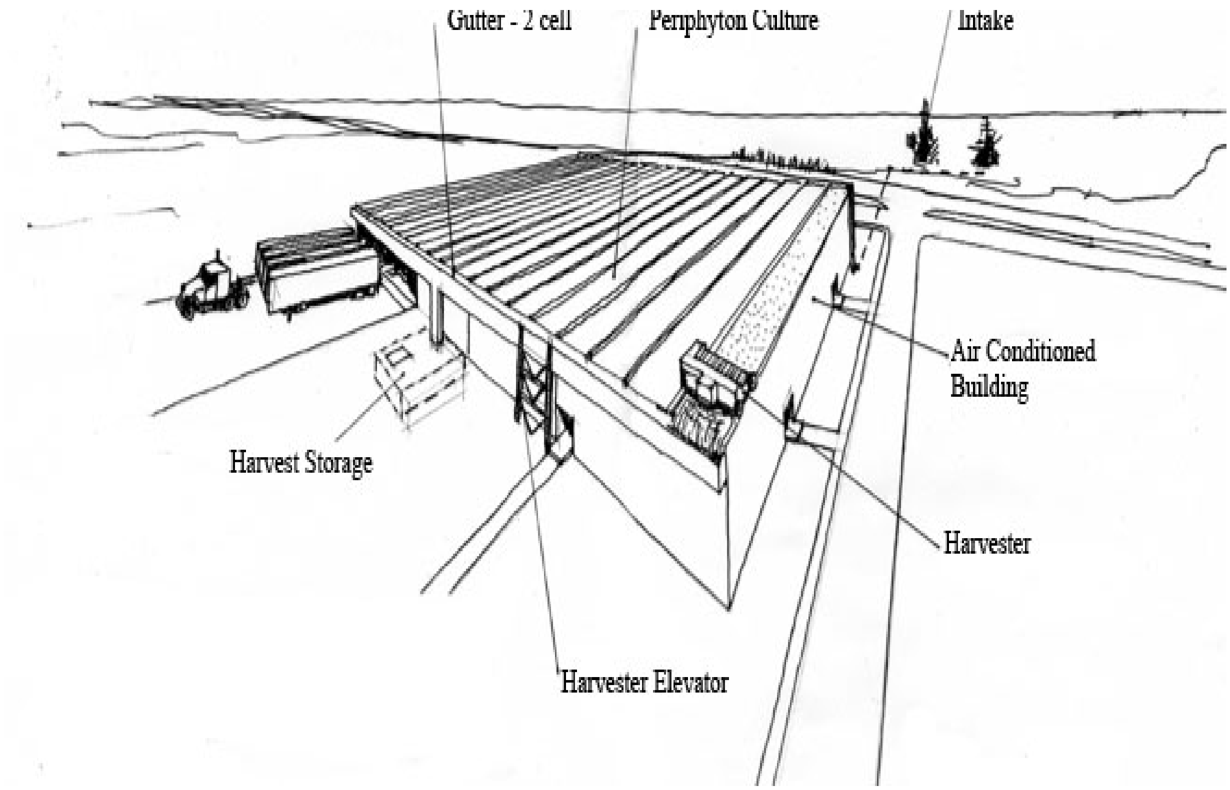
Why You Should Consider A Periphyton Roof



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What Is Periphyton? (perry-fite-ton)
(Its attached algae)

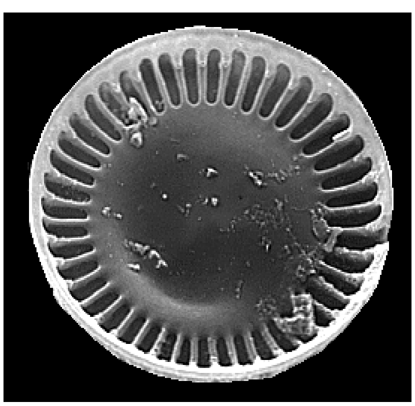
Periphyton is the attached growth on surfaces in shallow water. In well-lighted environments it is largely composed of photosynthetic attached algae but there is also bacteria and fungi in the community.

Attached Algae are primitive plants that get their nutrients from water passing over them. Almost every part of an algal cell takes up nutrients. [1] Terrestrial plants take nourishment primarily from only specialized cells in their roots. Algae consume carbon dioxide during respiration, produce oxygen and grow to make up the base of the aquatic food chain.

Algae typically show high biomass productivity in nutrient poor waters making them ideal for natural surface water treatment. Periphyton is capable of nutrient pollution removal down to very low, pristine ranges. [2] This is because the algae have ways to find food when it is in very short supply.

As algae consume Carbon Dioxide (CO_2) for respiration, the waters pH changes. CO_2 is a mild acid and plant uptake causes a shift in pH to higher values. As the pH rises, nutrients like phosphorus co- precipitate with elements like calcium and magnesium on the algae's cell wall where various bio-pathways allow the cells to take it in as food. The pH of the water quickly returns to that of the basin when CO_2 is mixed in water from the basin.

Periphyton cultures are found in most all water systems. Many times what looks like mud in a lake or streambed is actually periphyton algae. There are over 24,000 species of algae on Earth and thousands of them can grow attached. Algal species grown on Periphyton Filters are mostly from the green, blue green, and diatom groups. The Diatoms are particularly beautiful structures.


Cyclotella sp.
Figure 2, Other common Periphyton Filter species names:

spirogyra, rizoclonium, stigeoclonium, zygnema, oscillatoria, mougeotia, ulothrix, entromorphia

Why Grow Periphyton?
(It cleans water)

Periphyton grows faster than any other plant community on earth. This means they remove nutrient pollution and produce pristine quality outflows better than other aquatic plants. See Figure 3. Periphyton culture consumes between 100 and 1,500 pounds of phosphorous per acre per year compared to wetlands, which consume 1 to 10 pounds per acre per year.

Periphyton also removes carbon, nitrogen and even some dangerous elements like heavy metals. Algal concentrations for these pollutants are so low they have not been considered hazardous in over 20 years of experience with surface water.

Periphyton is actually the most active nutrient uptake process in a wetland, however as the biomass is not harvested, it decomposes and 20% goes to soil and 80% goes back into the water column as dissolved available nutrient pollution.

What is a Periphyton Filter?
(It's a photosynthetic water filter)

Periphyton Filters are aquatic culture systems, which provide shallow stable culture surface for algal cells to attach and grow, and a harvesting device or system for harvest of mature periphyton. Periphyton grows logarithmically in the first week or 2 and then slows. Harvesting keeps the periphyton culture growing at maximum rate and physically effects removal of sequestered pollutants from the water system.

Typically Periphyton Filters are colonized by species existing in the water system. Species existing in the region but not dominantly present in the water have been successfully seeded. This procedure has the benefit of selecting an algal community, which has certain desirable manufacturing properties. In some cases the alga is dominated by the standing crop of plant species in the lake. This is common in hyper eutrophic lakes with large plankton stands.

The first large scale Periphyton Filter was constructed in Patterson California. It was .25 acres in area and constructed in 1993 from landfill liner. The system was operated for one year successfully removing 1,675 lbs of phosphorus on an acre basis, which is the record high rate for a Periphyton Filter. The system was treating treated wastewater from the city treatment plant. The following chart shows productivities from other systems.

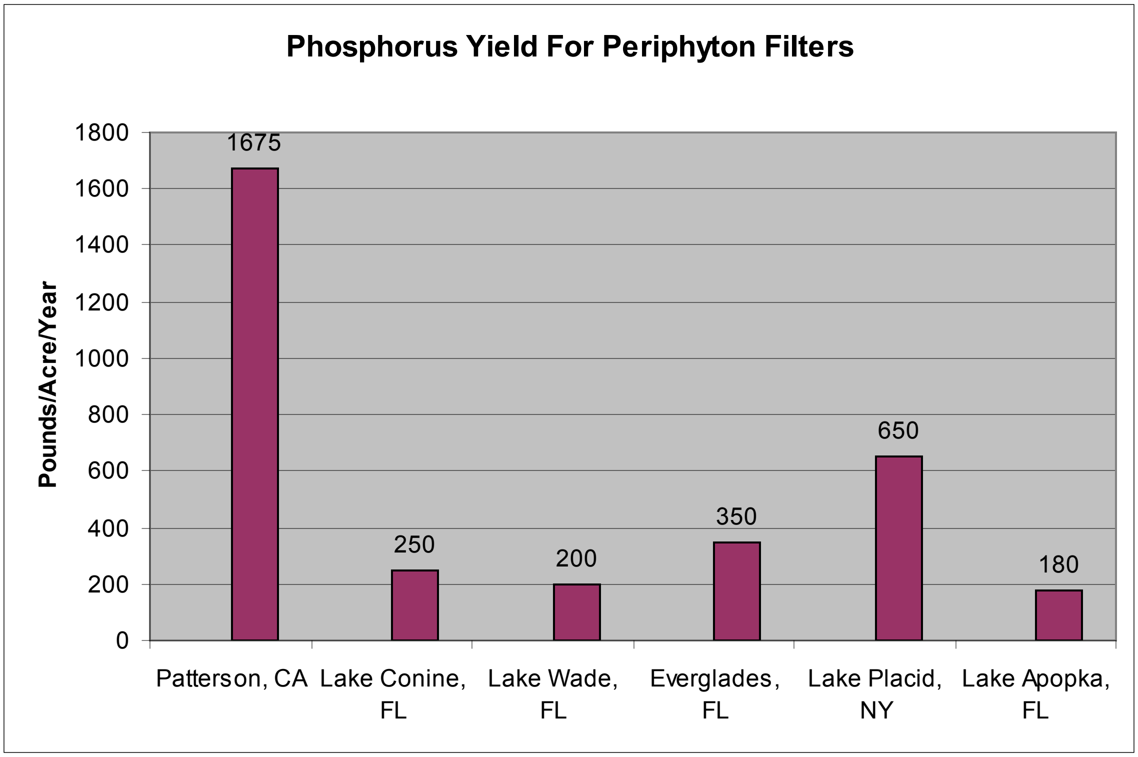


Figure 3

Periphyton Filters have been used in Aquaculture and advanced aquaria as well as in restoration. They are particularly suited for this because they produce oxygen and consume carbon dioxide while they remove fish waste and add vitamins and other beneficial compounds to the water. The fish love it!

Periphyton Filters can be very large in scale and constructed from harvestable modules. Compared to manmade wetlands, Periphyton Filters have a much shorter hydraulic residence time. Wetlands hold water for 7-14 days where Periphyton Filters usually only hold water for less than 1 hour. Periphyton Filters remove 100 to 1000 times more phosphorus than a wetland filter making much smaller treatment sites feasible for treatment and remediation. There is almost no limit to the level the water can be treated.

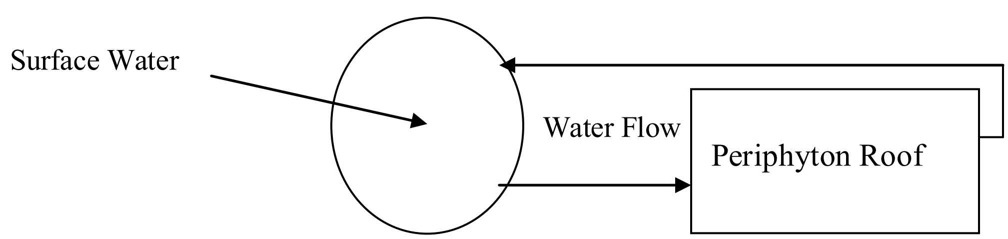


Figure 4, Periphyton Roof Process Schematic

What is a Periphyton Roof?

(It's An Aquatic Type of Green Roof)

A Periphyton Roof (patent pending) is an adaptation of a Periphyton Filter integrated into a sunlit exposed building surface. Water is taken from and returns to a surface water body of significant size, (figure 4). The culture system is thermally linked to the building interior, which studies show dramatically reduces Solar Heat Gain and consequent energy needs for interior cooling and in some cases heating. It's like a water-cooled building envelope.

The main Benefit – Energy Savings:
Water flowing over the roof intercepts radiant heat from the sun, greatly reducing heat irradiated on the building roof by a minimum 67% (figures 8 to 13) [7]. This will lower building electrical usage at the peak hours of demand, which intern reduces carbon emissions and the need for additional power generation for peak loads. The cost of pumping water on roof is less than 10% of the cooling load cost value calculation. Not just any water will work. Ideally the roof is tied to a natural water system like a lake, river, wetland or other large surface water. On site wet retention basins are excellent water sources and in some cases a periphyton roof can reduce the size required for on site storm water treatment systems and other restrictions imposed in the name of surface water quality.

The sun will heat water on Periphyton Roofs during daytime intercepting almost all of the sun's radiant heat. Evaporative cooling of water exposed to the atmosphere limits the heat the water can take on just as in natural water systems.

Periphyton Filters can have steep slopes, however, the optimal slope is about 1" in 30' or 1/32" per foot. While this is below the recommended slope for building roofs on flat buildings, the periphyton roof is designed to never flood no matter how much rain falls. Steep slopes must be very carefully designed to preclude splashing of the water.

The harvester is a building integrated component (figure 5) not unlike a window washing system in a high-rise building. The harvesting function can be completely automated if desired. Water flow is shut off prior to harvest in selected floways. This reduces the volume of the wet biosolids to process. 5 to 10% of the floways are shut down for harvesting during off peak hours leaving the remaining culture surface operating.

The Secondary Benefit – Water Conservation and Remediation:
PR's are similar to green roofs in that they support plant growth. PR's remove nutrients from the water that passes over them. Green Roofs are typically nutrient sources when excess rainfall cannot be stored and is discharged to storm sewers and surface waters. [8] A PR uses shallow flowing water that comes from, and returns to, a nearby surface water body. Attached algae called periphyton naturally settle and grow on the roof surface. CO_2 is taken up by algae in the form of bicarbonate and sequestered in plant tissue. Depending on biomass use, CO_2 can stay sequestered. Periphyton is harvested with a robotic scraper and phosphorus, nitrogen, metals and other pollutants are removed from the surface water in the algae. Additionally, the water is oxygenated via photosynthesis before returning to the source in improved condition. Credits for removal of pollutants can be sold to meet Clean Water Act TMDL's. This income has the potential to pay a significant portion of the mortgage on the building.

Requirements For A Periphyton Roof

(Climate)
Periphyton doesn't grow in freezing water and freezing water expansion issues can compromise roofing system integrity if not designed properly. While Periphyton Filters have been operated north of Toronto through the winter in a green house, currently they are only recommended for semi tropic and tropic areas due to freeze concerns. Periphyton Filters can be shut down and started up quickly. They can be left dormant in winter in northern climates where building insulation would provide insulation requirements.

(**Water Source)**
Periphyton Roofs require a sizable water source such as a small lake, river, or wetland system such as the Everglades. Linking the filter to natural water systems allows for nutrient pollutant export from the environment. Storm water ponds can be excellent partial water sources for Periphyton Filters.

(Pumping)
Pumping water on the roof is an essential part of Periphyton Filtration. If pumping stops due to a power failure the system just stays wet until the power comes back on. If the system dries that is no problem either. In some water systems the culture surface is harvested and purposely allowed to desiccate. This serves to eradicate aquatic insects, which can eat the algae and reduce the filters effectiveness.

(Harvesting)
Harvesting of the algae is not absolutely required as the algae will grow to a point of sloughing and flow out with the water. However, if harvesting is stopped, so too will much of the nutrient removal unless the slough is screened out of the outflow.

Rough Cost Study

A hypothetical cost study shows the significant benefits of a Periphyton Roof System. These costs are based on design and operation of many land based Periphyton Filters and knowledge of a detailed proposed design. Following is a listing of cost and benefit for a theoretical 4-acre roof air-conditioned building in South Florida. At $120 per square foot its construction value is $20,908,000. Monthly payment at 5% is $112,239.

1. Additional roof construction costs
The simplest of Periphyton Roofs requires nothing more than growing periphyton on the roof membrane and manually scraping the periphyton to a collection drain with a squeegee. This embodiment does not provide redundancy and initially we concluded this could cause the rooftop wear out prematurely with some roofing systems.

Roofing membrane provided by Sarnafil was glued down to a concrete substrate in an existing periphyton filter. The roofing system is typically direct glued to concrete substrates. After almost 3 years of operation there is no visible degradation of the membrane. At this point we feel the performance of the heavy-duty systems with membrane redundancy are likely to be warranted for 20 years by Sarnafil. Further testing is needed in this area. Thermal expansion considerations are important in this direct-glued application and this adds a slight additional cost to the roof system.

Advanced electrical leak detection systems are available which pinpoint any leaks any time. This provides a high performance roof with no hidden leaks over the life of the roof. This can result in insurance savings. The leak detection system combined with a dual ply membrane looks to be a less expensive and more forgiving system design than other redundant systems evaluated. We elected to use a dual ply roofing system with leak detection and a large contingency for our cost evaluation.

The cost of this system was recently estimated to be $6 /s.f. - $2.50 s.f. Standard roof = $3.50/s.f. Additional building cost for a 4 acre Periphyton Roofing = $609,440. We increase this up to $1,000,000 for safety factor and unknowns. **Additional 4 Acre building cost = $1,000,000**

Robotic harvesters provide a means to harvest large roof areas without damage to culture system membranes.

Figure 5, 1st generation robotic harvester

2. Cost of harvesting Periphyton

Semi skilled labor crews much like lawn maintenance or window-washing crews harvest periphyton. Robotic harvesting eliminates all but one operator from the process. 10 man-days per week are needed to manage the four-acre culture system. 52*10=520 man-days. $125,000 is allocated for this work annually. An additional $25,000 is allocated for harvester maintenance. **Total cost harvesting Periphyton $150,000 per year.**

Currently Periphyton Filters have been demonstrated to remove 100 –1000 times or more nutrient pollution than that of a wetland treatment system per unit area (figure 3). Periphyton Algae have been cultured and harvested on grade in over 100 systems worldwide up to the scale of acres. Performance of a Periphyton Filter is variable and the rate depends on many complex interrelated factors. Seasonal fluctuations due to sun season and temperature, water quality with respect to nutrients and minerals as well as the speciation of algal biomass on the filter are some main factors influencing pollution removal via periphyton culture. Location specific issues need to be characterized regarding the periphyton culture.

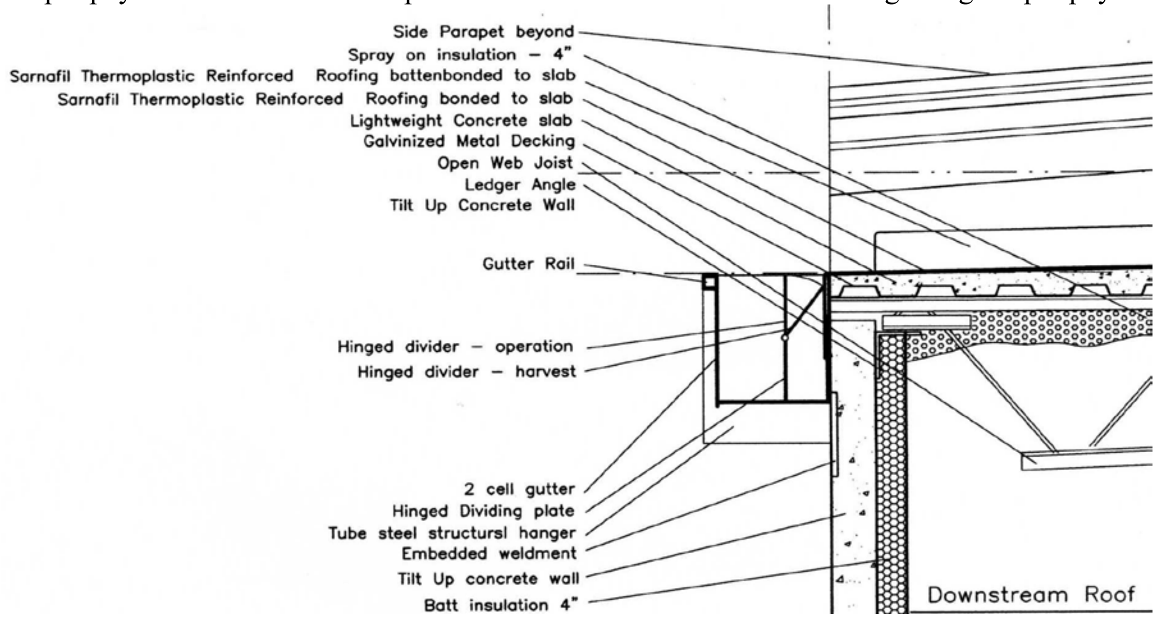


Figure 6, Periphyton Roof Edge Detail

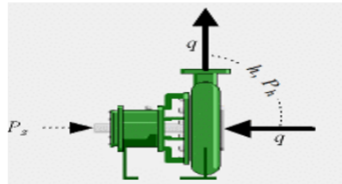
Work on PR's and periphyton systems in general has lead us to this point of technology development. See Fig. 6. A shed roof accommodates storm water roof drainage with a 2-cell gutter at the low end. Note the 2 positions of the dividing plate are shown. Filtered water falls off of the roof into the roof side cell under all conditions including 100-year storm flows. Overflow standpipes in the roof side cell precludes overflowing into the biomass cell. During harvest of a particular flow way, the water is turned off, and the algae scraped to the biomass gutter. The center gutter divider swings over and bridges the filtered water flow in the roof side cell. Biomass is collected in the outward cell and flows by gravity to a place of collection. A second embodiment uses a diversion chute placed over the outflow cell to convey biomass to the biomass cell.

3. Cost of pumping water

Water must be pumped up an elevation of roughly 30' in most cases. A four-acre system would require 4 million gallons per day. This will take about 32 kW @ $.08/kW = $62.00/day, 22,630 per year. $25,000 allocated for pump maintenance. See figure 7. **Total Pumping Cost Rounded up to $50,000.**

Pumping Power

Shaft power, P_s the power required to run the pumps at 4 MGD



$P_s = P_h/\eta$ — η is the pump efficiency—we assume 50% (common)

$P_h = Q*\rho*g*H$ — P_h is the power needed to pump the fluid (in an ideal situation, the shaft power equals the hydraulic power), but pumps are inefficient, so we have to put in more power than we need to get a specific job done

$\eta = 0.5$

$Q_{total} = 4$ MGD

$Q_{pump} = 210.4\ m^3/hr$

$\rho_{h20} = 1000\ kg/m^3$

$g = 9.81\ m/s^2$

$H = 30\ ft = 9.144\ m$

$P_s = 10.48$ kW per pump

Total power for pumps

$P_{pump\ total} = 31.4$ kW $2.50 per hour

Figure 7

4. Disposal of Periphyton

In it’s simplest embodiment contract haulers pick up periphyton biomass. The material is used as an organic soil amendment. $100,000 per year is allocated for this item to start with the expectation that costs will go down as experience is gained. **Total cost Disposing Periphyton $100,000 per year.**

5. Energy Savings

Periphyton Filters intercept the radiant heat from the sun shunting it off of the building roof. This solar gain only occurs if the water remains flowing so during harvest, when the water is turned off, the roof would see increased solar gain until restart. Harvesting off solar maximum greatly reduces this gain. The system can be restarted immediately unless desiccation is required for micro-invertebrate control.

Periphyton Roofs also exhibit evaporative cooling dependant on relative humidity of the atmosphere and reflection of energy. The Periphyton itself utilizes energy from the sun to cleave the water molecule and convert carbohydrates to simple sugars. Both of these factors total roughly 3%, however they are not included in the calculations because they are highly variable.

Radiation is a form of energy transport consisting of electromagnetic waves traveling at the speed of light. No mass is exchanged and no medium is required. Simple energy balance for a dry roof is shown in Figure 8. Still water was ponded on roofs in the 1940’s to 1950’s in some regions but has been since condemned by architects as a thermal strategy for flat roofs. We propose shallow flowing water intercept infrared heat and the waters thermal inertia be used as a shield.

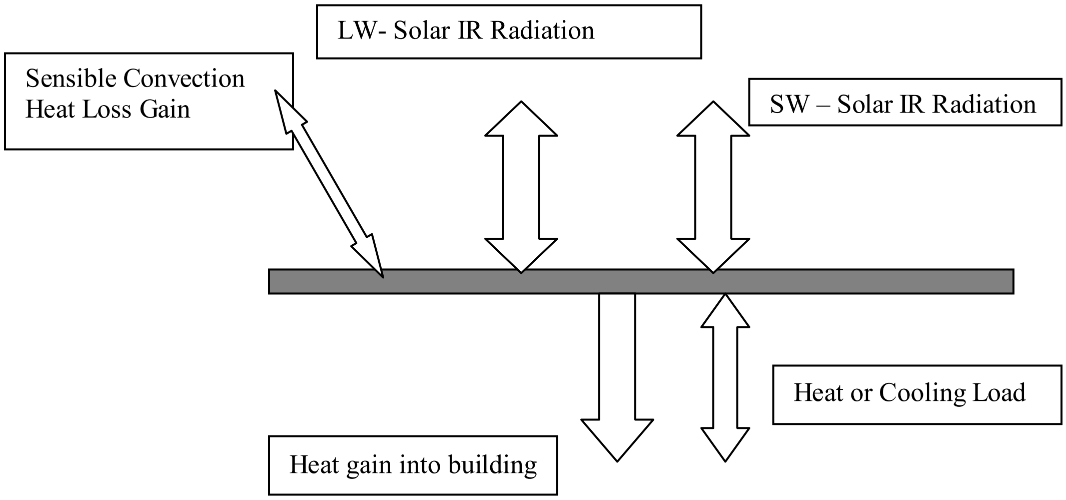
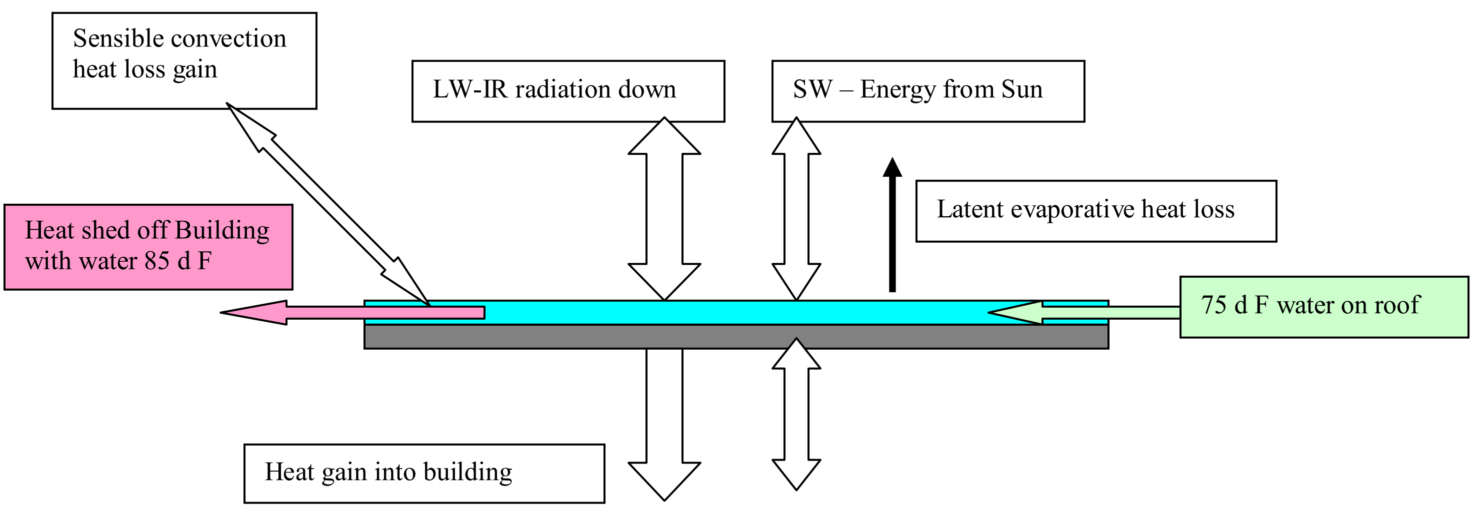


Figure 8, Thermal Schematic Dry Roof

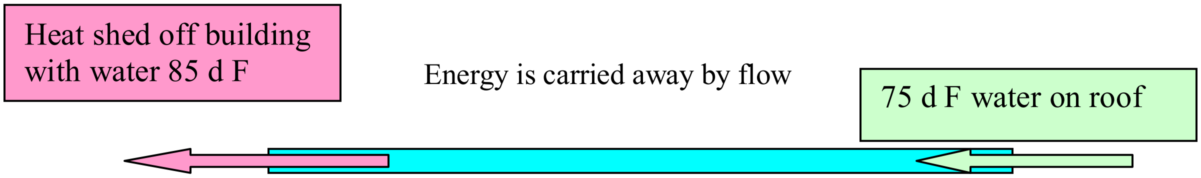
Theoretically this should reduce the cooling load on a large flat roof significantly. The details of just how much is unknown. Data sets from the shallow flowing systems noted in Figure 3 showed a significant amount of radiant heat falling on the submerged surface is shunted off with the flowing water. The max increase measured was 10 degrees F.

Figure 9, Thermal Schematic Flowing Water On A Roof



The flowing water also exhibits evaporative cooling dependant on relative humidity of the atmosphere and reflection of energy. This factor is roughly 1% and therefore not a large contributor to heat shedding.[5] It can also be highly variable.
Circulating cool water over the roof membrane reduces thermal loading on the insulation, which should have the effect of higher R factor beyond R-50, but technically it is not increased Resistance, it is cooling and thermal inertia. Energy savings calculation for a PR is a complex

problem with many variables. Typical measurements from shallow flowing Periphyton Filters in south Florida show a max 10 degree F rise in temperature at peak sun.



$q_{tot} = m{*}C_p{*}(T_{out} - T_{in})$ [5] **$q_{tot} = 4{,}110$ kW**

q_{tot} is the total amount of heat the water picks up as it travels over the surface of the roof
Delta T 10 deg. F = 5.6 deg. K
m = is the mass flow rate [kg/s] = 175.3 kg/s
C_p is the specific heat of water 4184 J/kg*K

Figure 10, Quantifying Solar Gain On A Wet Roof - Schematic

Assuming that at a given time the solar flux is about 750 W/m^2 (this means a total of 12120 kW) for the given area of 4 acres (417' x 417').
If we solved for this quantity of heat calculating: Qtot=m*Cp*(Tout-Tin). Where: qtot= Heat gain in kW; m = Mass flow rate in kg/sec; Cp=Specific heat of water in J/kg*K;
T= Temperature in degrees K. 67%, or 8 Mega Watts/hour is carried away by the water. While insulation greatly reduces thermal flow in roof construction, the raw value @ $.12/kW equates to $960/hour, or $7,680 for an 8 hour radiation period day.

Other factors affect IR attenuation in shallow flowing water, such as natural organisms, dissolved compounds, scatter and attenuation of light off of particulates, light harvesting algae, dissolved gasses, particularly dissolved oxygen.[5, 6] The contribution of these elements separately and together is currently unknown and will be variable on a site-by-site basis.

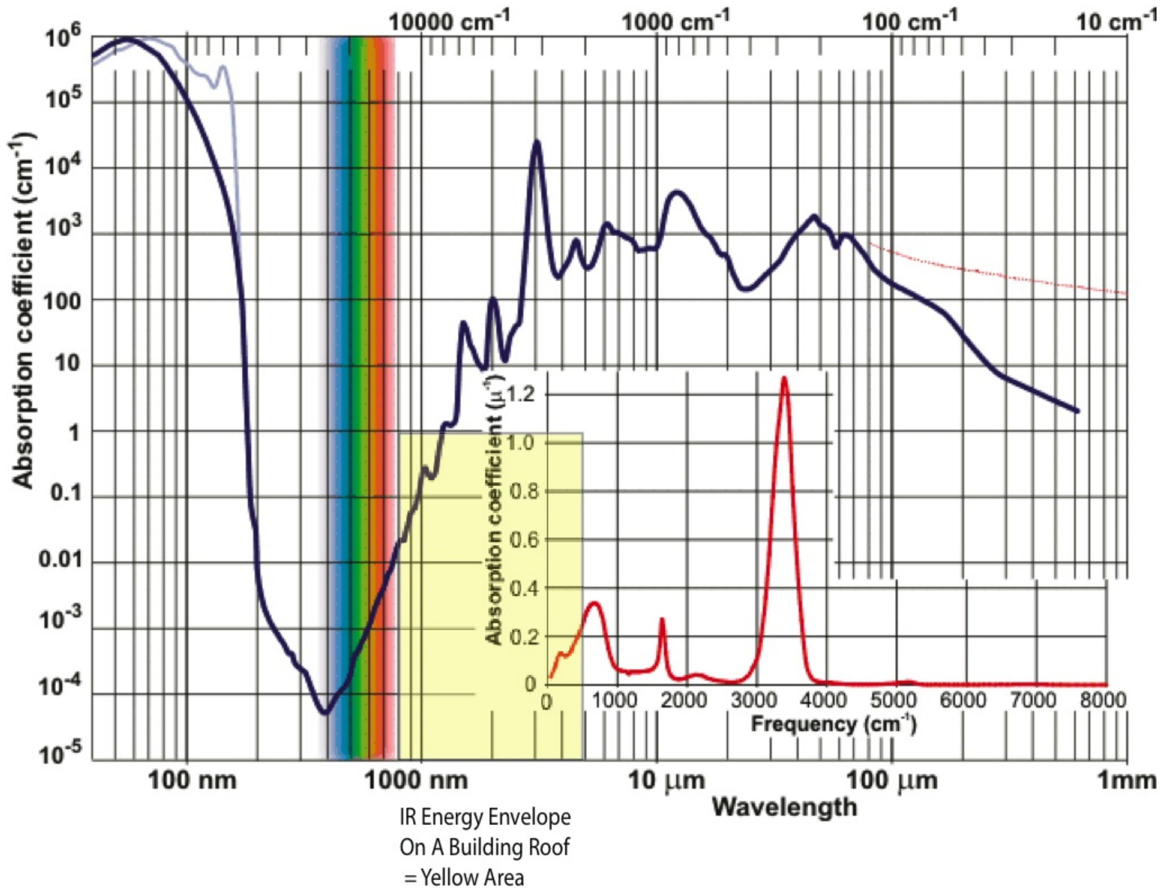


Figure 11, Absorption Coefficient for Light in De-ionized, Degassed Water
Figure 11 exhibits the IR absorption coefficient as a function of wavelength that is required to calculate the ratio of the incident to transmitted light traveling through water. The absorption coefficient is used as follows do the calculation. I_0= incident light intensity, I = intensity of transmitted light after passing through a layer of water of thickness L cm. In the case of the PR, the light will have to travel through 2.54 cm.

$$\frac{I}{I_0} = e^{-\alpha L}$$

Table 1.

IR Transparency From 800 to 1400 nm		
Frequency nm	thickness cm	2.54
nm	alpha	IR transparency %
800	0.019	0.95
900	0.07	0.84
1000	0.7	0.17
1100	100	0.00
1200	10000	0.00
1300	100	0.00
1400	400	0.00

Figure 12, Absorption Of Infrared Energy - chart

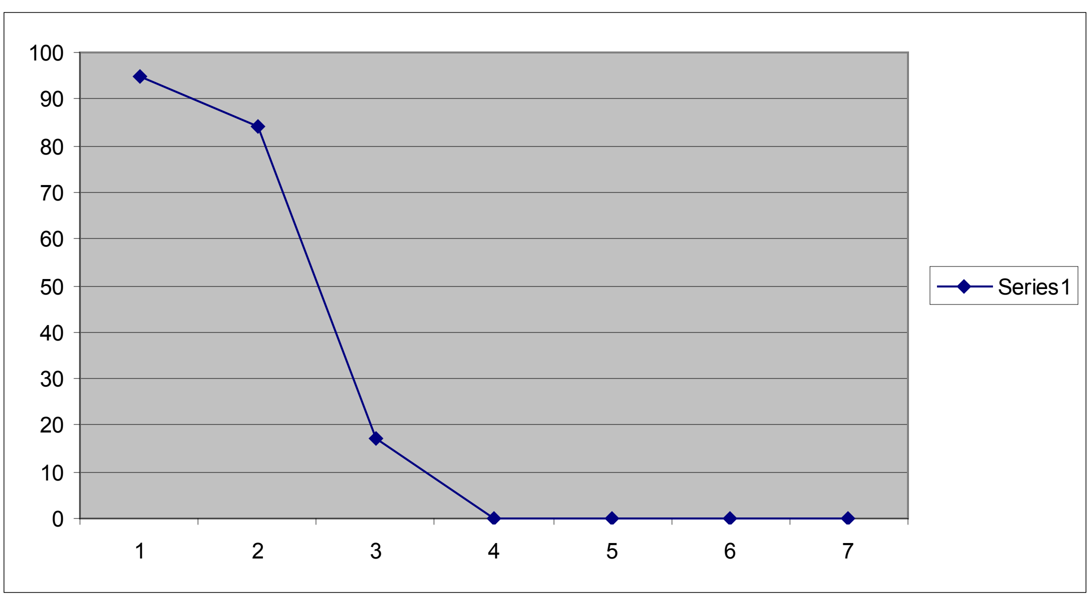


Figure 13, Absorption Of Infrared Energy - Graph

known absorption of incoming sunlight, particularly in the infrared region, and about 60% of the atmospheric absorption of thermal radiation by the Earth known as the greenhouse effect. CO_2 absorption bands occur around 1400, 1600 and 2000 nm, but its presence in the Earth's atmosphere accounts for just 26% of the greenhouse effect. [7] Carbon dioxide gas absorbs energy in some small segments of the thermal infrared spectrum that water vapor misses. This extra absorption within the atmosphere causes the air to warm just a bit more and the warmer the atmosphere the greater its capacity to hold more water vapor. This extra water vapor absorption then further enhances the Earth's greenhouse effect.
Conversely, there is an atmospheric window between approximately 800 and 1400 nm, in the near-infrared spectrum where carbon dioxide and water absorption is weak. [9] This window allows most of the thermal radiation in this band to be radiated out to space, keeping the Earth's atmosphere from going into thermal runaway. This band is also used for remote sensing of the Earth from space, for example with very near IR imaging.
The water vapor absorption bands are related to molecular vibrations involving different combinations of the water molecule's three fundamental vibrational transitions:
V1: symmetric stretch mode, V2: bending mode and V3: asymmetric stretch mode.
The absorption feature centered near 970 nm is attributed to a 2V1 + V3 combination, the one near 1200 nm to a V1 + V2 + V3 combination, the one near 1450 nm to a V1 + V3 combination, and the one near 1950 nm to a V2 + V3 combination. [10] In liquid water, rotations tend to be restricted by hydrogen bonds, leading to librations, or rocking motions. Also stretching is shifted to a lower frequency while the bending frequency increased by hydrogen bonding.

This technological approach to coastal building design has the potential to eliminate peak cooling loads and lessen electrical demand, while at the same time, restore filtration capabilities, which once existed in coastal wetlands. This technology has the potential to effect large energy savings on new and existing buildings while reversing the trend in cultural eutrophication of surface water. Applied on large scale, this approach to energy savings could postpone or even eliminate the need for planned fossil fuel power plants and the environmental cost associated with them. Applied on large scale, this approach to energy savings could postpone or even eliminate the need for planned fossil fuel power plants and the environmental cost associated with them.

Environmental Benefits
This Technology fosters multi level improvements in energy efficiency and environmental water quality simultaneously.
A. Reduction of electrical usage at Peak Periods, which reduces green house gas emissions
B. Bio-fixation of CO_2 during Daylight equal to 160 acres of trees (Dr. Rupert Craggs 2/2002 ltr. to Aquafiber Technology)
C. Reduction of urban heat island effect as roof is cool.
D. Water Pollution Removal, See Figure 5
Economic Impacts:

The Economics of Nutrient Removal from surface water make a compelling case for implementation. Total P removal, 400 lbs per year in light of the price paid for a pound of removal by other means. Hydromentia, (Hydromentia.com) a company in the business of growing Periphyton on land for nutrient removal for Water Management Districts, estimated their bottom price would be $450 per pound of P removed. P removal through watershed improvements is currently in the range of $250-$800 per pound. AT $250 per pound, a conservative annual income from P removal is $100,000 per year, almost 1 monthly mortgage payment. See P removal for various Periphyton Filter systems, Figure 5. If 300 lbs per acre were achieved as in the Everglades, and $500 per pound paid, 300x4x500 = $600,000 which is 5.3 monthly mortgage payments. **Energy Savings Assessment**

Energy savings calculation for a Periphyton Roof is a complex problem with many variables. As of the writing of this brief, work to characterize the cooling energy reduction is ongoing. We present 2 different methods to basically characterize the energy performance of a Periphyton Roof.

The Value of Heat Shed By Periphyton Roof

Using solar irradiating data for Miami Florida, we calculated the shortest and longest day and expressed the monetary value of energy removed by the periphyton culture in dollars.
From: http://wwwlogger.fsec.ucf.edu/met/

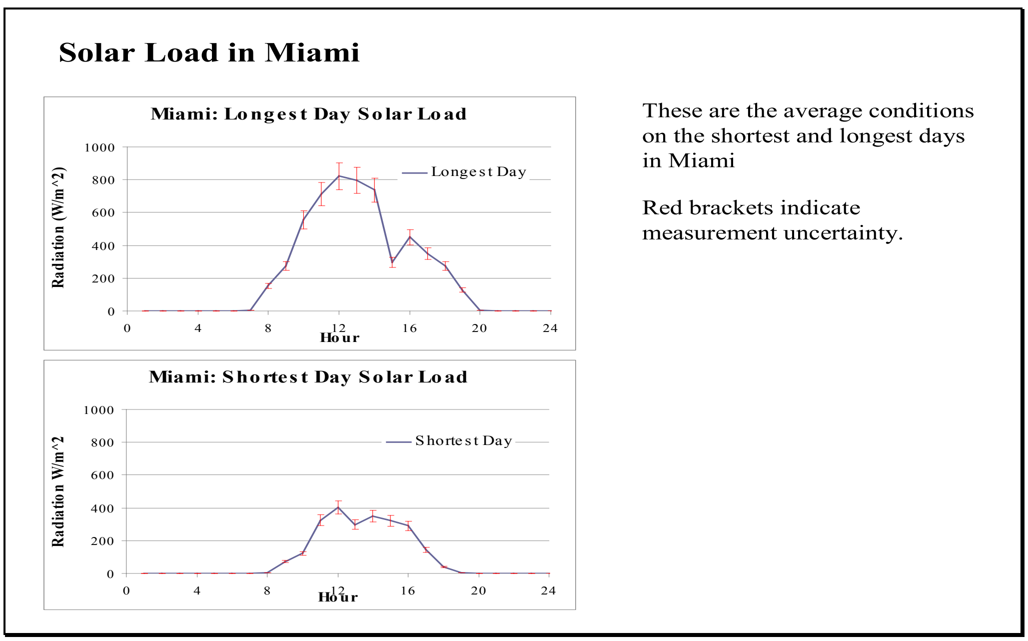


Figure 14, Energy Shedding Analysis:

Energy shedding analysis – (Ignoring Insulation and minor factors):
Using the Solar Load graph from Miami, we assume average radiation of short and long days to last 8 hours from about 9 AM to 5 PM at intensity of 500 watts/M2. 4 acres is 172,240 sf or 16,594 M2. 16594 M2 x 500 W/M2 = 8,297,000 W. 8,297,000 x 8 hr/d x 365 d/y = 24,227,240,000. 24,227,240,000/1000 = 24,227,240 x .08 $/KWH = $2,907,269. We only take 67% of this number, $1,947,870 until we document the contribution of other factors mentioned in section 1.3, insulation effects and cloudy days.

6. Storm Water Treatment System Size Reduction
Depending on many complicated circumstances there may be reductions in the required storm water systems, which require land, construction and maintenance costs. This case-by-case item is assigned no value in this compilation.

7. Maintenance and repair costs
The single ply membrane Periphyton Roof is expected to have a 20 to 40-year lifespan with maintenance and repair. We feel we can get a 20-year warranty. **Annual cost for maintenance and repair is $50,000**.

8. CO2 mitigation credits
CO2 credits are currently bought from projects, which remove CO2 from the atmosphere. Algal uptake of CO2 from the four acre Periphyton Roof would be 60,000/2000*4 acres = 120 tons per year at $17 per ton = **$2,040 per year CO2 credits.**

9. Value of water filtration
The value of filtration was first calculated in comparison to wetlands, which are routinely purchased by the Florida Water Management Districts. Present day value for one wetland acre in the best location is $30,000. Wetlands provide filtration as well as water storage and habitat. Only 1/3 ($10,000) of this price is assumed for the purposes of valuing filtration alone. (St Johns River Water Management District, and H.T. Odum, PhD personal communication)

At this price, assuming the worst productivity of a 4-acre Periphyton Filter, 400 lbs Phosphorus (P) removal per year is the most conservative rate for comparison. In the Everglades agricultural area 300 lbs per acre was maintained. Wetlands in south Florida remove between 2 and 10 lbs/year. Using the conservative 400 lbs the P removal of Periphyton Roof is equivalent to between 200 and 40 wetland acres. At $10,000 per acre the one time value is between $2,000,000 and $400,000 or 10.4% and 1.9% of construction cost. **We will use the average of $1.2 million.**

A more accurate second characterization can be made by looking at the total P removal, 400 lbs per year in light of the price paid for a pound of removal by other means. TDML's (Total Daily Maximum Loads) are the max pollution a water body can assimilate with degradation of the water past it's rating (class 1, 2, 3 ect.). The Clean Water Act requires this limit be met, however the law is not currently being strictly enforced. The enforcement of the Clean Water Act TMDL’s is moving slowly but is making progress. TMDL's took a long time to develop and now that they are complete, the municipalities and other landowners are slowly being forced to meet them. The regulators are forcing many other structural and operational changes on the stakeholders like street sweeping and ponds ect. The price per pound for these measures is climbing fast. Solutions costing 350 /lb are largely already completed. In some cases the cost to remove a pound of P tops $1,000 /lb and some of these projects are being executed. Stakeholders need a cheaper solution for the sake of the taxpayer.

Hydromentia, a company in the business of growing Periphyton on land, estimated their bottom price would be $500 per pound of P removed. P removal through watershed improvements is currently in the range of $250-$800 per pound. AT $250 per pound, a conservative annual income from P removal, with 100 lbs P sequestered per acre, is $100,000 per year. If 300 lbs per acre were achieved, and $500 per pound paid, 300x4x500 = $600,000 which is 5.3 monthly mortgage payments. **We will use the average of $350,000 per year or 3.1 mortgage payments.**

Cost Tabulations

Point in time calculation using one time value:
One time cost items, + = savings
- $1,000,000 added construction cost
+ $1,200,000 1 time value of filtration
+ $ 200,000

Annual cost items, + = savings	
Cost Pumping	- $50,000
Cost Harvesting Periphyton	-$150,000
Cost Disposing Periphyton	- $100,000
Cost maintenance and repair is	- $50,000
Value Nutrient credit trading	+ $350,000
Energy shed by Periphyton Roof	+ $581,453
Value Carbon dioxide credits	+ $2,040
Total	**+ $583,040**

What Do You Do With The Harvested Periphyton?
(Many Sustainable Things)

The development of periphyton biomass use has moved slightly behind the development of the filter system and definition of its capabilities.

1. Soil Amendment
The fall back use for periphyton biomass is to use it as a soil amendment. This use has far greater demand than supply. Algae have been used since medieval times as a fertilizer for crops. Harvested Periphyton is most simply sprayed on organic crops where it provides not only primary nutrients, but also a wide array of micronutrients, which have become depleted in today's soil bank. The biomass can be blended with other waste streams and composted. Fluid Mud Culture Technology produces crops like sod.

The Periphyton elemental composition varies with the water in which it is grown.

3-12% Nitrogen
.1-4% Phosphorus and Potassium

2. Methane Generation. Biomass is digested into methane gas and burned for energy purposes. Residual stream measurement shows higher nutrient levels than in the harvested algae. The biomass volume is reduced by about 1/3. Study with digesters on Periphyton show the digester

effluent can be dewatered and dried with 1/3 of the methane produced. Work is under way to inject the CO2 into the periphyton culture so it can be fixed in biomass.

3. Paper and Paper Products. The periphyton is fibrous and is blended with recycled newsprint and manufactured into paper and paper products. This is synergistic for paper manufacturing in that most facilities have a significant wastewater discharge, which can be cleaned up with the Periphyton Filtration.

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