# Photovoltaic Installations at Williams College

Ruth Aronoff
Williams Luce Project

## SUMMARY

Williams College is at a unique crossroads. The College is undertaking new building projects and renovations to enhance the facilities available to its students, faculty, and staff; it has also made a firm commitment to environmental sustainability by defining greenhouse gas emission reduction goals. These separate endeavors can be achieved congruently in the form of sustainable buildings, and a very important aspect of green building is renewable energy.

This report examines the feasibility of photovoltaic arrays on buildings at Williams College. It provides an overview of photovoltaic technology and its installation requirements. A history of the College and solar projects is given, along with recommendations for new photovoltaic sites. Graphs and models provide projections for financing systems. There is a summary of similar projects undertaken around Berkshire County and at other schools throughout the country, as well as recommendations for incorporating this new technology into future projects and current buildings.

Given the College's position as a leader in the campus sustainability movement, it is imperative that the College considers renewable energy technologies. Solar energy will not only reduce greenhouse gas emissions, but it will also provide a valuable educational opportunity for the campus community.

## INTRODUCTION

Williams College has committed itself to a sustainable future, most specifically in the form of a greenhouse gas reduction goal. As the College moves forward with new building projects and renovations to enhance current facilities, it is now evaluating in detail the environmental impact of these actions. In addition to making buildings themselves efficient so that they consume less energy, the College needs to examine how that energy is produced. Both new and existing buildings provide a great opportunity for clean energy generation using solar power. Photovoltaic (PV) panel installations are a simple way for the College to provide for a portion of its own energy in a way that releases no greenhouse gases.

Photovoltaic arrays are most commonly found on south-facing rooftops, although they can also be mounted in a stand-alone fashion on a pole. Panels can be fitted to most roof types, and may be angled or flat.

Figure 1: At left, a roof-mounted array on a south-facing roof on a house in Becket, MA. At right, a pole-mounted array. Photos courtesy of BPVS[1].

The best locations for solar arrays get continuous sunlight throughout the day (from about 9 AM to 3 PM) for the entire year. This means the panels should not be significantly shaded by trees or by shadows from other buildings or rooftop structures like vents. The roof need not be facing directly south; a location within 20 degrees of true south will work.

1 http://www.bpvs.com/

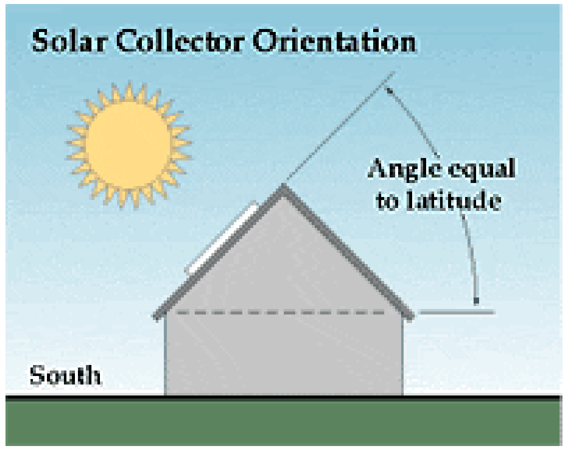


Figure 2: A diagram illustrating ideal panel placement. The panels must be south facing, and the ideal tilt is equal to the latitude, although other angles will work. Image Courtesy of EERE[2].

Photovoltaic panels follow a rule of thumb that 10 Watts of power fit into every square foot of roof space (or 0.1 square meters). This means a 1 Kilowatt (kW) system needs just over 100 $ft^2$ of space (or 9.3 $m^2$). Depending on the size of the total array, panels cost between $7.50 and $10 per Watt of power installed; smaller systems cost slightly more to install per Watt, while larger systems cost less since they are bought in bulk and there are often economies of scale in installation. (Financing a system will be discussed in detail below.) Table 1 illustrates approximate numbers for a 5 kW array. For reference, most residential PV systems are either about 2 kW or between 5 and 7 kW. We assume an installation cost of $9 per Watt, which is an average price for small systems. Annual energy production numbers are based on conditions in Berkshire County. Under these conditions, a 5 kW array could be expected to produce about 5% of Kellogg House's annual electricity consumption – or to produce enough energy to run 18 computers if the PCs were put to sleep when not in use, but never turned off.[3]

Table 1: Example PV Facts

| | |
|---|---|
| Size | 5 kW |
| Area | 590 $ft^2$ |
| Annual energy | 5,500 kWh |
| Installation Fee | $45,000 |
| Kellogg Electricity | 5% |
| PCs Powered | 18 |

[2] http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12890?print

[3] Computer calculations done with the help of the EnergyStar calculator: http://www.eu-energystar.org/en/en_007c.shtml

## PV Panels on Morley Science Center and Other Potential Sites

The College already has some experience with producing small amounts of clean electricity; PV panels were installed on the roof of the Morley Science Center in 2004 by Berkshire Photovoltaic Services (BPVS), an Adams company that has been installing panels for over 20 years. The 7.2 kW array on top of Morley (Figure 3) is slightly larger than the example discussed above, but it is still considered a small unit. Continuous monitoring of the panels since 2005 provides useful information about annual PV output in Williamstown, and the Morley panels are a useful model for future projects in terms of funding, installation and operation.[4]

Figure 3: The Morley Panels seen from the online webcam[5] on July 10, 2007

Morley is a good location for PV because of the amount of sunlight hitting the roof year-round, but many other campus locations could be fitted with solar panels. Suggested areas are outlined in purple in the map below (Figure 4). The new Library Project includes ample south-facing roof space for panels, and since the building is tall it would not be shaded by other structures. The proposed offsite storage facility for the library is situated perfectly for solar power, and since the building is climate-controlled it requires continuous energy use. Panels could be installed without penetrating the roof so as not to disturb the building envelope. The Children's Center currently being constructed was originally designed as a green building, and would benefit from green energy. Another possible location for PV is Kellogg House. As the home of the Center for Environmental Studies, solar power on this building would serve as an excellent teaching tool and act as a visible representation of the College's commitment to sustainability. Since Kellogg is scheduled to move and undergo renovations during summer 2008, this would be an ideal time to add green features to the building.

---

[4] http://www.williams.edu/resources/sustainability/solar.php

[5] Webcam may be accessed here: http://www.williams.edu/resources/sustainability/solar.php

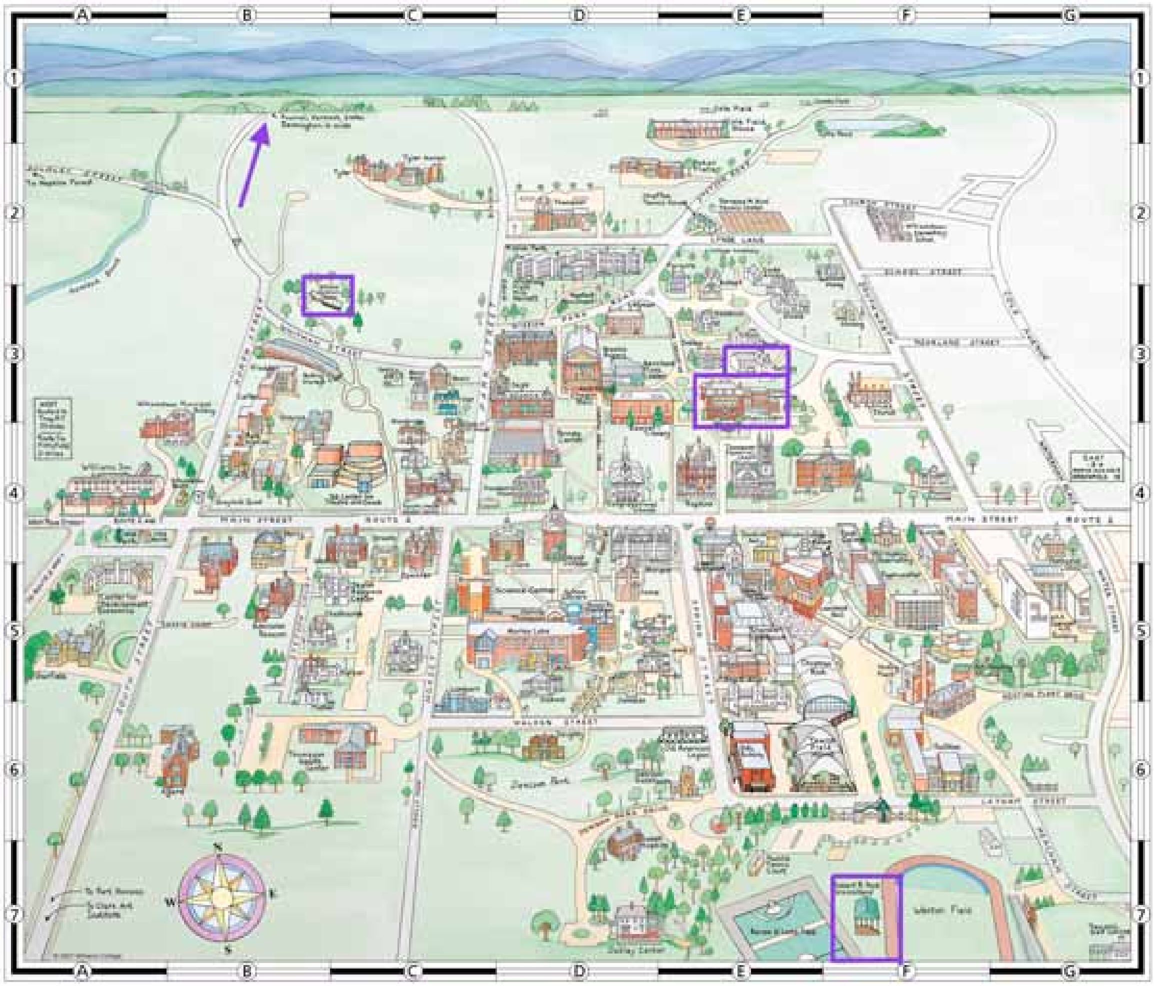


Figure 4: Locations for possible photovoltaic installations. Sites are outlined in purple. The arrow points in the direction of the offsite storage facility, which is not on the map.

The renovations planned for the facilities at Weston Field are an ideal place for solar hot water as well as electricity, since demand for hot water is high in the locker rooms and the field gets ample amounts of sunlight. Hot water systems are similar to photovoltaic arrays in that they involve a roof-mounted panel or group of tubes, and they are used to either provide hot water, or pre-heat water so that it requires less energy to warm enough for building use. A solar hot water system was installed on Fort Hoosac in 2006.[6] The locations mentioned above are particularly good choices for solar projects because they are or will soon be undergoing renovation, but there are other existing buildings that deserve careful consideration for PV as well. Many buildings on campus meet the requirements for location, roof type, and amount of sunlight, making them ideal candidates for solar power.

---

[6] http://www.williams.edu/resources/sustainability/solar_hot_water.php

## MODELING PAYBACK PERIOD

One can model installation costs and payback period for new panels using information from the Morley PV array and from Berkshire Photovoltaic Services (BPVS). Currently, a system is installed at a given price per watt of power. This cost may be defrayed by a grant from the Massachusetts Technology Collaborative (MTC) Small Renewables Initiative.[7] The minimum grant awarded recently is about $2 per watt, but the College would likely receive more funding because Williamstown is designated by MTC as an economic target area. Additional funding is available if the panels are made in Massachusetts, which was true for the Morley panels. The length of the payback period is determined by the cost of electricity, since the panels save the College from buying power; whether the College decides to sell the array's Renewable Energy Credits (RECs); and specific attributes of the array such as size and production. The factors that have the largest impact on the payback period of the panels are installation cost per watt, future electricity price, and annual production. Each of these factors is modeled individually in figures 5, 6, and 7 respectively.

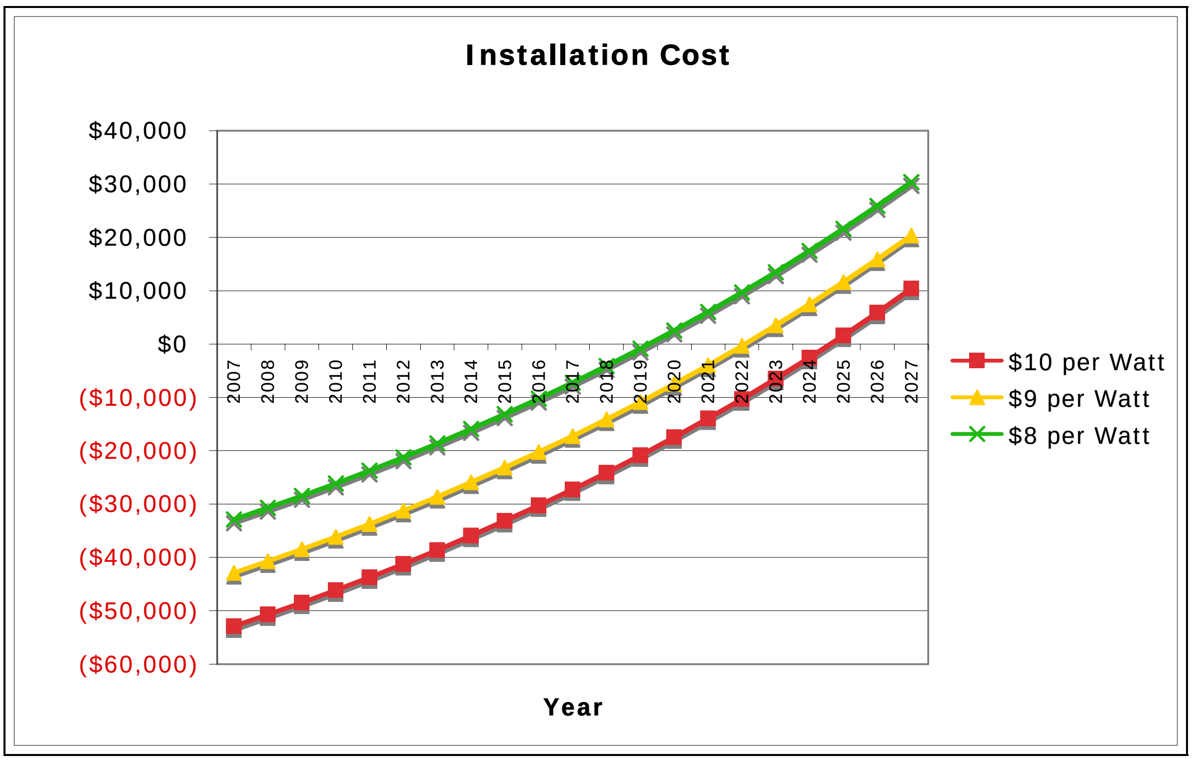


Figure 5: Dependence of payback period on installation cost, given a 10 kW array.

[7] http://www.mtpc.org/renewableenergy/small_renewables.htm

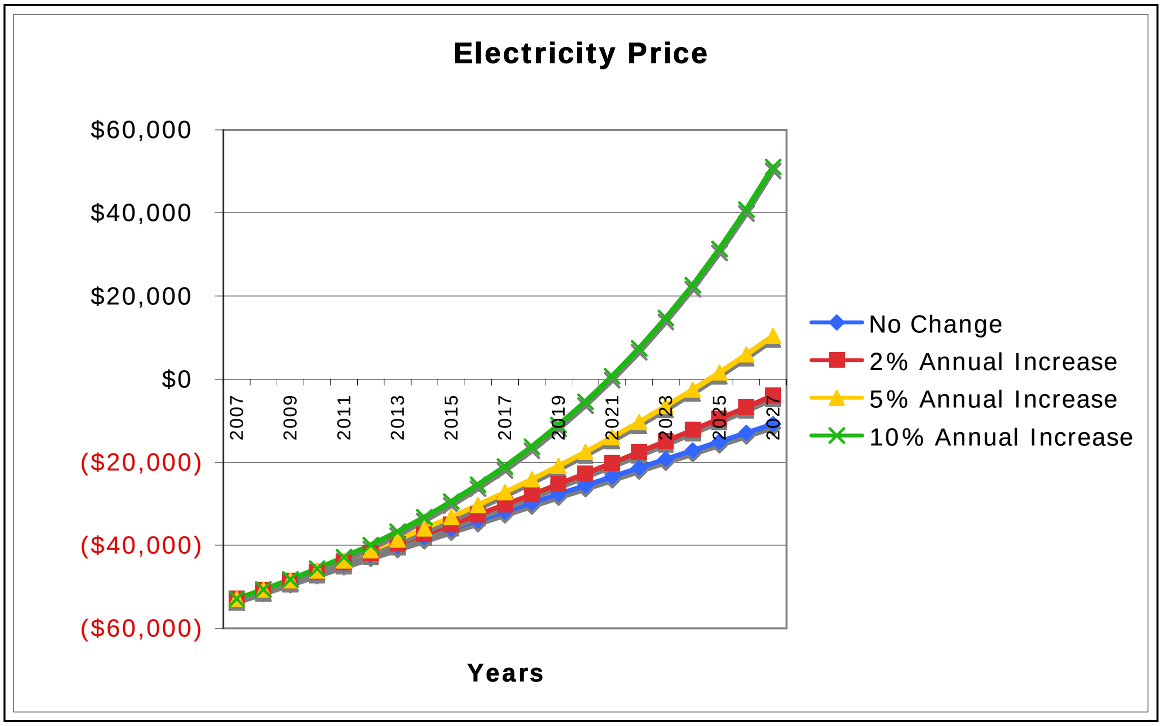


Figure 6: Dependence of payback period on annually increasing electricity prices, in constant dollars, of a 10 kW array.

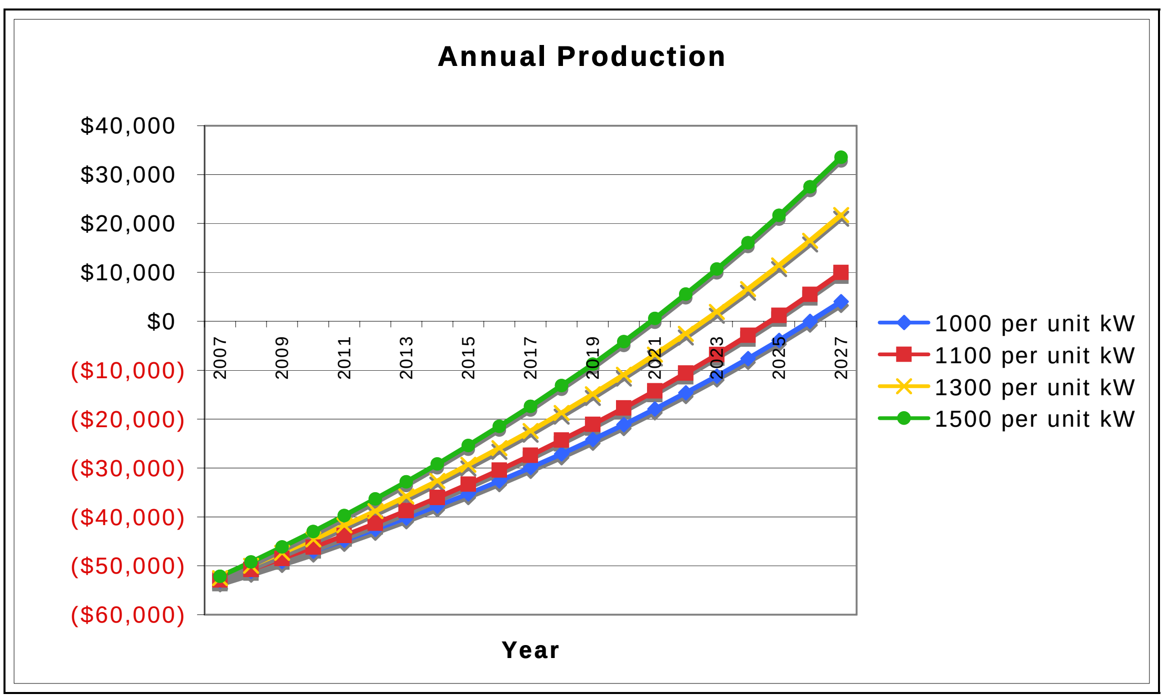


Figure 7: Dependence of payback period on different annual production outputs, expressed per unit kilowatt.

Some variables can be better predicted than others. The installation cost (Figure 5) of PV is decreasing thanks to an increase in supply of PV panels, so the College can expect to pay $8 – 9 per Watt on future projects.[8] The Morley Panels provide useful data on expected annual production in Williamstown (Figure 7). In two years that the Morley panels have been in operation (April 2005 through April 2007), they produced an average of 7,972.3 kWh per year, or an output of 1,107.3 kWh annually per unit kW. A PV installation at Gould Farm in Monterey, MA, 43 miles from Williamstown, produced an average of 7,018.2 kWh per year with its 6.9 kW system.[9] This is an annual output of 1,082 kWh per unit kW. These panels are tilted at 35º, while the Morley panels are tilted at 5º. Electricity cost (Figure 6) is the most difficult to predict, since it is unclear what the future energy market will be. The International Energy Agency (IEA) predicts that global prices for crude oil will continue to slowly rise through 2030,[10] while energy demand will increase as much as 53% in that same time period.[11] These indicators point to increasing consumer prices for electricity for the foreseeable future.

By compiling factors affecting payback period, one can create different scenarios for new PV systems. I modeled the best and worst case scenarios below (Figure 8) along with a moderate set of conditions likely to occur. Under the worst case scenario, the installation fee is $10 per Watt, electricity price stays constant at $0.13, and production is 1000 kWh per unit kW, which is lower than Morley's production. This scenario yields a payback that is longer than 20 years. Under the best case scenario, the installation is only $8 per Watt, electricity price inflation is 10% annually, and production is at 1500 kWh. This yields a payback of approximately 10 years. Under the likely scenario, I assume that the College pays $9 per Watt to install the unit, electricity price inflates at 5% annually, and production is 1100 kWh, which is equivalent to Morley. This yields a payback period of approximately 18 years. These scenarios are juxtaposed against a scenario that would occur under new state legislation regarding solar power. The legislation being considered by the state of Massachusetts, known as a feed-in tariff, is similar to systems being adopted by European countries. Under this new law, grants would be replaced by a simple $0.51 per kW fee paid to the energy producer – the College – by the government, guaranteed for the lifetime of the system. The new legislation yields a payback of approximately 15 years, and that calculation is not dependent on variables like electricity price. The models shown here do not include income from RECs. If the College wishes to include solar installations as part of an emissions reduction plan, it cannot sell RECS. Renewable Energy Credits are the green attributes of the energy produced by solar power, so if the College sells the RECs, it may not have an ethical claim to the emissions credits.

---

[8] Meeting with Chris Kilfoyle of BPVS, 7/23/07

[9] http://www.soltrex.com/systems.cfm?systemid=S00000000241

[10] IEA World Energy Outlook 2005 Fact Sheet: http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1873

[11] IEA World Energy Outlook 2006 Fact Sheet: http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1898

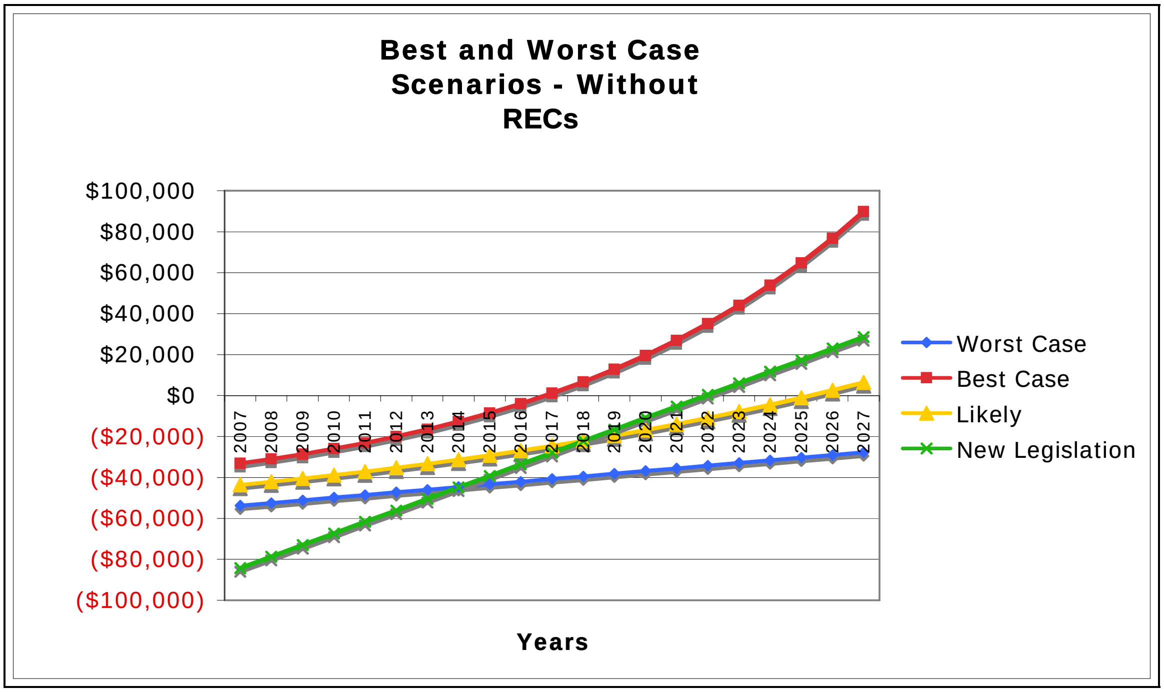


Figure 8: Possible payback scenarios given variances in installation cost, electricity price, and production.

## BENEFITS

The decision not to include RECs in the models highlights an important aspect of solar energy: its non-financial benefits. Last winter, the Trustees of the College named "greenhouse gas emissions reductions specifically"[12] as an institutional priority, calling for Williams to reduce its emissions to 10% below 1990-91 levels by 2020. PV installations are completely clean, and the power they create saves the College from producing greenhouse gas-emitting energy. For instance, the Morley panels, a 7.2 kW installation, save us 3,267 kg of $CO_2$ equivalent (meaning other greenhouse gases as well) per year. That's as much greenhouse gas emissions as driving a Honda Civic about 10,350 miles![13] Renewable energy is also an important aspect of the US Green Building Council LEED® certification process both for new construction[14] and for existing buildings,[15] which is a rating system the college is currently using as a guideline for sustainable building. For new buildings, one to three points are awarded if 2.5, 5, and 7% respectively of the building energy is on-site renewable. One to four points are awarded to an existing building if 3, 6, 9, or 12% of the energy is renewable. Renewable energy is also important to Williams for educational purposes. Installations can be used as teaching tools in a variety of classes, and familiarity with renewable energy will be important to students living in an environmentally sensitive world.

[12] http://www.williams.edu/admin/president/letters/070124_CAC.php
[13] https://www.fueleconomy.gov/
[14] http://www.usgbc.org/leed/nc/
[15] http://www.usgbc.org/leed/eb/

Campuses and institutions around the country are embracing new solar opportunities as well. The Association for the Advancement of Sustainability in Higher Education (AASHE), of which Williams is a member, lists over 100 schools with solar panel installations.[16] Yale University just installed a 40 kW system on the roof of a dorm, citing commitments to sustainability, energy conservation, and leadership in these areas as reasons for the large undertaking.[17] Georgetown University stepped up in 2003 to become the home of what it reported to be the largest single-installation PV panel in the world at the time with its 337 kW array.[18] It is not just large private universities that are undertaking solar power; two of the five largest campus solar installations are at community colleges, and the State University of New York at Farmingdale installed its 80 kW worth of solar between 1992 and 1993.[19] Fellow liberal arts colleges like Oberlin and Pomona also have photovoltaic installations. In fact, Oberlin's 160 kW solar parking pavilion, which provides shade to an existing parking lot, is an innovative example of additional benefits that can be reaped from solar power. The panels that shade the parking lot, combined with an array on the roof of the Environmental Studies Center, will provide all of the power for that building, and will also send any unused power back into the grid.[20]

Figure 9: Yale Divinity School Dean Harry Attridge learns about the school's 40 kW installation. Photo courtesy of Yale Divinity School.[21]

16 http://www.aashe.org/resources/solar_campus.php
17 http://www.ctinnovations.com/news/320.php
18 http://www.thehoya.com/news/042503/news8.cfm
19 http://info.lu.farmingdale.edu/depts/met/solar/background.html
20 http://www.oberlin.edu/alummag/summer2005/ats_2.html
21 http://www.yale.edu/divinity/news/060710_news_soloar.shtml

Businesses and schools in Berkshire County have been actively embracing solar power as well. The North Adams Public Library underwent renovations in 2003 – 2005, and now has a geothermal heating and cooling system in addition to 9.6 kW worth of photovoltaic panels.[22] Massachusetts College of Liberal Arts has a 9 kW array on a building,[23] and Williamstown Elementary School has a 24 kW array.[24] Mass MoCA in North Adams just installed a 50 kW PV array, which visitors will be able to look at from an adjacent building.[25] Large installations like Mass MoCA's and Yale's, which generally cost less per watt to install, are more difficult to finance because the grant process is competitive. The MTC Large Onsite Renewables Initative (LORI)[26] for systems over 10 kW is different from the Small Renewables Initiative (SRI),[27] which is a non-competitive rebate. It may be more feasible to incorporate multiple small installations into a number of new building projects than to install one large array.

Figure 3: The 50 kW installation at Mass MoCA. Photo courtesy of Ruth Aronoff.

[22] http://www.naplibrary.com/NAPLgreen.htm
[23] http://www.mcla.mass.edu/Publications/News__Press_Releases/20060217130507.php
[24] http://www.williamstownelementary.org/
[25] http://masstech.org/renewableenergy/press/pr_7_5_06_massmoca.html
[26] http://www.mtpc.org/renewableenergy/large_renewables.htm
[27] http://www.mtpc.org/renewableenergy/small_renewables.htm

## RECOMMENDATIONS

Sustainability is a priority of the College that requires an initial investment in order to reap long-term benefits. Incorporating solar energy into building renovations and new construction allows Williams to independently and cleanly account for portions of its own energy consumption, and importantly, the College can use these installations as a teaching tool. Funding from state grant programs like MTC and access to reliable installers like BPVS make installing photovoltaic arrays at Williams simpler and more economically feasible than at most colleges. It is therefore recommended that the College:

- Consider renewable energy technologies for the building projects enumerated above: Stetson Library, Offsite Storage Facilities, Weston Field, Children's Center, Kellogg House
- Consider renewable energy in all future building projects and major renovations
- Analyze existing buildings on campus to determine which are the best candidates for solar technology retrofits
- Create a target percentage of total campus energy consumption that must come from renewable sources by 2020

A commitment to renewable energy is an important aspect of a sustainable campus. It makes sense to include new energy technologies into sites undergoing major construction, since it is easier to install panels and associated equipment at this stage. It is important to carefully consider renewable energy technologies on a broad, campus-wide scale as well as a building-by-building basis. As a leader in the campus sustainability movement, the next logical step for Williams is to create a well-integrated campus plan that defines energy goals and ensures that renewable energy is considered in all new construction and renovation.

## ACKNOWLEDGEMENTS

This report was created as the culmination of my summer internship under the Luce Foundation Grant awarded to Williams College. I would like to thank David Dethier, Stephanie Boyd, and Amy Johns for working closely with me on this project. Special thanks for information also go to Sarah Gardner, Don Clark, and Chris Kilfoyle of Berkshire Photovoltaic Services.