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# Moving Towards the Future of Solar Energy Use at Williams College

## The Current Environment at Williams

In 2007, Ruth Aronoff presented a report on the possibilities of photovoltaic arrays at Williams College. Coming at a time when the College was in the planning stages of its largest construction project ever, the report examined the feasibility of photovoltaic arrays on College buildings (Aronoff 1). The report recommended that the College:

- "Consider renewable energy technologies for the building projects…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 for total campus energy consumption that must come from renewable sources by 2020" (Aronoff 12).

Though it has only been one year, none of these visions have come to fruition as of yet, though there are several encouraging events that show the college is on the right track. The decision to build a 24 kW array on an off-campus book storage building and the debate over a possible 22 kW photovoltaic array and solar water heating system on the new Weston Field athletic facility mean that solar energy is now at least part of the dialogue. It is time for the College to more aggressively pursue solar energy arrays throughout campus. As the college attempts to reach its stated goal of lowering greenhouse gas emissions to levels 10% less than 1990-1991 levels by the year 2020, there is much work left to do.

The student body has recently been in an uproar over changes to low-flow faucets and shower heads, and the debate over the possibly abolition of trays in dining halls is nearing a boiling point. While the thought behind these actions is admirable, the cost to student comfort and the possible creation of a student body disgruntled with renewable actions and therefore less likely to approve of later, more drastic measures is not worth the short term drops in water use and heating use. The college would be far better served engaging in activities that do not alienate the student body, that do not have a discernable negative effect on quality of life, and that improve the on-campus awareness of renewable energy. The installation of photovoltaic arrays and solar hot water panels fits that description.

Williams College owns around sixty buildings, with that number fluctuating with ever-present construction. Of those, many are old slate-roofed buildings that will need repair at some point within the next year. Chris Kilfoyle, the head Photovoltaic installer of Berkshire Photovoltaic Services, estimates the number of buildings that will need work on the roof within the next ten years as high as fifty percent (Kilfoyle Interview). Along with this, Williams is also in possession of either newer buildings with sturdy and sometimes flat roofs or in the process of planning new buildings to be built with LEED certification in mind. There is no better situation to plan for the implementation of widespread solar energy arrays than the one Williams College finds itself in today.

**Solar Photovoltaic and Solar Hot Water Heater Background**

I will now give a cursory introduction to how photovoltaics and solar hot water heaters work. For our purposes, we will focus on photovoltaics and both flat-panel and evacuated tube water heaters because other technologies like parabolic trough water heaters are more directed towards the creation of electricity and would require an ability to utilize space that the College has yet to show. Both photovoltaics and solar water heaters produce their energy rather simply and through solely the power of the sun. Arrays are often placed on rooftops, though a quick drive through nearby Pownal, Vermont turns up arrays on both the ground and elevated posts. Both photovoltaics and solar water heaters face south, though “a location within twenty degrees of due South will work” (Aronoff 2). Photovoltaic arrays have no moving parts, and therefore have long lifespans, on average lasting over fifty years. They use a material called a semiconductor, normally Silicon.

> “The cell is covered with a thin layer of anti-reflective coating (ARC) to minimize light reflection. The top semi-conducting layer, or 'n' type layer, is doped with tiny amounts of phosphorus so that almost every thousandth silicon atom is replaced by a phosphorus atom. This creates free moving negative charges called 'electrons'. The base semi-conducting layer, or 'p' type layer, is doped with miniscule amounts of boron so that almost every millionth silicon atom is replaced by a boron atom. This creates free moving positive charges called 'holes'. When the 'n' and 'p' type layers are placed close together, as they are in a solar cell, the positively charged 'holes' and the negatively charged 'electrons' are attracted to each other. As they move into their respective neighboring layers they cross a boundary layer called the 'p-n junction'. This movement of negatively and positively charged particles generates a strong electrical field across the p-n junction. When sunlight strikes this field it causes the electron particles and the whole particles to separate, which in turn creates a voltage of around 0.5V. The voltage pushes the flow of electrons or 'DC current' to contacts at the front and back of the cell where it is conducted away along the wiring circuitry that connects the cells together” (Cel-f Solar Systems).

Evacuated tube water heaters are a newer technology that utilizes the cycle of latent heat of vaporization followed by the latent heat of condensation:

> “Sunlight heats round aluminum heat sinks that runs the length of the tube. A small copper tube is located in a slot in the aluminum. Inside this tube are drops of glycol which change to [vapor] that goes up the tube and into the manifold where the water changes state from [vapor] to [liquid]. It is this changing of state from water to steam that gives the tubes the high efficiency that makes them produce about 40% more heat than a flat plate collector” (BeyondOilSolar).

A flat-panel water heater “consists of a shallow rectangular box with a transparent glass ‘window’ covering a flat black plate. The black plate is attached to a series of parallel tubes or one serpentine tube through which air, water, or other heat transfer fluids pass” (CanRen). Among water heaters, evacuated tube heaters are slightly more expensive than flat panel heaters initially but also more efficient at creating hot water. Since the college will be installing these for the long term, I recommend the installation of evacuated tube heaters. Regardless, it is clear from the descriptions that the most important factor of a successful solar-powered system is unfettered access to the sun, access that can be garnered through the elevation of systems either on to poles or on the roofs of buildings.

Aronoff’s paper does a very good job at outlining the economics of installing photovoltaics. The upshot of her discussion of economics is that, even at the worst-case scenario of a system that performs worse than the current system on Morley at an expensive $10 per Watt installation cost with a constant energy price, the payback time for a system is a little over twenty years while a best case scenario creates a payback time of approximately ten years and an average scenario has a payback time of around eighteen years (Aronoff 8). The important thing to glean from this is that, with the average lifespan of a photovoltaic panel at fifty years and rising and the minimal amount of work needed to maintain it, even under a worst-case scenario the panel will pay for itself in the long run. Therefore, the College would be smart to look into a much greater proliferation of photovoltaics.

One example of previously unexplored area of photovoltaic installation on campus is pole-mounted photovoltaics. At first glance, the idea of having pole-mounted photovoltaic arrays may seem doomed to failure in a place so married to traditional aesthetics as Williams College.  However, simply ignoring this possibility as unfeasible is a dangerous oversight to what could, in fact, be a very solid addition to the renewable energy model on the Williams College Campus.

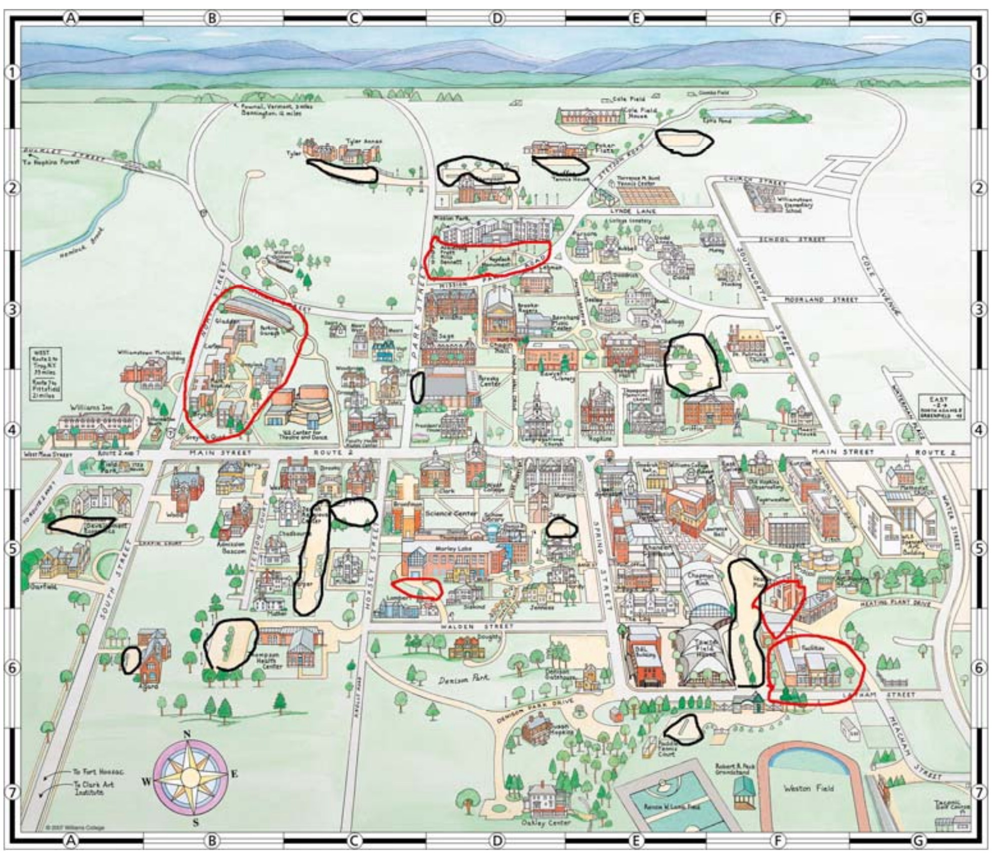
**Pole-Mounted Photovoltaics at Williams**


Source: Eskimo.com

There are currently zero pole-mounted photovoltaics at Williams.  While the array on top of Morley Science Center is certainly not exceedingly large, it would still dwarf a single pole-mounted photovoltaic system.  "Generally, large area arrays are the most cost-effective," says Chris Kilfoyle.  This is certainly true.  However, the pole-mounted photovoltaics have the advantage of taking up minimal space on the ground and so could be placed in areas where the College has either space limitation or no real building presence at all.

For example, the College currently owns land on Berlin Mountain with plans to either build a wind turbine or sell to a company that will build the turbine.  It is encountering resistance, however, from the Town of Berlin, which would be averse to having a large windmill spoiling their view.  Without going too deeply into aesthetics, a series of pole-mounted photovoltaics would take up almost the same space on the ground while being much more inconspicuous to the eye. Better still, the pole-mounted photovoltaics could be incorporated into a future wind turbine site, using the same power lines as the turbine while again requiring minimal space to be cleared on the ground. As my group-mate Taylor Mikell has found, it is important in a snowy climate like Western Massachusetts to keep photovoltaic arrays at an angle to minimize the amount of snow that sticks to the array. By either implementing poles with movable photovoltaics or placing the photovoltaics at an angle, the problem of snow covering could be more easily addressed too.

On the campus, the placement of pole-based arrays becomes trickier. One must be mindful of the aesthetic concerns of the college while realizing that placing the poles too far away from buildings will cause the arrays to be less cost-effective. Here is a campus map:



The areas circled in red are possible sites near buildings where pole-mounted systems could exist while not interrupting aesthetics or student life while remaining close to high-use buildings on campus, while the areas circled in black are parking areas where photovoltaics could either be mounted on poles or fitted on top of future roofs. Parking lots are clearly the least aesthetically pleasing parts of campus, have ample open space for poles and have preexisting lampposts and security blue-light systems that could be powered at least partially by photovoltaics. The Greylock quad and the cooling plant beyond it has several areas which could easily accommodate several poles while creating an unobstructed view of due South. As there are already thoughts of outfitting the parking lot next to Greylock with roof-mounted photovoltaics, additional pole-mounted systems would also be possible and have an easier time being approved. The south side of Morley Science center is not frequented very often yet has ample room for pole-mounted arrays. This means that very little foot traffic will be impeded and complaints to return to the formerly pristine nature of the area (it boasts a loading dock and parking lot) will be minimal. Finally, the heating plant and facilities building seem like natural fits for poles. Neither is particularly aesthetically pleasing in the first place and as symbols of energy creation and consumption, would be emblematic of Williams's commitment to green initiatives. The facilities building also has ample roof space for a roof-based photovoltaic or solar hot water array, and it is not alone among Williams College buildings. I will now argue for the proliferation of roof-based photovoltaic arrays and solar water heaters on College buildings on a scale exponentially greater than is currently in the Williams College's construction plan.

**Roof Based Photovoltaics and Solar Water Heaters**


Source: Williams College Sustainability Website

A campus map with all of the buildings that could possibly carry photovoltaic arrays and solar water heaters would be unreadable for all the circles. As previously stated, the college owns around sixty buildings, up to half of which will require roof renovation within the next ten years. "Typically," Kilfoyle says, "we cannot add even the slight extra weight of PV panels to slate roofs" without an expensive installation (Kilfoyle Interview). However, "metal standing seam roofs are gaining acceptance on campus- no need to re-roof [and] there is a non penetrating PV mount perfect for these instances" (Kilfoyle). The proliferation of photovoltaic panels and solar hot water heaters could take place gradually and naturally as successive roofs need renovation.

The current 7.2 kW array on Morley Science Center has had an actual total energy output of 22,484 kWh, while its model output for that time is 23,590 kWh. This is an over 95% realization of goals and shows that the college can maintain a photovoltaic array well and is further illustrated in the table below. Coupled with my colleague Taylor Mikell's findings that building arrays at an angle increases the overall efficiency of the system, this shows that it is unequivocally time to build more.

| Month | Model production on Morley in kwhrs | Average Actual production on Morley in kwhrs |
|---|---|---|
| January | 326 | 166 |
| February | 436 | 272 |
| March | 682 | 555 |
| April | 775 | 773 |
| May | 893 | 950 |
| June | 866 | 931 |
| July | 902 | 993 |
| August | 815 | 903 |
| September | 661 | 735 |
| October | 488 | 451 |
| November | 288 | 292 |
| December | 250 | 129 |

Williams College is unlike many other schools in the large number of buildings built like houses. This creates a decentralization of living space and allows for the prudence of individual arrays and solar water heaters on the many smaller buildings. The solar water heaters could be paired with tank-less water heating systems to reduce water-related energy use and the photovoltaic arrays would supply energy to the house and reduce the need for purchasing energy on campus. At the same time, Williams also has several very large buildings with large roof areas to accommodate larger photovoltaic arrays. This means that the College can combine the advantages of decentralized smaller arrays with the economies of scale enjoyed by larger arrays. When I first began researching this project, my question was whether the College would be better served with larger centralized arrays or smaller decentralized arrays. The unequivocal answer is that the College should pursue both.

There are two main possibilities with regards to photovoltaic arrays, stand-alone arrays and arrays that replace shingles or are glued to a metal roof as a thin membrane. While those who worry about aesthetic complaints against stand-alone arrays look to the shingles and thin membranes as a possible solution, it will unfortunately not be feasible at Williams in the near future.

> "Now you may know of the several products which replace shingles or membrane roofing materials or can be glued onto metal roofs. None of these products are recommended by my firm. They simply do not have the durability needed for our weather and frequently the PV cells are of thin film or amorphous constructions, meaning their power output will degrade in 10-15 years. There are also way too many wire connections with these products which means more faults and of course a harder time narrowing down where a fault is - imagine having to remove hundreds of PV shingles to find the short circuit. Keep in mind that MIT 's Lincoln Labs thoroughly researched PV as roofing materials and concluded it was not good sense for our climate" (Kilfoyle).

The upshot of this is that solar energy must be a substantial and visible part of the College's vision of going green. The College must make a strong commitment to solar energy to stand firmly against any possible early criticism. While some of the larger and flatter buildings will be able to hide their arrays, most residence halls will not, nor should they.

**Williams College Taking a Stand**

A solar panel is an iconic symbol of renewable energy. By proliferating visible photovoltaic arrays and solar water heaters on campus, Williams will be making a strong statement of its commitment to renewable energy. Already, the signs exist that the College is moving closer to a solar-centric model. An agreement has recently been signed ensuring that the new book storage building will have a photovoltaic array over three times the size of the Morley array, and plans are in the works for the new Weston Field to have a 22 kW photovoltaic array and solar hot water-heated showers. This is all positive change and indicative of a cultural change that will mean greater acceptance of solar power on campus.

Ruth Aronoff's paper suggests that the College "carefully consider renewable energy technologies on a broad, campus-wide scale as well as a building-by-building basis" (Aronoff 12). This anticipates the possibilities for a veritable explosion of solar energy-related apparatuses on campus. She goes further to say the College should "create a well-integrated campus plan that defines energy goals and ensures that renewable energy is considered in all new construction and renovation" (12). I will now make recommendations for what such a plan might contain:

- Exploration of pole-mounted photovoltaic arrays on Berlin Mountain and many more places throughout campus.
- Just as Middlebury College sets aside 1% of the cost of each new building to the purchasing of art for that building, setting aside a percentage of new building costs for photovoltaic arrays and solar water heaters. This will also work with the scale of buildings, as larger buildings will cost more and will also be able to hold more photovoltaics.
- Committing to renovate old slate roofs into roofs that can hold photovoltaic arrays and solar water heaters.
- Educate students on the advantages of solar energy.
- Work towards a creation of a campus where solar energy arrays are a norm, not a nuisance.
- Establish goal percentages of college electricity and hot water created by renewable energy, increasing incrementally until 2060.

This is a long-term project. The transformation of Williams College into a campus committed to solar energy will not happen overnight, but the evolution should, building by building, keep Williams among the leaders of the campus sustainability movement. Issues such as aesthetics will be assuaged as unobtrusive pole-mounted arrays and roof-mounted photovoltaics and solar water heaters become norms rather than outliers. Adherence to such a plan of action would ensure that Williams College would be universally seen as a symbol of action towards the increasing use of renewable energy.

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