and the 42.27° tilted systems worked much better than the 0° system. Both of these systems have their pros and cons that must be weighed since they have the same yearly average sun hours. The 42.27° system would generate less electricity during the summer hours but would also generate more over the winter months. Inversely the 27.27° system would generate more in the summer and less in the winter. At 42.27° the snow would slide off much easier in the winter but would limit the number of panels that could effectively harness the suns energy within one parcel of land. This can be seen in Figure 1.

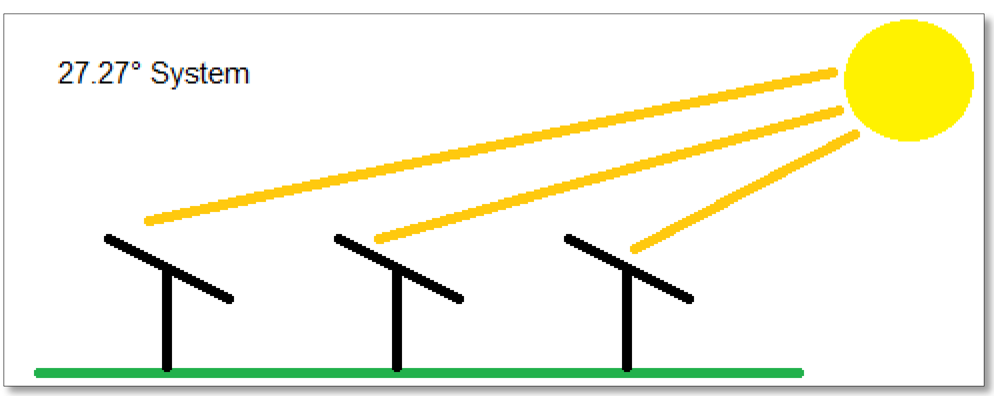

FIGURE 1: 27 DEGREE TILT

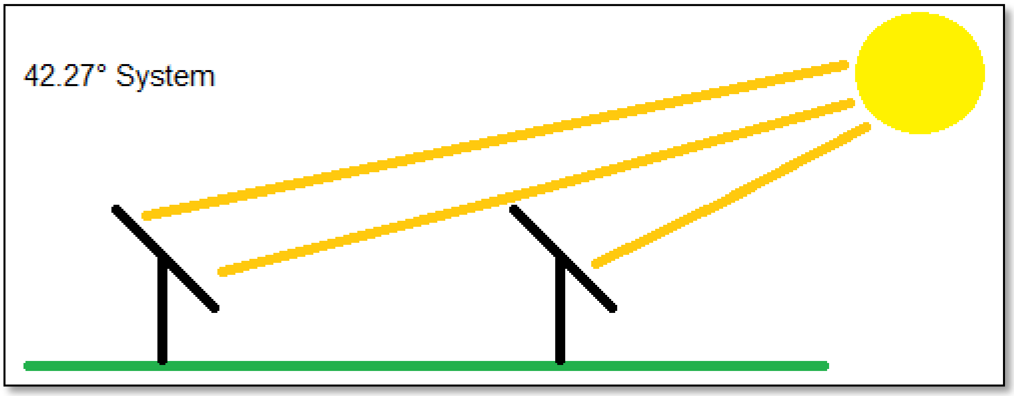

FIGURE 2: 42 DEGREE TILT

The 42.27° system has more direct light on the panels but with few panels, this could be an issue if space was a problem and will be taken into account in the final analysis in the findings section. The best solution often depends greatly on the location and the expected snow in the winter. If it is expected that the panels will be covered in snow most of the winter anyway and the amount of energy gathered in the winter is nominal then a lower angle is probably most beneficial. However, higher angle panels shed snow more readily.

1-AXIS SUN TRACKING SYSTEM

The final system we investigated was 1-Axis Sun Tracking, which allowed for the panels to stay at a fixed pitch in relation to the southern sky but followed the sun from east to west as it traversed the sky. This system has a much higher install cost and is often far too expensive to make it worth the extra energy creation. Chart 5 shows the irradiation data for the 1-Axis Sun Tracking System.

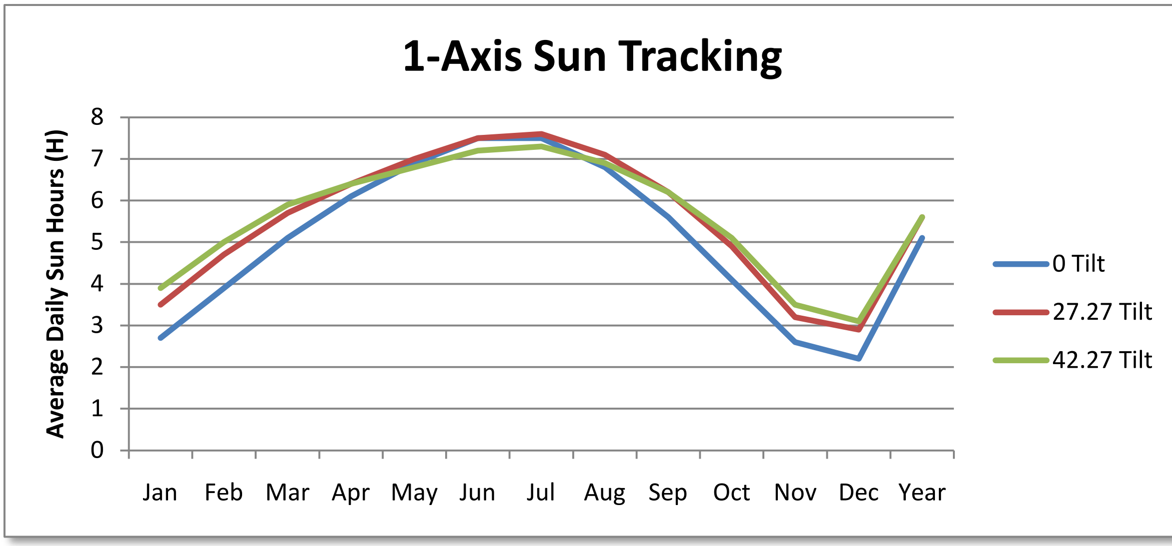

CHART 8: 1 AXIS TRACKING (NATIONAL RENEWABLE ENERGY LABORATORY, 2008)

It is easy to see that the amount of energy that could be generated with a 1-Axis Sun Tracking system is about 25% more than that of the fixed position panels. Even though this is a substantial amount, the expense of the tracking system is such that it would take longer for the system as a whole to achieve a positive return on investment.

FINAL ANALYSIS

Given the results of the data presented it seems that there is a relatively clear result for the technology and use thereof. The best panel for this type of project was the Sharp ND-176UC1 as it has the highest watt per meter ratio and lowest cost per watt. The sun tracking system does not offer enough added benefit to counter the extra cost and engineering that must take place, so a fixed position system is best. The panels should be placed facing south at an angle between 27 degrees and 42 degrees. Depending on the desired number of panels this angle can change but the closer to 42 degrees the better. The steeper pitch allows for snow to slide off the panels in the winter and also has a more constant power output throughout the year.

As for the properties involved, all five plots analyzed in the findings section have many benefits. The best location for payback is 55 Tainter St. as it has the lowest cost per watt and allows for the largest power installation. Given the vast size of 55 Tainter St. it may be of interest to the investing parties to build the project on a smaller location or resell portions of the remaining land. Given the size restraint 33 Kilby St. becomes much more attractive with its low cost per watt and low total investment costs. The payback period is comparable with 55 Tainter St. and would be a great entry point for a power plant for the KGH community.

CONCLUSION

As oil prices continue to rise and coal loses the support of the public opinion, the demand for clean energy sources becomes even more prevalent. In addition to financial and public opinion issues there is the extremely prevalent issue of global pollution that must be curbed. These factors became the basis behind a study of a solar power plant in the Kilby Gardner Hammond (KGH) Neighborhood. Once the decision was made to investigate the possibility of a renewable energy plant in the KGH Neighborhood, we came up with a list of specific goals that had to be achieved and took on accomplishing the four most demanding hurdles for installation.

This project began by finding an appropriate property location for the plant. Many areas throughout the neighborhood had available space and would be adequate, but by taking the investigation a step further, we were able to narrow the properties down to just two locations. Both 55 Tainter St. and 33 Kilby St are very viable locations for a solar plant and depending on the needs of the KGH neighborhood in conjunction with the amount of funding available, either could become the final property for the plant.

Given the understanding of where the plant could be installed, the next step in the renewable energy planning process was finding suitable solar panels for the project. The difficulty finding an appropriate solar panel is the fact that there are so many options to choose from. The solar panel industry has grown exponentially in recent years with large corporations and small businesses jumping to take a piece of the growing market. Once we had collected a substantial number of solar options, we were able to use our limited requirements of space, lighting and cost to filter out the best panels for our implementation.

After gathering information and making several estimates about irradiance, array size and panel efficiency, we were able to project a total maximum power output for a renewable energy station at each of the locations. The results of this were very promising; in the case of 55 Tainter St, the expected energy output would be enough to power close to 400 average American homes using 600kWh a month. This is extremely important information as it is central to the projected payback period calculations and the number of residents who would benefit from the project.

As with any investment, the payback period of this project is central to the feasibility of the project in the long run. We were able to use the property value of the land and the installation costs of the panels to determine the total initial investment. This, combined with expected energy output allowed us to calculate an expected payback period of about 20 years. This is worst case scenario as it does not take into account and government funding or rebates. For a plant of this size, this is a very acceptable payback period for the KGH Neighborhood.

This project was successful in achieving the desired goals. We have been able to lay a solid foundation for future work in aiding the MSCDC to create a solar power plant in the KGH neighborhood of Worcester, MA. For this project to become a success, there is still a long ways to go. The KGH Neighborhood has to figure out their desired energy output in order to come up with an appropriate plant size. The integration with National Grid must be negotiated for maximum payback to the residents of the community. Due to ever changing government funding it will be important to determine the amount of funding available. Once these hurdles are overcome the MSCDC can move forward with the project and bring final fruition to a solar power plant in the KGH Neighborhood.

APPENDIX A

FINANCING

LOCAL STATE GOVERNMENT POLICY AND FUNDING

Governor Patrick of Massachusetts is committed to developing renewable energy and is consistently setting new regulations and incentives for green energy. A strong proponent of the Cape Wind Project and other energy projects, Patrick creates an environment in which it is much easier to move forward with renewable energy projects. A few of the local state regulations are laid out here including the Green Communities Act of 2008, Massachusetts Solar Stimulus, RPS Solar Carve-Out along with others. All of these incentive programs could be beneficial to the KGH neighborhood if the correct steps are taken to secure funding. The process of applying for each specific incentive or program is constantly changing as new regulations arise, so contact with state officials at the time of project installation and funding must be made to assure that all the correct steps are taken.

MRET

The Commonwealth of Massachusetts has recently passed a large amount of legislature to aid in the ease of development for renewable energy sources. A prime example of one of the trust funds created to help fund these projects is the Massachusetts Renewable Energy Trust. This trust was created to "maximize environmental and economic benefits for the Commonwealth's citizens by pioneering and promoting clean energy technologies and fostering the emergence of sustainable markets for electricity generated from renewable sources" (Massachusetts Renewable Energy Trust, 2009).This trust is a very open organization and can provide funding for individuals, businesses, non-profits, communities and affordable housing developers. One piece of this trust is the Green Affordable Housing Initiative, a $25 million fund aimed at integrating renewable energy into affordable housing as an aid to the residents (Massachusetts Renewable Energy Trust, 2009).

Thus far, MRET has aimed to develop 1,600 green properties with a total of 2,175 kilowatts of power generation, which is more than enough energy to power the 1600 properties as the average home in the United States consumes about 1.2 kW. The MRET program would be very interested in helping out a project with the KGH neighborhood as the project aims to achieve the very goals of the MRET program, bring cheaper cleaner energy to the residents of Massachusetts.

THE GREEN COMMUNITIES ACT OF 2008

The Green Communities Act (GCA) was signed into Massachusetts legislature in 2008 and pushes strong energy reform by creating incentives for renewable energy (Massachusetts Technology Collaborative, 2008). The Green Communities Act takes steps to make it easier for not only utility companies to install and own renewable energy sources, but for private entities as well. The GCA now makes it legal for private renewable power plant owners to sell their energy back to the power utility companies for the same rate that they purchase it for. This practice of buying and reselling power off the grid is known as "net metering". As of 2008, installations up to 2MW may participate in this program before they need to sell their excess generated energy at a wholesale rate. The proposed installation for the KGH neighborhood would fall well inside of the 2MW limit for "net metering" and therefore could benefit greatly over time from the return payment for the power generated above and beyond that required by the residents within the KGH neighborhood.

COMMONWEALTH SOLAR STIMULUS (MASS)

Commonwealth Solar Stimulus is managed by the Massachusetts Clean Energy Center (CEC) and paid for by the American Recovery and Reinvestment Act (ARRA, see the National Funding section for more information on the ARRA). This stimulus creates rebates for new installations of grid-tied photovoltaic systems. The project size must be at least 5kW and less than 200kW but there is a structured payment depending on the size of the installation. Installations under 25kW can receive $1.50/W which would amount to $30,000 for a 20kW system. Above 25kW the price per watt drops to $1 and drops again above 100kW to $0.50/W. With this in mind an initial investment at the Kilby, Gardner and Hammond Neighborhood could fall easily under the 25kW size with a substantial rebate opportunity.

In order to benefit from this program, the system installers must complete the required applications and receive the appropriate permits. These are all filled out through the CEC and most solar installation companies throughout the state are familiar with these procedures and are able to complete the appropriate documentation prior to the installation. It is recommended that the installers obtain a North American Board of Certified Energy Practitioners (NABCEP) PV installer certification. Lastly, there are additional compliance requirements due to the funding from the ARRA that often change depending on the source of the current funding. These specific regulations will have to be determined at the time of installation for the site.

NEIGHBORHOOD NET METERING

Net Metering allows an entity with an onsite renewable energy generation plant to sell excess power generation to the electric supplier at a price just under retail. This can be extremely cost effective for a plant such as the case study with the Kilby, Gardner and Hammond Neighborhood. The Net Metering guidelines prohibit the inclusion of utilities into the net metering program but allow the inclusion of neighborhood power solutions. This opens the door for a solution for the Kilby, Gardner and Hammond Neighborhood to create a centralized power plant that must generate power for at least 10 homes in the neighborhood as well as local commercial locations. The coordination of this is a bit more complicated due to the inclusion of multiple entities and further investigation is needed.

"Credits may be carried forward to the next month indefinitely, and credits from net metering facilities may be transferred to another customer of the same utility as long as they are within the same service territory and ISO-NE load zone. Utilities may choose to pay for the net metering credits for Class III facilities rather than allocating the credits. If a neighborhood facility has NEG at the end of a billing

period, the credits are awarded to designated neighborhood customers. The amount of NEG attributed to each such customer is determined by the allocation provided by the neighborhood net metering facility. Credits may be carried forward to the next month indefinitely." (Phelps, 2009)

SRECS

Solar Renewable Energy Credits are a helpful funding solution for midsized solar arrays below 2MW in size. In order to fully understand Solar Renewable Energy Credits, it is important to first look at the requirements of electric supply companies in Massachusetts. The state has a Renewable Portfolio Standard (RPS) that must be met by every energy supplier in the state. The RPS states that every supplier must acquire at least 15% of its energy from renewable energy sources and can do this through purchasing RECs or in the case of solar more specifically SRECs.

SRECs can be purchased through two main sources. The first, Solar Credit Clearinghouse Auction (SCCA), is cheaper for the supplier as the cost is $300/MWh. The second is the Solar Alternative Compliance Payment (SACP) for $600/MWh. These two different price marks act as a base rate and a maximum rate for SRECs in the state and the way that it is implemented gets a bit confusing. The SACP rate is paid by the supplier if they are unable to purchase an adequate number of SRECs and therefore do not meet the required renewable energy requirement. This is then the maximum that any supplier will pay for an SREC. The SCCA price is a minimum set by the state to regulate the price of SRECs in a manner that creates a financially intelligent environment for renewable energy.

The result of the SREC program is a large bonus for renewable energy generation plants. In the case of the Kilby, Gardner and Hammond Neighborhood case study, an installed solar array would receive $0.12/kWh through net metering as well as $0.30-$0.60/kWh from the sale of SRECs. Due to the fact that the SRECs are only purchased on a MWh scale the production facility must be large enough to generate an excess MWh in a reasonable amount of time to benefit from the SREC program. Given an average of 2.5 sun hours a day the array size would have to be at least 14 KW in order to generate a MWh in a month. A 20KW system would be a good lower limit on the size of an array that could benefit greatly from the SREC program (DSIRE, 2010).

LOCAL GOVERNMENT FUNDING CONCLUSION

The process of getting state funding for a solar project is very involved and requires an up to date guide to the available money and what needs to be done to qualify. The good news is that most if not all solar installation companies have large amounts of knowledge on the subject and will often complete all the necessary forms and steps to make sure that the funding comes through for the project. With this in mind one of the most important decisions for funding becomes deciding which installation to work with. There are many options in Massachusetts and we have laid out the best candidates for the KGH neighborhood in the Solar Installers section of the study.

FEDERAL GOVERNMENT FUNDING

With the inauguration of President Obama the federal government has taken a much more liberal approach to renewable energy and funding projects to create renewable energy solutions. The American Recovery and Reinvestment Act has also had a large impact in renewable energy as much of this stimulus money has been geared towards renewable energy and creating a easier incentive program for those people, organizations or communities interested in installing solar power systems. As President Obama continues to push forward with his energy agenda, there will be many more opportunities that arise for greater funding of the KGH neighborhood project. Many of these funding options are in the early stages of fruition and as stated before in the state funding section will be known best at the time of installation by the installation company. With this said, we have laid out a couple of the currently available federal financing options that could be helpful for the KGH neighborhood and in conjunction with the state funding could cover much of the cost of installation.

THE AMERICAN RECOVERY AND REINVESTMENT ACT OF 2009

A large scale federal program signed into law by President Obama, this program focuses on the renewable energy and breaking our dependence on imported oil (White House, 2009). The ARRA provides at least $6.3 billion dollars for state and local renewable energy projects. This money is pushed toward smaller state and local projects and could be applied toward development of a renewable energy plant in the KGH project. Much of the funding for the state funding opportunities are actually funded by the ARRA and would not have been possible had this funding not been made available. The main idea behind the ARRA is to make the funding available to the states so that they can allocate the appropriate funds in the manner that they see fit.

EPA: BROWNFIELDS PROGRAM

As we stated before, the land in the KGH neighborhood is previously developed land. The properties are filled with industrial manufacturing buildings that are now abandoned. The land is heavily polluted and many of the plots need to be cleaned up and decontaminated before being developed. The Environmental Protection Agency is firmly committed to helping anyone clean and make good use of those properties (Environmental Protection Agency, 2009). The Brownfields Program provides funding to developers to evaluate the pollution, assess costs to clean up the soil and support the actual removal and disposal of the contaminated soil. When assessing the costs of cleaning of soil and actual cleaning, developers can apply for grants limited to $200,000 and in some cases wave that limit up to $700,000. Aside from grants, the Brownfield Program allows development entities to apply for subsidized low interest loans up to $1,000,000 to help in the actual cleaning and construction associated with the cleaning of the property. The EPA even grants money for the training of members of communities impacted by these Brownfield properties to work in the redevelopment and construction process; this part of the program has totaled over $25,000,000 and trained 5,000 people, with more than 3,250 people obtaining jobs in the environmental field. Many of the EPA's Brownfield Programs can be applied to the KGH project; the revitalization of the neighborhood doesn't just have to stop after the construction, it can continue with helping members of the community through possible job training and maybe even creating jobs.

FEDERAL GOVERNMENT FUNDING CONCLUSION

In general, the federal government has made it a practice to allow the separate states determine exactly how funding is distributed to the specific areas and this has continued with the funding for renewable energy. With this said, there have recently been federal programs targeted at specific renewable projects; these programs often have a limited supply of funding and are available for a limited period of time. At the time of installation for this project there will be other federal funding options that will allow for greater funding but will be determined by what is available at the time. Depending on how successful President Obama is with his energy plans this funding could be a substantial source for the KGH neighborhood and the Main South CDC.

TECHNOLOGY

Photovoltaic panels are large flat panels of silicon that convert the sun's energy into direct current electricity via the photovoltaic effect (United States Department of Energy, 2006). This direct current electricity must then be stored, buffered and converted into alternating current electricity. Once the electricity is converted to alternating current electricity it can be synchronized with the local electrical grids and then stored there, or it can be used by the local entities to power common electrical components. Unfortunately, photovoltaic power is not capable of producing power during the night, so there is still dependence on the existing electrical grid. Fortunately, through producing a large amount of energy, an entity could generate enough power during the day to pay for its typically reduced night time usage.

HOW IT WORKS

The photovoltaic effect involves the creation of a voltage (or a corresponding electric current) in a material upon exposure to electro-magnetic radiation. A solar cell is a device that converts the energy of sunlight directly into electricity by the photovoltaic effect. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic (PV) cell is used when the light source is unspecified. Assemblies of cells are used to make solar panels, solar modules, or photovoltaic arrays.

PV cells are made of special materials called semiconductors most commonly made out of silicon. When light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred into the semiconductor and knocks electrons loose, allowing them to flow freely through the semiconductor. PV cells also all have one or more electric fields that force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally. (United States Department of Energy, 2006)

The most commonly known solar cell is configured as a large-area P-N Junction made from silicon. The P-N Junction structure is formed by the intimate contact of P-type and N-type semiconductors; "P-Type and N-type semiconductors" refers to the chemical properties of the semiconductors. The important characteristic of a P-N Junction is that it will conduct electric current with one polarity of applied voltage (forward bias) but will not conduct with the opposite polarity (reverse bias). This only allows current to flow in one direction through the material.

When a piece of P-type silicon is placed in intimate contact with a piece of N-type silicon, then a diffusion of electrons occurs from the region of high electron concentration (the N-type side of the junction) into the region of low electron concentration (P-type side of the junction). When the electrons diffuse across the P-N Junction they recombine with holes on the P-type side. The diffusion of carriers does not happen indefinitely, however, because charges build up on either side of the junction and create an electric field. The electric field creates a diode that promotes charge flow, known as drift current that opposes and eventually balances out the diffusion of electron and holes. This region where electrons and holes have diffused across the junction is called the depletion or space charge region due to the fact that it no longer contains any mobile charge carriers.

Solar power modules are made by connecting several cells (usually 36 or more) in series and parallel to achieve useful levels of voltage and current, and putting them in a sturdy frame complete with a glass cover and positive and negative terminals on the back.

CONCLUSION

Due to the complexity of solar panels, many companies have varying methods of creating the panels and there are many different specific panels that could be used at the KGH neighborhood location. There a large number of different corporations building solar panels of all different sizes and efficiencies for different costs and the exact panel make and model for this location is laid out much more specifically in the KGH neighborhood section under Technology.

APPENDIX B

CRITERIA

SIZE

The size of a lot is a major selling point for the feasibility of a photovoltaic plant. Because solar panels must be laid with no obstruction of direct sunlight, they cannot be built in layers or positions that allow their solar cells to overlap. The size of a lot directly relates to the number of panels that may be installed affecting the maximum power potential of the entire system. Also, given the zoning conditions of a lot, it may be against the local zoning ordinances to build structures close to the edge of a property, so free space may be a requirement of a lot. On the other side, choosing a very large lot could prove to be a waste of developable space.

LOCATION

Given the goals of this project the location of the property is extremely important. The chosen location must be able to support a large solar installation with minimal negative impact to the surrounding neighborhood as well as being well suited for solar generation. Residents may not want a large power plant installed in their back yard but inversely it has to be located in a manner that lends to easy power distribution to the community. As well as aesthetic and distribution concerns it must also be noted that there much be solar exposure and limited chance that a large structure will be built that blocks such exposure.

TOPOGRAPHY

Lot topography can become the deciding point for the feasibility of any structure, whether it is a building or a power plant. In the case of photovoltaic arrays, lot topography is especially important. An uneven topography could cause large construction costs to level or resurface a property. Because the particular latitude of New England, the property's solar exposure could be greatly reduced if it slopes downhill in a direction other than directly south. In the case that the land is poorly exposed, either a considerably sized structure must be built or the surface must be altered. These added costs can make the payback period of a photovoltaic array much longer.

BROWNFIELD STATUS

Over the past century in Worcester, many factories and commercial structures have been constructed and operated. In many cases, contaminants have been left behind in the soil by various sources such as oil and metals. These properties require special considerations when developed, such as the cleansing of contaminated soil and disposal of hazardous remains. These heavily polluted properties are known as Brownfields. Brownfield properties may be expensive to clean, so they may not be attractive to builders. A possible approach for a Brownfield property is to cap it with concrete so that the contamination is limited to that location. When a property is capped like this, it makes it an attractive spot for photovoltaic plants because the property is flat, level and not developable for large structures. Another consideration that could be made is that if the property qualifies for the Environmental Protection Agency's Brownfield Program, funding could be available for the development of this property.

DEVELOPMENT POTENTIAL

Many properties are not attractive to builders. If the lot is not attractive, then it will not have a high property value due to its illiquidity. Lots like this can be gold mines for photovoltaic developers because their cost is typically low and they may be highly suitable for this type of structure. Some properties may have large amounts of clay, which are very poor for building homes on due to the settling of the earth; luckily, photovoltaic structures are typically very light and have a wide weight distribution. Often, stand-alone photovoltaic structures can be a good way to utilize wasted undevelopable space.

ZONING

In cities such as Worcester, zoning can vary very heavily through even a neighborhood. City zoning ordinances dictate the types of structures allowed and other specifics for development of respective lots. Certain zoning types may entirely restrict the construction and operation of any energy generation stations. These zoning rules often may require special permits for specific structures or may entirely restrict them.

CONDITION

The existing condition of a lot could be deterministic in the feasibility of developing it for any purpose. If the initial cleanup costs of a lot are very high, it may not be worth investing in for a photovoltaic application. A major concern for the feasibility of a photovoltaic plant is the final cost. If the lot in question has a large factory building on it, the cost to demolish the building, dispose of the ruins and fill the soil could make the final cost unreasonable. In many cases, developers may seek funding assistance from the city or other agencies to clean up these distressed sites. Other preexisting conditions of the site could include extremely unlevel or pitted terrain that requires filling or excavation, cement structures such as foundations left from previous buildings or natural water stores that may need to be filled or avoided.

GRID CONNECTION

The final purpose of a community photovoltaic farm is generating electricity for use on the grid. When choosing a suitable location, a factor that could make or break a lot is if the lot can handle the current load of photovoltaic system. If the power output of a solar plant is very large, it may be a poor choice to choose to transmit that power over low voltage lines for typical housing application. Connection to a higher voltage line is advantageous for large scale energy production to prevent unnecessary losses or destruction of existing infrastructure such as transformers. The grid may be very hesitant to allow a photovoltaic module to connect if the electrical connections are not guaranteed to be sufficient for the application. Another factor to consider with electrical connections is the number of connections present to the property. If there are multiple connections, there may be more options for how the lot is developed and connected to the grid. These options may help reduce construction costs is it prevents further construction on the developer’s end.

APPENDIX C – DATA

IRRADIATION DATA

Tilt (°)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	***Average***	1.9	2.8	3.8	4.7	5.5	6	5.9	5.2	4.2	3	1.9	1.5	3.9
	Minimum	1.6	2.2	3	4	4.6	5	5.3	4.6	3.7	2.7	1.5	1.3	3.7
	Maximum	2.2	3.4	4.3	5.4	6.4	6.8	6.6	5.9	4.7	3.5	2.1	1.8	4
27.27	***Average***	3	3.8	4.6	5.1	5.5	5.8	5.9	5.6	4.9	4	2.8	2.4	4.5
	Minimum	2.4	2.9	3.5	4.2	4.6	4.9	5.2	4.8	4.2	3.5	2	1.8	4.2
	Maximum	3.5	5	5.4	6	6.6	6.8	6.6	6.4	5.7	4.9	3.2	3	4.7
42.27	***Average***	3.4	4.2	4.8	5	5.2	5.4	5.5	5.3	5	4.3	3	2.8	4.5
	Minimum	2.7	3.1	3.5	4.1	4.3	4.5	4.8	4.6	4.2	3.6	2.2	2	4.2
	Maximum	4.1	5.6	5.7	5.9	6.2	6.2	6.1	6.2	5.7	5.3	3.6	3.5	4.7
57.27	***Average***	3.6	4.4	4.7	4.6	4.6	4.6	4.8	4.8	4.7	4.3	3.2	3	4.3
	Minimum	2.8	3.2	3.4	3.8	3.8	3.9	4.2	4.2	4	3.6	2.3	2.1	4
	Maximum	4.4	5.9	5.7	5.5	5.5	5.4	5.3	5.6	5.5	5.3	3.8	3.8	4.5
90	***Average***	3.5	4	3.8	3.1	2.7	2.6	2.7	3	3.4	3.5	2.9	2.8	3.2
	Minimum	2.7	2.8	2.6	2.5	2.3	2.3	2.5	2.7	2.8	2.9	2	2	3
	Maximum	4.3	5.5	4.9	3.6	3.2	2.9	2.9	3.5	4	4.4	3.5	3.7	3.4

SOLAR RADIATION FOR 1-AXIS TRACKING FLAT-PLATE COLLECTORS WITH A NORTH-SOUTH AXIS (kWh/m2/day)														
Axis Tilt		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
0	**Average**	2.7	3.9	5.1	6.1	6.9	7.5	7.5	6.8	5.6	4.1	2.6	2.2	5.1
	Minimum	2.2	3	3.7	4.7	5.4	5.9	6.3	5.7	4.7	3.5	1.9	1.6	4.8
	Maximum	3.3	5.2	6.1	7.4	8.4	8.9	8.7	7.9	6.5	5.1	3	2.7	5.4
27.27	**Average**	3.5	4.7	5.7	6.4	7	7.5	7.6	7.1	6.2	4.9	3.2	2.9	5.6
	Minimum	2.8	3.5	4.1	4.9	5.5	5.8	6.3	5.8	5.1	4.1	2.3	2	5.2
	Maximum	4.3	6.4	6.9	8	8.6	8.9	8.8	8.4	7.3	6.1	3.8	3.7	5.9
42.27	**Average**	3.9	5	5.9	6.4	6.8	7.2	7.3	6.9	6.2	5.1	3.5	3.1	5.6
	Minimum	3	3.6	4.1	4.8	5.3	5.6	6.1	5.7	5.1	4.2	2.5	2.2	5.2
	Maximum	4.8	6.8	7.1	7.9	8.4	8.6	8.5	8.2	7.3	6.4	4.2	4.1	6
57.27	**Average**	4.1	5.1	5.8	6.1	6.4	6.7	6.8	6.6	6	5.1	3.6	3.3	5.5
	Minimum	3.2	3.7	4	4.6	4.9	5.2	5.7	5.4	4.9	4.2	2.5	2.3	5.1
	Maximum	5	7.1	7.1	7.6	7.9	8	7.9	7.8	7.2	6.5	4.3	4.3	5.8

SOLAR RADIATION FOR 2-AXIS TRACKING FLAT-PLATE COLLECTORS (kWh/m2/day)														
Tracker		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
2-Axis	***Average***	4.1	5.1	5.9	6.5	7.1	7.7	7.7	7.1	6.2	5.2	3.6	3.4	5.8
	Minimum	3.2	3.7	4.1	4.9	5.6	6	6.5	5.9	5.1	4.2	2.5	2.3	5.4
	Maximum	5.1	7	7.1	8	8.7	9.1	8.9	8.4	7.3	6.5	4.3	4.4	6.2

DIRECT BEAM SOLAR RADIATION FOR CONCENTRATING COLLECTORS (kWh/m2/day)														
Tracker		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
1-X, E-W	***Average***	2.2	2.5	2.6	2.8	3	3.3	3.3	3.1	2.9	2.7	2	1.9	2.7
Hor Axis	***Minimum***	1.5	1.6	1.7	1.7	1.9	1.9	2.3	2.1	2	1.9	1.1	0.9	2.3
	Maximum	2.9	3.9	3.4	3.9	4.3	4.4	4.4	4.1	3.8	3.8	2.7	2.7	3
1-X, N-S	***Average***	1.5	2.2	2.9	3.5	3.9	4.3	4.3	4	3.4	2.5	1.4	1.2	2.9
Hor Axis	***Minimum***	1	1.4	1.8	2	2.5	2.5	3	2.8	2.3	1.8	0.8	0.6	2.6
	Maximum	2	3.4	3.7	5	5.5	5.7	5.7	5.3	4.4	3.6	2	1.7	3.2
1-X, N-S	***Average***	2.4	3	3.5	3.8	3.8	4.1	4.1	4.1	3.9	3.3	2.2	2	3.3
Tilt=Lat	***Minimum***	1.6	2	2.2	2.2	2.5	2.4	2.9	2.8	2.7	2.4	1.3	1	2.9
	Maximum	3.2	4.6	4.5	5.4	5.4	5.4	5.5	5.4	5.1	4.6	3	2.8	3.7
2-X	***Average***	2.6	3.1	3.5	3.8	4.1	4.4	4.5	4.2	3.9	3.4	2.3	2.1	3.5
	Minimum	1.7	2	2.2	2.3	2.6	2.6	3.1	2.9	2.7	2.4	1.3	1	3
	Maximum	3.4	4.8	4.5	5.4	5.7	5.8	5.9	5.6	5.1	4.7	3.1	3.1	3.9

AVERAGE CLIMATIC CONDITIONS														
Element		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Temp.	(° C)	-5.1	-4	0.9	6.9	13.1	17.9	20.9	20	15.7	10	4.1	-2.6	8.2
Daily Min	(° C)	-9.4	-8.6	-3.9	1.5	7.3	12.2	15.6	14.8	10.3	4.7	-0.4	-6.6	3.1
Daily Max	(° C)	-0.7	0.6	5.8	12.2	18.8	23.6	26.3	25.2	20.9	15.3	8.6	1.5	13.2
Record Lo	(° C)	-28.3	-24.4	-20	-11.7	-2.2	2.2	6.1	3.3	-1.1	-6.7	-14.4	-25	-28.3
Record Hi	(° C)	15.6	19.4	27.2	32.8	33.3	34.4	35.6	35.6	32.8	29.4	25.6	21.1	35.6
Rel Hum	percent	65	64	63	60	64	69	70	73	74	69	70	70	68
Wind Spd.	(m/s)	4.9	4.8	4.8	4.6	4.1	3.8	3.5	3.4	3.6	4	4.5	4.6	4.2

(National Renewable Energy Laboratory, 2008)

SOLAR PANELS

Panel Model	Manufacturer	P_{Out}	V_{open}	I_{Closed}	$V_{Operate}$	$I_{Operate}$	Efficiency (%)	MSRP ($)	Surface Area (m^2)	Mass (kg)	Cost Per Watt ($/W)	Watt Per Area (W/m^2)	Number of Cells	Warranty (yrs)
AS-5M-185	Amerisolar	185	44.5	5.4	37.5	4.95	14.5	$ 901.89	1.28	15.5	$ 4.88	145	72	10
AS-5M-180	Amerisolar	180	44.2	5.35	36.8	4.9	14.1	$ 877.51	1.28	15.5	$ 4.88	141	72	10
AS-5M-175	Amerisolar	175	43.9	5.3	36.2	4.85	13.7	$ 853.13	1.28	15.5	$ 4.88	137	72	10
AS-5M-170	Amerisolar	170	43.6	5.25	35.8	4.75	13.3	$ 828.75	1.28	15.5	$ 4.88	133	72	10
AS-5M-165	Amerisolar	165	43.2	5.2	35.6	4.65	12.9	$ 804.38	1.28	15.5	$ 4.88	129	72	10
AS-5M-160	Amerisolar	160	42.8	5.15	34.9	4.6	12.5	$ 780.00	1.28	15.5	$ 4.88	125	72	10
ES-A-210-FA3	Evergreen	210	22.8	12.1	18.3	11.5	13.4	$ 1,282.05	1.57	18.6	$ 6.11	134	114	25
ES-A-205-FA3	Evergreen	205	22.7	11.9	18.2	11.3	13.1	$ 1,251.00	1.57	18.6	$ 6.10	131	114	25
ES-A-200-FA3	Evergreen	200	22.6	11.8	18.1	11.1	12.7	$ 1,221.00	1.57	18.6	$ 6.11	127	114	25
G-EA060	Kaneka	60	91.8	1.19	67	0.9	6.3	$ 352.00	0.95	13.7	$ 5.87	63		25
P-LE055	Kaneka	55	23	4.68	17	3.33	5.6	$ 354.00	0.98	14.4	$ 6.44	56		25
SCHOTT POLY 210	Schott	210	36.1	7.95	29.3	7.16	13.82	$ 1,050.00	1.67	23	$ 5.00	126	60	25
SCHOTT POLY 217	Schott	217	36.4	8.1	29.6	7.33	14.28	$ 1,085.00	1.67	23	$ 5.00	130	60	25
SCHOTT POLY 220	Schott	220	36.5	8.15	29.7	7.41	14.47	$ 1,100.00	1.67	23	$ 5.00	131	60	25
SCHOTT POLY 225	Schott	225	36.7	8.24	29.8	7.55	14.8	$ 1,125.00	1.67	23	$ 5.00	134	60	25
SPM005P	Solartech	5	21.7	0.31	17.1	0.3	6.5	$ 32.25	0.08	1.2	$ 6.45	64	1	25
SPM010P	Solartech	10	21.8	0.64	17.3	0.59	8.76	$ 62.25	0.11	1.4	$ 6.23	88	2	25
SPM020	Solartech	20	41.3	0.65	33.9	0.61	10.38	$ 124.50	0.19	2.8	$ 6.23	104	4	25
SW 175	World	175	44.4	5.3	35.8	4.89	13.4	$ 1,263.00	1.30	15	$ 7.22	134	5	25
ND-224UC1	Sharp	240	37.4	8.65	30.1	7.98	13.74	$ 1,044.58	1.63	20	$ 4.35	147	60	25
ND-176UC1	Sharp	176	29.3	8.22	23.42	7.52	13.3	$ 742.09	1.32	16.5	$ 4.22	133	48	25
ND-198UC1	Sharp	198	32.9	8.23	26.3	7.52	13.4	$ 837.11	1.48	18	$ 4.23	134	54	25
PVL-68	Uni-Solar	68	23.1	5.1	16.5	4.13	6.7	$ 521.00	1.12	3.9	$ 7.66	61	11	5
PVL-136	Uni-Solar	136	46.2	5.1	33	4.13	6.3	$ 981.00	2.16	7.7	$ 7.21	63	22	5
PVL-144	Uni-Solar	144	46.2	5.3	33	4.36	6.6	$ 1,055.00	2.16	7.7	$ 7.33	67	22	5

(Advancing the Green, 2009)
(Amerisolar, 2009)
(Evergreen Solar, 2008)
(Kaneka, 2006)
(SCHOTT Solar, 2009)
(Sharp USA, 2010)
(SolarWorld, 2007)
(Uni-Solar, 2008)

BROWNFIELD LOTS

Release Address	Site Name/ Location Aid	Notification Date	Chemical Type
35 ARMORY ST	FROST ASSOCIATES, INC.	1/20/2005	
65 ARMORY ST	SWIP 3 SONS TRUCKING BLDG	6/4/1997	Oil
69 ARMORY ST	WRIGHT MACHINE CORP	2/27/1991	
69 ARMORY ST	FORMER WRIGHT MACHINE CORP FACILITY	10/25/2006	Hazardous Material
98-102 ARMORY ST	FORMER CITY BUILDERS SUPPLY	8/29/2006	Oil
64 BEACON ST	COME PLAY PRODUCTS	8/22/1997	Oil
79 BEACON ST	AJD ENTERPRISES	8/16/2002	Oil and Hazardous Material
80 BEACON ST	BEACON STREET SUBSTATION	1/9/2009	
32 CAMBRIDGE ST	UPPER PARKING LOT	12/14/1994	Hazardous Material
72 CAMBRIDGE ST	SALVATION ARMY PARKING LOT	6/22/2004	Oil
91 CAMBRIDGE ST	DRAKE PETROLEUM CO INC	12/12/2005	Oil
118 CAMBRIDGE ST	PAD-MOUNTED ELECTRICAL TRANSFORMER	12/24/2008	Oil
190 CAMBRIDGE ST	INTERSECTION OF FREEMONT ST	11/22/2001	Oil
231 CAMBRIDGE ST	HONEY FARMS	11/10/1998	Oil
641 CAMBRIDGE ST	WACHUSETT WIRE CO	9/2/2000	Hazardous Material
670 CAMBRIDGE ST	GAS STATION FMR	7/15/1993	Oil
680 CAMBRIDGE ST	MYSTERY DUMPING	11/25/1997	Hazardous Material
418-440 CAMBRIDGE ST	ESTATE OF LEROY P SMITH	5/2/2007	Oil
7 9 CANTERBURY ST	SCRAP YARD FMR	6/16/1999	Hazardous Material
7-9 CANTERBURY ST	SCRAP METAL YARD	11/12/1992	Oil
11 CANTERBURY ST	WILLIAM F LYNCH	9/14/1998	Oil
11 CANTERBURY ST	WILLIAM F LYNCH CO	6/15/2004	Oil and Hazardous Material
49 CANTERBURY ST	THOMAS SWEENEY	3/7/2005	Hazardous Material
53-65 CANTERBURY ST	CITY OF WORCESTER	4/24/2003	Oil and Hazardous Material
3 CONGDON ST	N F SHELDON INC	8/8/2000	Hazardous Material
1 CONGDON ST	NEAR FRANKENSTEIN"S RECYCLING	1/20/2010	Oil
41 FREMONT ST	GESSNER CORP GHM INDUSTRIES	6/26/1992	Oil
45 FREMONT ST	CHEMICAL SALES SERVICE	5/28/1997	
45 FREMONT ST	CHEMICAL SALES AND SERVICE	2/4/1999	Hazardous Material
60 FREMONT ST	VALKYRIE PROPERTY	1/18/1996	Oil
84 FREMONT ST	KESSELI & MORSE CO	11/28/2000	Hazardous Material
160 FREMONT ST	CONDOMINIUM UNITS	9/17/2009	Hazardous Material
158-160 FREMONT ST	THE ABRAMS GROUP	4/29/2005	Hazardous Material
GARDNER AND TAINTER ST	GKH PROJECT AREA	2/8/2002	Oil and Hazardous Material

85 GARDNER ST	SOUTH WORCESTER INDUSTRIAL PARK	9/6/2006	Oil
93-95 GATES ST	UNIVERSITY PARK LOFTS	1/18/2006	Oil and Hazardous Material
93-95 GRAND ST	GRAND INDUSTRIAL PARK	9/20/1993	Oil
75 HAMMOND ST	PROVIDENCE & WORCESTER RR	6/1/2003	Oil
HERMON ST	WORCESTER STORAGE CO	7/14/1996	Oil
52-54 HERMON ST	WORCESTER LION DISTRIBT	1/15/1989	
35 HERMON ST	CHAFITZ PROPERTY	11/6/1998	Hazardous Material
38 HERMON ST	PAP REALTY TRUST	4/15/1989	
53 HERMON ST	DANIEL FREELANDER	12/20/2002	Hazardous Material
KANSAS ST	ACROSS FROM ENV INC	8/2/1996	Hazardous Material
KANSAS ST	CANADA IMPERIAL OIL ASPHALT RELEASE	10/15/2001	Hazardous Material
KANSAS ST	ROADWAY	7/6/2004	Hazardous Material
2 KANSAS ST	BABCO REALTY	10/31/1985	Oil and Hazardous Material
2 KANSAS ST	NAPL	3/6/1997	Oil
2 KANSAS ST	CAMBRIDGE ST	4/3/1997	Hazardous Material
2 KANSAS ST	FMR INDUSTRIAL SITE	6/17/2002	Hazardous Material
2 KANSAS ST	KANSAS STREET AT SHERMAN STREET	5/30/2008	Hazardous Material
MAIN ST	WEBSTER SQ PLAZA	1/15/1989	Oil
MAIN ST	ROADWAY SPILL AT WHITE HEN PANTRY	9/21/2004	Oil
175 MAIN ST	BTWN SCHOOL AND THOMAS ST	3/10/1995	Hazardous Material
175 MAIN ST	AT&T	8/4/1995	Oil
390 MAIN ST	SLATER BUILDING	5/29/2002	Oil
446 MAIN ST	SOVEREIGN BANK	12/22/2000	Hazardous Material
570 MAIN ST	FEDERAL PLAZA GARAGE	2/27/2007	
653 MAIN ST	HADLEY APARTMENTS	10/23/2008	Oil
661 MAIN ST	FORMER CARAVAN BUILDING	2/25/2009	Oil
661 MAIN ST	FORMER CARAVAN BUILDING	3/31/2009	Oil
661 MAIN ST	FORMER CARAVAN BUILDING	4/3/2009	Oil
662 MAIN ST	MART BLDG	8/3/2000	Oil
667 MAIN ST	BUSINESS-RESIDENTIAL BUILDING	3/19/2008	Oil and Hazardous Material
779 MAIN ST	SUNOCO STATION	7/15/1993	
875 MAIN ST	WORCESTER COMPREHENSIVE CHILDCARE SERVIC	11/8/2005	Hazardous Material
875 MAIN ST	WORCESTER COMPREHENSIVE CHILDCARE	8/22/2006	Hazardous Material
950 MAIN ST	JONUS CLARK BLD	3/4/2002	Oil
950 MAIN ST	NEAR POWER PLANT CLARK UNIV	7/21/2005	Oil
1013 MAIN ST	ATAMIAN MOTORS FMR	7/11/1994	Hazardous Material
1078 MAIN ST	MOBIL	9/16/1994	Hazardous Material
1078 MAIN STREET	MOBIL STATION 01 FND	4/15/1988	

1078 MAIN STREET	EXXON MOBIL GAS STATION	1/24/2003	Hazardous Material
1148 MAIN ST	MERIT GAS STATION	3/28/1994	Oil and Hazardous Material
1174 MAIN ST	ALLESCHECK PARTNERSHIP	6/10/2002	Oil
1227 MAIN ST	NORTH OF WEBSTER PLAZA	4/22/1998	Oil and Hazardous Material
1227 1241 MAIN ST	NO LOCATION AID	5/24/1995	Hazardous Material
1233 MAIN ST	GAS STA FMR	9/12/1997	
1238 MAIN ST	GATES LANE SCHOOL	2/20/2002	Oil
1256 MAIN ST	BRITE CLEANERS	2/18/1993	Oil
1256 MAIN ST	BRITE CLEANERS	7/18/2008	Hazardous Material
1260 MAIN ST	WEBSTER SQUARE VETERAN MEMORIAL POOL	12/14/2009	Hazardous Material
1275 MAIN ST	1275 MAIN ST PROPERTY	2/18/1993	Oil
1275 MAIN ST	TEXACO FMR	5/26/1999	Oil
1475 MAIN ST	MILLBROOK FACILITY	10/19/1995	Hazardous Material
211-215 MAIN ST	NEW WORCESTER TRAIL COURT - ODONNELL	2/11/2002	Oil and Hazardous Material
15 RIPLEY ST	CATHOLIC CHARITIES OF THE DIOCESE OF WOR	4/3/1995	Oil
15 RIPLEY ST	CATHOLIC CHARITIES OF THE DIOCESE OF WOR	12/6/1995	Oil
2 SHERMAN ST	LEYDEN DEVELOPMENT CORP	3/5/1998	Oil and Hazardous Material
18 SHERMAN ST	ROME BUILDING PRODUCTS	10/11/2005	Hazardous Material
18 SHERMAN ST	SAM-JAY REALTY TRUST	9/28/2006	Hazardous Material
111 SHREWSBURY	CORNER OF S HILL ST	7/6/1998	Hazardous Material
17 SOUTHGATE PL	SWIP PARCEL 10A	7/10/2000	
17 SOUTHGATE PL	SWIP ABANDONED FOUNDRY BUILDING	3/4/2008	Oil
SOUTHGATE ST	POLE 3-3	1/31/2010	
25 SOUTHGATE ST	SWIP PARCEL 9A	7/10/2000	
25 SOUTHGATE ST	SWIP ABANDONED FOUNDARY BUILDING	3/4/2008	Oil and Hazardous Material
25 SOUTHGATE ST	SWIP CITY OF WORCESTER	11/20/2009	Oil
28 SOUTHGATE ST	PARCEL 4A	7/10/2000	
28 SOUTHGATE ST	WBC REALTY CORP	8/15/2008	Hazardous Material
65 TAINTER ST	GKH PROJECT	8/2/2002	Oil

(Environmental Protection Agency, 2009)

LOCATIONS OF INTEREST

10 GRAND STREET

10 Grand Street is a small parking lot at the intersection of Grand Street and Main Street. This location is currently owned by the Roman Catholic Bishop of Worcester. This location is used as a parking lot, but could be modified to have a parking structure of sorts to house photovoltaics. This location has good Southern exposure during the mid-day, but does see some shading due to local housing in the hours of the morning and near dusk. Existing parking lots make good locations for photovoltaic retro-fits because they are already cleaned, paved and typically zoned for non-residential purposes. A parking structure with photovoltaic installation could provide shade and generate electricity and prove to be a useful entity.

10 Grand Street Basic Data

Attribute	Value	
Lot Owner	Roman Catholic Bishop of Worcester	
Lot Size (sq. m)	691	
Lot Value	$ 89,300	
	Justification	***Rating***
Lot Location Rating	Near Main St., awkward for a PV.	3
Lot Topography Rating	Lot is flat, but has solar obstructions.	7
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks very developable.	2
Lot Current Structures Rating	This lot has no structures and is paved.	9
Lot Raw Score		29

92 GRAND STREET

92 Grand Street is parking structure location owned by Sion Mills Limited in the industrially zoned park of the KGH neighborhood. The area is distressed and surrounded by abandoned structures. The lot is paved, level, flat and has excellent overall Southern solar exposure. This area is known to have a lot of vandalism and other issues such as vagrancy. This lot would be an excellent location to place a flat photovoltaic array as build costs would be smaller due to the existing plot topography and condition. This lot is a known Brownfield site and could be eligible for grants to help with development costs and any contamination cleanup costs. In addition to the technical value of the land, the aesthetics for development make sense as this lot is away from homes and in an industrial area.

92 Grand Street Basic Data

Attribute	Value	
Lot Owner	Sion Mills Limited	
Lot Size (sq. m)	8,845	
Lot Value	$ 285,500	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	8
Lot Topography Rating	This lot is flat and level.	10
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks very developable.	2
Lot Current Structures Rating	This lot is flat and paved.	10
Lot Raw Score		39

93 GRAND STREET

93 Grand Street is a former manufacturing plant that is now abandoned and has major issues with vandalism and pollution. This lot is owned by the Main South Community Development Center already. This lot has good Southern solar exposure atop the existing structure in place. If photovoltaic modules were placed at ground level, much light would be obstructed by structures at 95 Grand Street. This lot would make a good location for rooftop photovoltaics, but not a ground array. The large surface area of this lot gives great optionality for optimization of placement for modules. This lot is also a Brownfield, so funding could come from the EPA for development costs.

93 Grand Street Basic Data

Attribute	Value	
Lot Owner	Main South CDC	
Lot Size (sq. m)	6,976	
Lot Value	$ 716,500	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	8
Lot Topography Rating	This lot is flat but has solar obstruction.	6
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks developable with work.	2
Lot Current Structures Rating	This lot has large abandoned structures.	1
Lot Raw Score		26

95 GRAND STREET

95 Grand Street is another old factory building owned by the city of Worcester. Upon further investigation, it appears there are several small companies operating currently on the property. The property is an old dilapidated factory building in need of serious repair. This building is also a Brownfield site. The Southern exposure of the building is excellent as it is bordered by the Providence-Worcester Railroad. This railroad is unlikely to move any time soon, which provides some stability to whether the solar exposure would change or not. This lot is spacious and flat, and could be an excellent candidate for either rooftop or flat arrays.


95 Grand Street Basic Data

Attribute	Value	
Lot Owner	City of Worcester	
Lot Size (sq. m)	9,869	
Lot Value	$ 206,700	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	8
Lot Topography Rating	This lot is flat and level.	7
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks developable with work.	2
Lot Current Structures Rating	This lot has large abandoned structures.	1
Lot Raw Score		27

30 HOLLIS STREET

30 Hollis Street is yet another old abandoned industrial building. This building is owned by a trustee and likely does not have any plans for near future development. This lot is in an industrial setting and could be suitable location for both rooftop and ground photovoltaic arrays. The Southern exposure of the building is clear at rooftop elevation, but may have some small ground level obstructions. This lot does have surrounding buildings on the West boarder, so later hours may also see some solar obstruction. Like other lots with existing structures, this is a Brownfield lot that may require considerable construction costs to clean the property of the years of damage and neglect.

30 Hollis Street Basic Data

Attribute	Value	
Lot Owner	Nancy Dworman, Trustee	
Lot Size (sq. m)	6,058	
Lot Value	$ 338,600	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	8
Lot Topography Rating	This lot is flat but has solar obstruction.	6
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks developable with work.	2
Lot Current Structures Rating	This lot has large abandoned structures.	1
Lot Raw Score		26

50 GARDNER STREET

50 Gardner Street is a corner lot on both Gardner and Hollis Street. This lot has a large old factory on it with some parking area. This lot is complicated by a smaller sub-lot located in the Northern corner of the lot. The railroad boarders this property on the South like other lots, and the solar exposure is decent for most of the day, except for late in the evening when Western bordering entities interfere. Immediately to the East of this property is the recently build Boys and Girls Club of Worcester; this may pose some risk as curious children from the club may try to play near the equipment, exposing them to some risk.

50 Gardner Street Basic Data

Attribute	Value	
Lot Owner	Nancy Dworman, Trustee	
Lot Size (sq. m)	6,170	
Lot Value	$ 488,900	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	8
Lot Topography Rating	This lot is flat but has solar obstruction.	7
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks developable with work.	3
Lot Current Structures Rating	This lot has large abandoned structures.	2
Lot Raw Score		29

0 GARDNER STREET

0 Gardner Street is a small corner lot within 50 Gardner Street. It has no large structures on it and is relatively flat and level. This lot could make for a good location for a ground photovoltaic array, but there are concerns about the safety of the children at the local Boys and Girls Club. This lot is small, so it would be an unlikely candidate to be developed alone. It is likely that this lot would just be an accessory to any development that occurs at 50 Gardener Street if it were purchased. This lot is in an industrial setting that could be appropriate for renewable energy plants.

0 Gardner Street Basic Data

Attribute	Value	
Lot Owner	68 Gardner LLC	
Lot Size (sq. m)	1,535	
Lot Value	$ 54,600	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	9
Lot Topography Rating	This lot is flat but has solar obstruction.	8
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned BL-1.0.	8
Lot Buildability Rating	This lot looks developable with work.	2
Lot Current Structures Rating	This lot has small abandoned structures.	5
Lot Raw Score		23

22 KILBY STREET

22 Kilby Street is a small lot sandwiched between a home and a business. This lot would be ideal for a photovoltaic array if placed on top of a small structure. This lot has excellent solar exposure and is very suitable for residential construction. This lot is owned by the Main South CDC and is slated as part of the Phase III KGH Project.

22 Kilby Street Basic Data

Attribute	Value	
Lot Owner	Main South CDC	
Lot Size (sq. m)	922	
Lot Value	$ 47,300	
	Justification	***Rating***
Lot Location Rating	This lot is in close proximity to homes.	4
Lot Topography Rating	This lot is flat but has solar obstruction.	7
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned RG-5.0.	0
Lot Buildability Rating	This lot looks developable.	2
Lot Current Structures Rating	This lot is clear, level and unpaved.	10
Lot Raw Score		23

2 KILBY STREET

2 Kilby Street is a small undeveloped lot at the corner of Main Street and Kilby Street owned by the City of Worcester. This lot is mostly level and has no existing structures. It is bordered on the North by businesses on Main Street and could be the future site of a home. This lot has excellent Southern exposure and is on the apex of a hill. If a home were built here, it could make for an excellent spot for rooftop photovoltaics. This lot is a long rectangle running East-West, so there is plenty of length to place rooftop photovoltaics.

2 Kilby Street Basic Data

Attribute	Value	
Lot Owner	City of Worcester	
Lot Size (sq. m)	352	
Lot Value	$ 44,600	
	Justification	***Rating***
Lot Location Rating	This lot is in close proximity to homes.	4
Lot Topography Rating	This lot is flat but has solar obstruction.	7
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned RG-5.0.	0
Lot Buildability Rating	This lot looks developable.	5
Lot Current Structures Rating	This lot is clear, level and unpaved.	10
Lot Raw Score		26

30 AND 32 HAMMOND STREET

30 and 32 Hammond Street are two adjacent lots at the base of the Hammond Street hill. These lots are very sloped with midday Southern exposure, but some shading during the evening and morning. If elevated, photovoltaic modules would see much less shading, so this location could be an excellent location for rooftop photovoltaic modules. This site is currently owned by the Main South CDC and is targeted for housing development.

30 and 32 Hammond Street Basic Data

Attribute	Value	
Lot Owner	Main South CDC	
Lot Size (sq. m)	795	
Lot Value	$ 49,400	
	Justification	***Rating***
Lot Location Rating	This lot is in close proximity to homes.	6.5
Lot Topography Rating	This lot is flat but has solar obstruction.	5
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned RG-5.0.	0
Lot Buildability Rating	This lot looks developable.	5
Lot Current Structures Rating	This lot is clear, unlevel and unpaved.	10
Lot Raw Score		26.5

44 HAMMOND STREET

44 Hammond Street is currently a self storage building owned by Nettle LLC. This building is an old clothing factory once owned by Chess King Inc. The company went out of business in the 1990s and the building has stood since. This lot is run down, but the building looks to be in decent shape, unlike the structures on Grand and Hollis Street. This building has almost no close proximity surrounding buildings, and is at a higher elevation than surrounding lots. The solar exposure of this lot is excellent throughout the entire day except the early hours in the morning. This building is suitable for rooftop photovoltaics and could also be suitable for a ground array.

44 Hammond Street Basic Data

Attribute	Value	
Lot Owner	Nettle LLC	
Lot Size (sq. m)	9,272	
Lot Value	$ 1,064,800	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting	8
Lot Topography Rating	This lot is flat and has solar exposure.	9
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks developable.	2
Lot Current Structures Rating	This lot has structures and pavement.	2
Lot Raw Score		31

33 KILBY STREET

33 Kilby Street is an elongated lot with excellent Southern exposure owned by the Kilby Gardner Hammond LLC. This lot has a long, incomplete cement foundation placed on it that faces south. The lot that immediately borders this to the South is 55 Tainter Street, which is a flat, empty field. This lot has been in Clark's plans to become an athletic field, but no progress has been made on it in some time. If this lot does truly become an athletic field, I would guarantee decent solar exposure for the duration of its existence. A major concern about this lot is that it is located directly below some housing units. Building a photovoltaic plant so close to these homes may not be aesthetically pleasing to the neighbors.

33 Kilby Street Street Basic Data

Attribute	Value	
Lot Owner	KGH LLC	
Lot Size (sq. m)	3,106	
Lot Value	$ 105,100	
	Justification	***Rating***
Lot Location Rating	This lot is in a somewhat industrial setting.	8
Lot Topography Rating	This lot is flat and has solar exposure.	7
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks somewhat developable.	5
Lot Current Structures Rating	This lot has a cement foundation.	7
Lot Raw Score		37

55 TAINTER STREET

55 Tainter Street is very large, flat lot owned by the KGH LLC. This lot is a project of Clark University, and is slated to become an athletic field. This lot would be an excellent site for a ground photovoltaic array because it is flat and has good southern exposure. A major concern about this lot is that it has swampy ground in the spring. High humidity causes corrosion and eventually failure of electronic devices such as photovoltaic modules. This lot may require quite a bit of filling before it is able to be used by any developer. However, because of the spacious nature of the lot, it is a prime candidate for placement of a photovoltaic array. The southern border of this lot is the Providence-Worcester Railroad, so it is unlikely any large buildings will be built to obstruct solar exposure in the near future.

55 Tainter Street Street Basic Data

Attribute	Value	
Lot Owner	KGH LLC	
Lot Size (sq. m)	12,144	
Lot Value	$ 292,400	
	Justification	***Rating***
Lot Location Rating	This lot is in a somewhat industrial setting.	9
Lot Topography Rating	This lot is flat and has solar exposure.	8
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks somewhat developable.	5
Lot Current Structures Rating	This lot is unpaved and clear but swampy.	10
Lot Raw Score		43

0 TAINTER STREET

0 Tainter Street is an undeveloped piece of land that lies below Beacon Street and is owned by the KGH LLC. This piece of land is controlled by Clark University as a part of the planned athletic field. This lot may require some cleaning and leveling as the land is not completely level, has large trees and has some stone walls running through it. Placing a photovoltaic array on this lot may not be aesthetically pleasing for some neighbors because it is located closely behind their homes. This lot may experience some morning shading by the large buildings at 44 Hammond Street, but otherwise has an excellent solar exposure much like 33 Kilby Street.

0 Tainter Street Street Basic Data

Attribute	Value	
Lot Owner	KGH LLC	
Lot Size (sq. m)	3,216	
Lot Value	$ 232,800	
	Justification	***Rating***
Lot Location Rating	This lot is in a somewhat industrial setting.	7
Lot Topography Rating	This lot is flat and has solar exposure.	6
Lot Brownfield Status	This lot is not a Brownfield.	0
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks somewhat developable.	7
Lot Current Structures Rating	This lot is unpaved and clear but swampy.	10
Lot Raw Score		40

49 CANTERBURY STREET

49 Canterbury Street is a large open lot owned by the City of Worcester. This lot is flat, level and has excellent southern exposure. This lot is also relatively square, so setting up photovoltaic arrays in an unobstructed grid pattern becomes easier for installers. This lot is located in a very commercial zone, so a photovoltaic generation plant would fit in well with the surrounding businesses. Because this lot is a Brownfield, it may also be eligible for financial aid for development. Unfortunately, due to the good topography of this lot, it is attractive to builders and comes with a high price tag.

49 Canterbury Street Street Basic Data

Attribute	Value	
Lot Owner	City of Worcester	
Lot Size (sq. m)	7,037	
Lot Value	$ 247,100	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	10
Lot Topography Rating	This lot is flat and has solar exposure.	10
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks developable.	2
Lot Current Structures Rating	This lot is unpaved, clear and flat.	10
Lot Raw Score		43

28 SOUTHGATE STREET

28 Southgate Street is a flat, mostly paved lot owned by the WBC Realty Corporation. This lot is a Brownfield site with very little remaining structure. This lot has excellent southern exposure at the current time, but if large structures are built across the street, it may be hindered. This lot is in an industrial area and developing a photovoltaic power station on it would likely blend in aesthetically with the neighborhood.

28 Southgate Street Street Basic Data

Attribute	Value	
Lot Owner	WBC Realty Corp	
Lot Size (sq. m)	3,527	
Lot Value	$ 109,100	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	10
Lot Topography Rating	This lot is flat and has solar exposure.	10
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks developable.	3
Lot Current Structures Rating	This lot is unpaved, clear and flat.	9
Lot Raw Score		43

25 SOUTHGATE STREET

25 Southgate Street is a very large parcel of land that is owned by the City of Worcester. The city recently demolished a very large industrial complex on this site. This site is a Brownfield and would be an excellent candidate for photovoltaic generation, citing its large land size, regular shape and good solar exposure. Any large factory building at this location would fare well with a rooftop photovoltaic station. This lot also has multiple access points for electrical hook-ups, so that option may prove valuable to developers.

25 Southgate Street Street Basic Data

Attribute	Value	
Lot Owner	City of Worcester	
Lot Size (sq. m)	9,884	
Lot Value	$ 206,800	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	10
Lot Topography Rating	This lot is flat and has solar exposure.	10
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks developable.	1
Lot Current Structures Rating	This lot is unpaved, clear and flat.	10
Lot Raw Score		42

17 SOUTHGATE PLACE

17 Southgate Place is a very large plot of land owned by the City of Worcester. This plot has several large buildings on it, and this plot will require significant construction as the condition of the ground is poor. This lot is a Brownfield and financial incentives may be available for developers. This lot also has good full-day solar exposure with a railroad as the southern border. This lot is in an industrial section of town and seems like a fitting place for a renewable energy plant.


17 Southgate Place Street Basic Data

Attribute	Value	
Lot Owner	City of Worcester	
Lot Size (sq. m)	6,476	
Lot Value	$ 179,700	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	10
Lot Topography Rating	This lot is flat and has solar exposure.	8
Lot Brownfield Status	This lot is a Brownfield.	1
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks developable.	3
Lot Current Structures Rating	This lot has large structures.	2
Lot Raw Score		34

26 SOUTHGATE PLACE

26 Southgate Place is an abandoned lot owned by WBC Realty Corporation. This lot has some very large concrete structures that will need demolition and disposal. This lot also slopes downward toward the north, so solar exposure is limited. This lot would require quite a bit of land leveling and cleaning to build anything and is likely not a very developable piece of land. The southern border of the lot is once again railroad tracks, so new development that could hinder solar exposure is unlikely. This lot is also not a known Brownfield, so it is unclear if financial aid for clean-up purposes will be readily available to the developer.

26 Southgate Place Street Basic Data

Attribute	Value	
Lot Owner	WBC Realty Corp	
Lot Size (sq. m)	3,527	
Lot Value	$ 109,100	
	Justification	***Rating***
Lot Location Rating	This lot is in an industrial setting.	10
Lot Topography Rating	This lot is flat and has solar exposure.	6
Lot Brownfield Status	This lot is a not Brownfield.	0
Lot Zoning Rating	This lot is zoned MG-2.0.	10
Lot Buildability Rating	This lot looks somewhat developable.	6
Lot Current Structures Rating	This lot has structures and not isn't level.	6
Lot Raw Score		39

APPENDIX D: KGH MAP

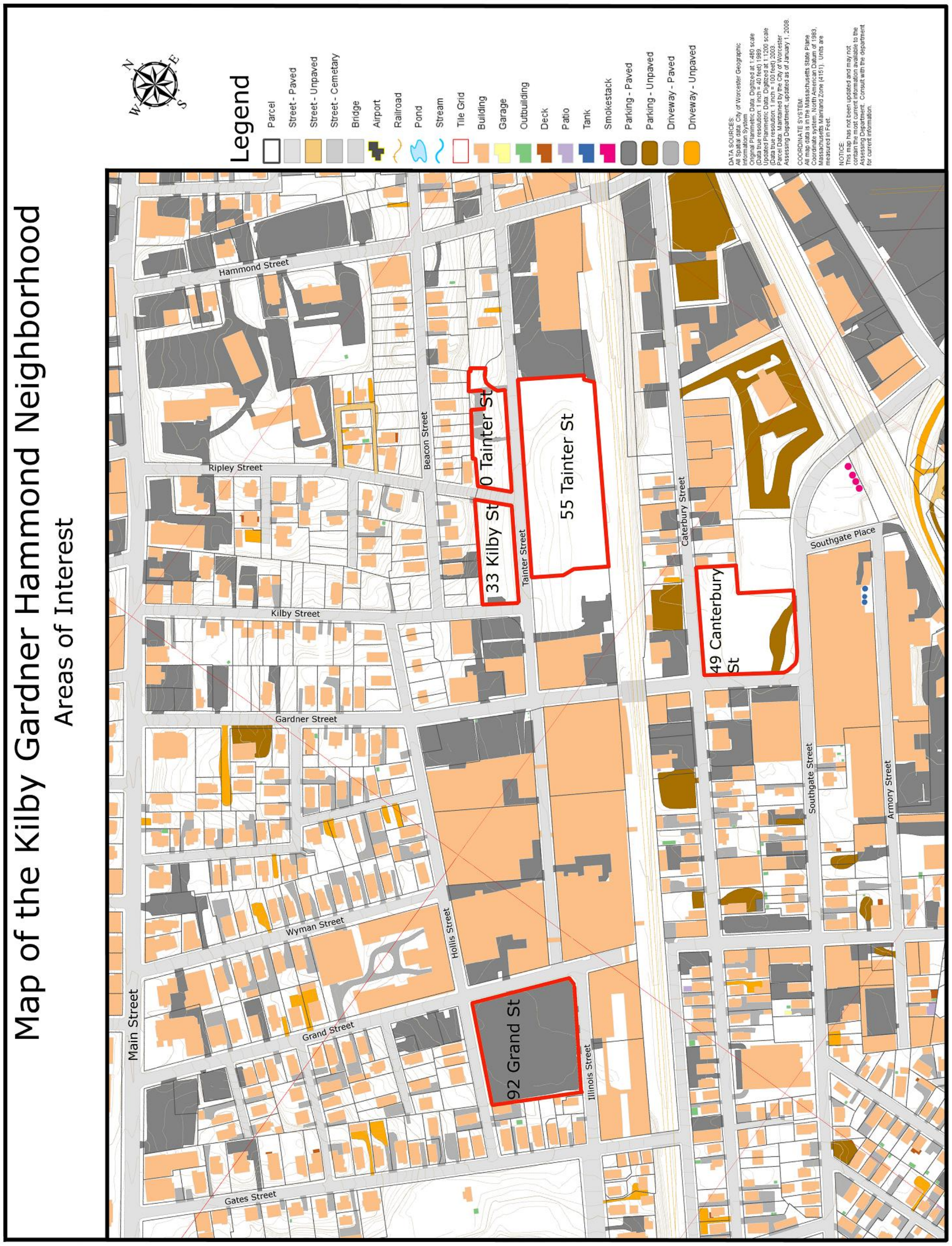

FIGURE 3: KGH NEIGHBORHOOD MAP WITH HIGHLIGHTED PLOTS (CITY OF WORCESTER, MASSACHUSETTS, 2009)

APPENDIX E – SOLAR PV PLANTS

BROCKTON BRIGHTFIELDS

Brockton Brightfields is a publicly owned solar photovoltaic facility located in Brockton, Massachusetts. The Brockton Brightfields facility was built on an existing Brownfield location and thus was eligible for grants and government aid to help absorb some of the costs of building. The Brownfield contamination was handled by installing a cement cap over the property. This three million dollar facility produces enough electricity to power 70 homes. This facility is at a similar latitude and has a very similar climate to Worcester, Massachusetts. This plant is also owned by a non-profit organization, namely the town that likely faced on a larger scale the same challenges and design choices that would be faced by the Main South Community Development Center.

Brockton Brightfields Information

Attribute	Value
Owner	Town of Brockton, Mass
Location	Brockton, Massachusetts
Latitude and Longitude (N,W)	40.083 , 71.018
Size of Facility (m^2)	14,981
Maximum Power Output (W)	425,000
Annual Energy Output (Wh)	535,000,000
Total Cost	$ 3,037,000
Yearly Income	$ 131,000
Cost per Power ($/W)	7.15
Power per Area (W/m^2)	2.64
Panel Manufacturer	SCHOTT Solar

(Town of Brockton, Massachusetts, 2006)

SOLAR FARM AT FRESNO YOSEMITE

The solar farm at Fresno Yosemite International Airport is a dual publically and privately owned Solar Photovoltaic plant. This plant provides as much as half of the airport's electric power and was built on undevelopable land that was unutilized. This facility is built in a southern climate and will likely have a higher production than anything built in the KGH neighborhood. This plant also has advanced tracking systems to follow the sun through the sky and capture the maximum amount of irradiation. Like most solar farms, this plant is funded heavily though government grants and is eligible for many tax incentives. The entire project was funded with no cost to the airport.

Fresno Yosemite Airport Solar Farm Information

Attribute	Value
Owner	City of Fresno, Cali and Solar Power Partners
Location	Fresno, Cali
Latitude and Longitude (N,W)	36.77 , 121.77
Size of Facility (m^2)	38,465
Maximum Power Output (W)	4,200,000
Annual Energy Output (Wh)	
Total Cost	$ 16,000,000
Yearly Income	$ 650,000
Cost per Power ($/W)	3.81
Power per Area (W/m^2)	10.15
Panel Manufacturer	Sharp Solar

(Airport Improvement, 2009)

DESOTO NEXT GENERATION SOLAR ENERGY CENTER

The DeSoto Next Generation Solar Energy Center is the largest photovoltaic plant in the United States at 25 MW. This plant is owned by the Florida Power & Light utility company. This plant is privately owned and operated. The plant covers 180 acres and operates 90,000 single axis tracking panels. Over the lifetime of the plant, it is expected that the electricity will cost approximately $0.12 per kilowatt-hour. This plant is located in a southern climate that has excellent solar exposure and an almost ideal climate for solar operation. The construction process behind this plant employed more than 400 people simultaneously and will generate millions of dollars in property taxes for the DeSoto County.

DeSoto Next Generation Solar Energy Center Information

Attribute	Value
Owner	Florida Power & Light
Location	Arcadia, Florida
Latitude and Longitude (N,W)	27.22, 81.85
Size of Facility (m^2)	728,807
Maximum Power Output (W)	25,000,000
Annual Energy Output (Wh)	42,000,000,000
Total Cost	$ 150,000,000
Yearly Income	
Cost per Power ($/W)	6.00
Power per Area (W/m^2)	3.19
Panel Manufacturer	SunPower

(LCG Consulting, 2009) (Florida Power and Light, 2009)

FLORIDA'S GULF COAST UNIVERSITY SOLAR FARM

Florida Gulf Coast University constructed their 17 million dollar solar farm on 16 acres of protected wet lands. This solar farm helps to power much of the buildings on the campus with its total peak output of 2 MW. Of the total cost, approximately one half came from state funding. This facility features 10,080 panels on 1 axis tracking that will follow the sun throughout the day and maximize captured solar irradiation. To compensate for possible hurricane forces, these tracking systems can endure 145 mph winds. This specific farm is small enough to operate via net-metering and sell its electricity back the utility company for the retail cost, greatly reducing its energy bills. The construction of the project went very smoothly and the entire cost ended up being 3 million dollars under budget.

Florida's Gulf Coast University Solar Farm Information

Attribute	Value
Owner	Florida's Gulf Coast University
Location	Fort Myers, Florida
Latitude and Longitude (N,W)	26.58, 81.86
Size of Facility (m^2)	64,783
Maximum Power Output (W)	2,000,000
Annual Energy Output (Wh)	
Total Cost	$ 17,000,000
Yearly Income	$ 730,000
Cost per Power ($/W)	8.50
Power per Area (W/m^2)	2.87
Panel Manufacturer	Mitsubishi Electric

(Florida Gulf Coast University, 2008)

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