PV Advice for Princeton, MA – Rev f - July 2023

Introduction

Disclaimer:

This advice is offered for free. Use it at your own risk. It is intended to help guide and inform residents of Princeton MA that might be considering adding a solar PV system to their home. This is not a PMLD sponsored or approved document and is written from the perspective of a homeowner that installed a PV system in Princeton but has some insights on PMLD policies and possible future changes. In this document I try to focus on some of the details that are specific to adding a solar PV system in Princeton as there are general published guides available elsewhere (See references at the end). Some investor-owned utilities still offer full retail rate net metering, but this is compensation rate is in decline. In such a case the utility is offering a free means of storing your solar power so you can use it after the sun is down. Few municipal utilities have such a generous offer as it impacts the rates for non-solar customers. While there are various tax benefits and incentives it is a complicated system to navigate.

Is solar right for you?

Before you plan a solar system, what do you want it to do?

Solar can do the following:

1. Reduce your electric bill.
2. Reduce your greenhouse gas emissions.
3. Supply some or all your electricity.
4. Provide backup power when the sun is shining.
5. Provide backup power at any time.
6. Disconnect from the electric grid and be "Off-Grid".
7. Alternatively, in the future, you could receive some of your power from a "Community Shared Solar System" if such a development were to happen and PMLD supported that.

Some of the considerations:

1. Only 15-25% of houses are suitable to have solar on the roof. This is because of shading, roof age, structural issues, etc.
2. Solar can also be mounted on the ground or garage if the house is not suitable.
3. You should look at your energy bills, electricity, oil/propane, etc.
4. Efficiency should be investigated first. "Negawatts" the purchased energy you can eliminate through efficiency improvements are faster and cheaper payback than solar PV. A more efficient house can use a smaller less expensive solar PV system. It is also more comfortable in good and bad weather, especially when the power is out. Consider passive solar home design alternatives for new construction and for renovations. Windows on the south facing vertical walls of you house gain more energy in the winter than they lose by heat loss.
5. PMLD offers free energy audits and through the Senior Center can arrange a thermal scan for free. Most homes have significantly more air infiltration than is needed to keep the air healthy. This air leakage can be measured with a blower door test. Another method is to put a fan in an upstairs window blowing out on a cold day and use incense around each door and window, closing off or opening rooms as you go around the house to find air leaks.
6. Are you thinking about installing high efficiency electric heating & cooling systems?
7. Are you thinking about an electric vehicle (EV)?
8. If your electric service is less than 200 Amps, it will likely need to be upgraded.
9. There are Federal and State tax credits for efficiency upgrade, electric service upgrades and solar PV.

10. There are PMLD rebates for efficiency improvements, heating system replacements, and EV Charging equipment.
11. Backup power can alternatively be supplied by installing a generator or a portable battery like that provided by Eco Flow. The generator can be a smaller portable generator or a whole house permanently installed unit. Portable batteries are effective only for a few hours and more limited loads.
12. In any case, solar and or backup generator should be installed by qualified licensed electrician for your protection and proper operation.
13. A solar electric system requires an electrical permit and inspection prior to operation.

PMLD has specific rules, applications, fees, and inspections that must be followed before you can connect a PV system to your home breaker box. Some of this is handled by the solar installer, but please review the PMLD interconnection policy on the PMLD website. https://pmld.com/policies-and-terms.html. PMLD also has a solar rate for residential customers. https://pmld.com/electric-rates.html. The solar rate pays the avoided cost (power and transmission) but requires solar PV owners to pay a minimum bill equivalent to 200kw*hrs of power to support the costs of maintaining the PMLD system. In practice few solar owners buy less than the 200kw*hr in a month. A larger PV system with large battery storage might see the 200kw*hr minimum in the summer.

You might think that if you put in a solar PV system you could eliminate your expensive electric bill and provide power during grid failures or even disconnect from the grid altogether and be fully self-sufficient. There are systems you could configure to achieve those goals but going completely off grid is an expensive proposition for any household. Computing the payback time of a PV system must consider the initial cost including installation, the value of the generated power, and various state and federal incentives and tax credits. Also, costs of maintenance and repairs. A PV system consists of PV panels on the roof or ground mounted on racks. Each panel produces DC power. Some PV panels have a DC to AC inverter on each panel, but other systems connect multiple panels DC wires together into what are called strings. The strings are wired to an inverter that is often installed in the cellar or the garage wall. Shading of even part of any panel will greatly reduce the solar power output of the whole string. This can be caused by trees shading the panels or maybe by snow. The PV system inverter converts DC power to AC power and is connected to the breaker box in the house. As more sunlight hits the PV panels the inverter makes more AC power and if that power exceeds the power used by the house it will flow out to the PMLD lines on the pole.

Solar PV owners will be provided with a solar meter. It has registers for consumed, exported, and net (the difference to the two)

Most solar PV systems are called "Grid Tied". This means the inverter supplied with the PV panels must synchronize with the 60-cycle grid and it cannot make any power if the grid goes down. Even if the sun is shining brightly, you will not get any power until the grid comes back. To provide backup many homeowners have an electrician install a gasoline powered generator with an AC transfer switch and a connection outlet on the outside of the house away from doors that could collect toxic fumes. For a significant extra price, you can get an off-grid inverter and batteries that can power some or all your house during an outage. It is very expensive to have enough PV panels and batteries for a house to go off grid and keep power to the house. Long cloudy periods or times when the panels are covered in snow typically require a gas/diesel generator to maintain power. Off-grid homes typically are arranged for a very frugal existence with little more than a refrigerator and some lights.

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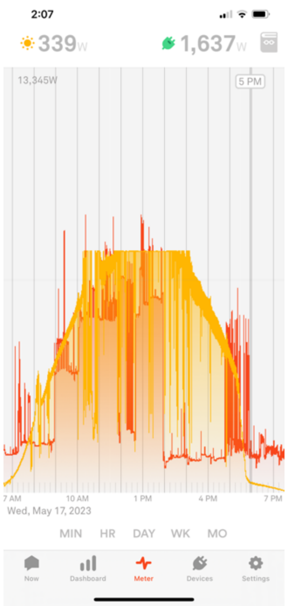
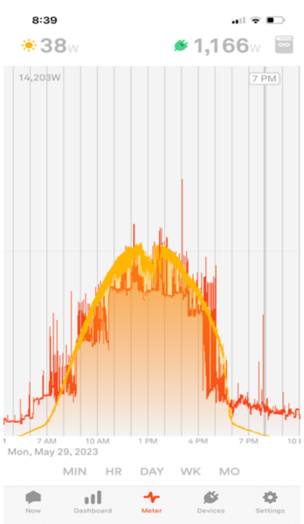


I sized my 8 kW PV system for my all electric and very efficient house to provide as much power in a year as my house used in a year. My experience was that even with some attempts to shift power use to sunny days, more than 50% of the PV power I generated was exported. Prior to the end of 2022, that power was a gift to PMLD as there was no compensation. There is a solar rate today that works out to roughly 8 cents per kw*hr or about 1/3 the retail rate of 24 cents. However, it still makes sense for PV owners to shift loads to sunny days. When I bought my first EV in 2018, I was able to reduce my exports to only 18% by using my Sense Energy monitor and carefully managing my EV charging times to match sunny days. Adding the EV to my load I am now a net importer of power from PMLD over the year. This is not something most people would do and it is not as convenient as having a PV system with a battery that will better automate the battery charging. I find that I buy more power in the winter months and export more power in the summer. As I work from home my EV is home during most days. In summer the PV panels make more power as the days are longer and the EV gets fully charged more easily. If you are truly interested in a solar PV system, you may find the Sense energy monitoring system useful. https://sense.com/. It can be installed prior to adding a solar PV system to understand how you use power today and when a PV system is added the additional sensor can be installed. The system measures the power to/from the grid and the solar PV production. It can identify individual devices by their inductive/resistance footprint. As it finds new devices you can name them and keep track of most of the devices in your house. I find it particularly useful to adjust the charge rate on my EV. I can change the EV charge rate in 1 amp increments from 5 to 48 amps. My 8kW PV system will max out when I have the charger set for about 24 amps or maybe a bit higher if I can reduce my "always on load". As the sun rises, I start at 5amps about 8:30 am and increment it up to 24 by midday and back to 5 amps by 5pm in such a way that most of my PV power goes to charging the EV, with virtually zero export power. There may be ways to automate this, and truth is that I don't do this perfectly and have some exports and situations where I simply buy utility power to charge my EV. The Sense application on my i-Phone along with the EV charging app enable this. A PV system with a battery would do this automatically and more precisely on partly sunny days.



You can see from this I-phone screen shot of the sense power monitor on a sunny day that by managing the charging of my EV and using the electric drier during the day, that I was able to self-consume most of my solar power. Notice that even at 8:39pm on that day (the time this data was captured) that I was gaining a small amount of solar power.

An interesting characteristic of solar panels is they make more power when they are cold. In this data below on a relatively cold but sunny day you can see the solar power from the PV panels exceeds the capacity of the inverter, so the power gets chopped off a little near noon (notice the flat top).

One of the things I could have done was to install some of my panels to face east or face west. This would have shifted more power in the morning and the afternoon with less in the midday. All my panels were on the roof, so this was not done. My roof points about 17 degrees west of true south which gives me a bit more power in the afternoon. Compared to facing true south, I do lose a few percent, but building my house at an angle to the street was rejected for aesthetics. Solar was always a part of the house building plan and the roof size was designed to fit PV panels with a clean look.

Basic PV principals

Basic estimates

A good place to start is to check your Utility bill to see how you much power you use each month. Your bill shows a 1-year summary by month. You might also imagine what new electric loads you may add in the future. Typical homes have oil or propane heat, but the yearly cost of power for a cold weather heat pump is less than the cost of fuel for oil and propane and at least competitive with natural gas. Heat pump hot water heaters are also relatively low cost to operate. Adding these to your home will reduce greenhouse gas emissions and will pay for themselves over time.

Solar PV panels convert sunlight to electric power. Shortly after my panels were installed, I noticed that oddly only 4 panels melted the snow. My strings are arranged with 4 strings, 3 that are 8 wide with two sections and one that is 3 high on the right side. When I checked my power production, I noticed the middle section of 8 was only making half the power of the top and bottom sections even with a little snow on them. Aha! Those four melting panels had a bad connection and because they were not making any power, they made enough extra heat to melt the snow. I had the installer come back and fix a lose wire connection.

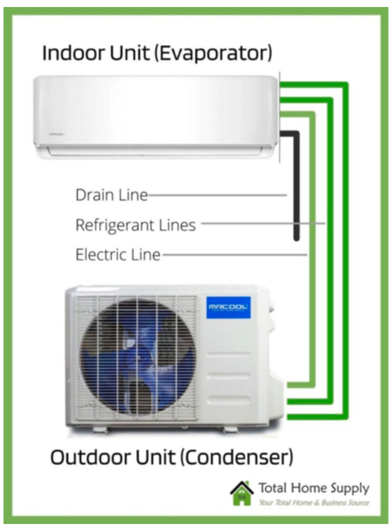
Electricity consuming devices

Heating & Cooling

Electric heating in our climate is best done with a cold weather minisplit or Ground Source Heat Pumps (GSHP). In either case they move heat rather than creating it by burning fuel. They have a COP (Coefficient of Performance of 3 or 4) which means 1 kW*hr of electric power will produce 3 or 4+ kW*hrs of heat. Compare that to a simple space heater or resistance baseboard which has a COP of 1 and thus is 3 or 4 times more expensive to heat the same space. Minisplits are most efficient with a single outside unit connected to single inside unit that is properly sized. Avoid oversizing, these systems have a variable speed compressor and variable speed air blower that adjust to meet load and run efficiently when used steady. There are lots more information about heat pumps on line. https://www.buildinggreen.com/blog/7-tips-get-more-mini-split-heat-pumps-colder-climates. It is best to first compute your house heating load with an auditor that is competent to make the calculation using the Manual J method. Companies like Mitsubishi, Daiken, and Fujitsu are known to provide good units but my data is a few years old so other suppliers might be competitive.

Outside unit needs 240V power and has the condensate drain

Inside unit is operated from a remote. Some systems have a WiFi app that allows remote operation from your phone over the internet. Very convenient when traveling.



The lineset has refrigerant lines, the condensate drain tubing, and power/control signals. Inside unit gets power from the outside unit.

Air conditioning

Minisplit heat pumps can also operate in an air conditioning mode. Minisplits have an inside unit and outside unit and a lineset. The lineset includes a condensate drain for air conditioning and needs to be installed with the lineset going continuously downhill to the outside unit where water will drip out.

Hot water

Electric hot water typically uses an 80 or 120 gallon tank. It may be simple resistance heated, or it may use a heat pump system. Heat pump water heaters use about 1/3 to 1/4 the power as a resistance heater, but need some space to take heat out of the air where they are located. They also remove some humidity and need a condensate drain or pump. They may cool the room they are in by several degrees. With a timer an electric water heating systems can be configured to operate during the sunny part of the day so they can use solar power and reduce solar PV exports. I've used a simple timer on my hot water heater called the little gray box.

Cooktop range

New induction cooktops are very efficient and can heat a pot of water faster than a propane cooktop. Additionally, they are much safer as they have no open flames, and the stove surface hardly gets hot to the touch and cools quickly.

Oven

An electric oven uses resistance heat, but is more environmentally friendly and safer that burning propane.

Dryer

Most electric driers are simple resistance heat, and they use a lot of power to dry clothes. There are some new heat pump driers that use less power but with lots more complexity and a much longer drying cycle. By scheduling your clothes drying to the sunny part of the day, PV system owners can reduce PV power exports and save a little money.

Dehumidifier

Dehumidifiers can use a surprising amount of power. Ideally, they are equipped with a pump to avoid constant dumping of the water collection tank. The risk of mold and the protection of furniture damage is important and may make dehumidification worthwhile. They can be operated during the sunny part of the day.

Water pump

In Princeton most homes have a private well and a water pump. The pump runs in proportion to how much water you use. Watering the flowers and vegetables during sunny days can reduce exported power for PV system owners.

Lighting

LED lights use a fraction of the power of incandescent bulbs. They can be dimmed if they are compatible to the dimmer and the bulb supports dimming. Natural light with light colored walls reduces the need for lighting. Specs on brightness, efficiency I.e., 100 lumens per watt is good, and CRI of 100 matches natura light. Use a high color renditioning index light for sewing or task lighting. Color temperatures are important. 5000-degree bulbs are rather blueish white and 2700-degree bulbs are a warmer color and not so harsh.

TV, computers, broadband, & Parasitic loads

There are lots of devices that consume power even when they are off. TV's computers, various charging systems, stoves, microwaves, printers, clocks, smoke detectors, security cameras, and many other devices remain on 24/7. Some of these are essential and need to stay on. But some can be disconnected using a power strip with a switch when not used.

Tax credits and incentives

Note that various tax credits and incentives change often – Check to make sure these credits are still in effect.

Details of Massachusetts Solar Incentives

Residential Renewable Energy Income Tax Credit
Purchase a new home solar system in Massachusetts and get a 15% credit of the final cost of your solar installation against your personal income taxes. This is limited to a $1,000 state tax reduction.

Any excess credit amount can be carried over to your personal income taxes for up to three years.
Solar Massachusetts Renewable Target (SMART) Program (This is for investor-owned utilities and is not supported by municipal power companies like PMLD)
Eligible homeowners can receive payments from their utility company in Massachusetts for every kilowatt-hour (kWh) of solar power they create for ten years.[7]

In other states, these credits are known as Solar Renewable Energy Credits (SRECs).
Solar Installation Property Tax Exemption
Add a new solar system to your home in Massachusetts, and your property taxes won't go up. Installing a system could also help you build home value.
Home Solar System Sales Tax Exemption
When you purchase a new solar system in Massachusetts, you won't pay any sales tax.

The exemption is for 100% of the sales tax of your new home solar project. This can save you 6.25% right off the bat.
Mass Solar Loan Program
Eligible low-income homeowners can have access to a low-interest loan to finance a PV system.

This program is administered in partnership between the Massachusetts Department of Energy Resources (DOER) and the Massachusetts Clean Energy Center (MassCEC).

Economics

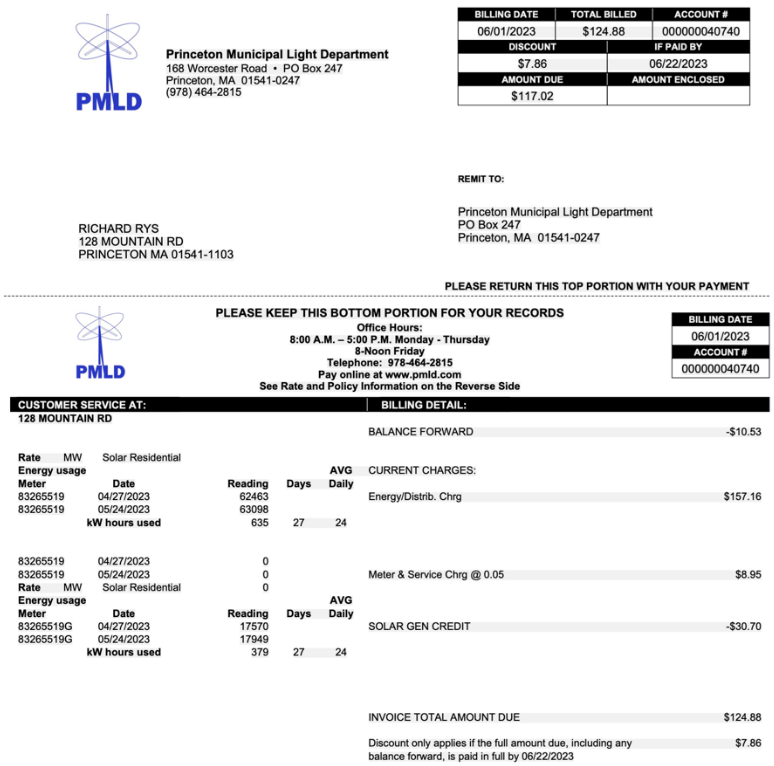
PMLD Interconnect policy

Please review the PMLD interconnect and solar rate policy on the PMLD website. Unlike some of the investor owned utilities that are required to support a full retail rate net meeting policy, PMLD and most other municipal utilities do not offer that. Be aware that the price PMLD will pay for your exported power will likely change significantly over the life of your PV installation. As a municipal power company, the rules for solar are different than those for investor-owned utilities like:
Eversource (Western Massachusetts Electric & NSTAR): www.eversource.com
National Grid: https://www1.nationalgridus.com/Massachusetts
Unitil (Fitchburg Gas & Electric Light): http://unitil.com/

Expected Power Production

Future issues that may impact the price PMLD will pay for your residential PV power.

The concept for computing the re-imbursement rate for exported residential PV power was to pay town residents the avoided costs and to ensure that PMLD does not penalize non-solar PV owners. PMLD is a nonprofit municipal entity and follows the utility standard of charging for power based on the amount of power consumed each month in kW*hrs. The rate of 24.75 cents per kW*hr must cover the power that PMLD buys as well as the overhead costs to maintain staff, equipment, and system maintenance. Roughly 8 cents per kW*hr is for the cost of energy and the transmission fees to get it into the PMLD system and the remainder is to cover the town system costs. PV customers are now paid this avoided cost or about 8 cents per kw*hr for the power they export into the PMLD system. See a sample of my bill for the month of May 2023:



Princeton Municipal Light Department
168 Worcester Road • PO Box 247
Princeton, MA 01541-0247
(978) 464-2815

BILLING DATE	TOTAL BILLED	ACCOUNT #
06/01/2023	$124.88	000000040740

DISCOUNT	IF PAID BY
$7.86	06/22/2023
AMOUNT DUE	**AMOUNT ENCLOSED**
$117.02	

REMIT TO:

Princeton Municipal Light Department
PO Box 247
Princeton, MA 01541-0247

RICHARD RYS
128 MOUNTAIN RD
PRINCETON MA 01541-1103

PLEASE RETURN THIS TOP PORTION WITH YOUR PAYMENT

PLEASE KEEP THIS BOTTOM PORTION FOR YOUR RECORDS
Office Hours:
8:00 A.M. – 5:00 P.M. Monday - Thursday
8-Noon Friday
Telephone: 978-464-2815
Pay online at www.pmld.com
See Rate and Policy Information on the Reverse Side

BILLING DATE
06/01/2023
ACCOUNT #
000000040740

CUSTOMER SERVICE AT:
128 MOUNTAIN RD

Rate MW Solar Residential
Energy usage

Meter	Date	Reading	Days	AVG Daily
83265519	04/27/2023	62463		
83265519	05/24/2023	63098		
	kW hours used	635	27	24
83265519	04/27/2023	0		
83265519	05/24/2023	0		
		0		

Rate MW Solar Residential
Energy usage

Meter	Date	Reading	Days	AVG Daily
83265519G	04/27/2023	17570		
83265519G	05/24/2023	17949		
	kW hours used	379	27	24

BILLING DETAIL:

BALANCE FORWARD	-$10.53
CURRENT CHARGES:	
Energy/Distrib. Chrg	$157.16
Meter & Service Chrg @ 0.05	$8.95
SOLAR GEN CREDIT	-$30.70
INVOICE TOTAL AMOUNT DUE	$124.88
Discount only applies if the full amount due, including any balance forward, is paid in full by 06/22/2023	$7.86

As you can see, I consumed 635 kw*hrs of power so there is no minimum charge as this is much more than the 200 kw*hr minimum. You can also see that I exported 379 kw*hr and I was compensated at about $8.1 cents per kw*hr or $30.70 for my exported power. In May I did consume about 2/3 of the power I generated which does not show up on this bill.
So not shown is the roughly 570 kw*hr of power that was consumed coincidentally to its production. Much of this was due to carefully charging my EV on sunny days. Without solar PV my bill would have been about double.

Customers that buy a lot of power pay more to cover the overhead costs. Solar owners tend to buy less power and thus pay less of the overhead costs. There is a provision that all PV owners must pay for the equivalent at least 200 kW*hr per month whether they use that or not. Only a few PV owners with large PV systems and batteries will consume less that 200 kW*hr in a month and most likely the current compensation they get for exported power more than covers the cost of paying for the fraction of 200 kW*hr they did not use. In this way all PV owners must contribute a minimum amount to pay for the electric system costs. PMLD will adjust the avoided cost and minimum payment yearly or as needed.

As a PV owner you are likely to be interested in how these prices might change over the life of your PV system. The current PMLD contract with NextEra is arranged so PMLD pays the same cost for power regardless of time of day, and regardless of the real time price of power in the New England region. This real time price (called LMP or Local Marginal Price) varies each hour, and it is what exporters of power will get paid and consumers of power will pay for power during that hour whether the power flow is to or from the New England grid. The New England grid is managed by ISO New England who reconciles payments for all registered grid entities like utilities and our wind turbines. The PMLD contract ends in 2028 and PMLD will need to procure more clean power to meet the MA climate law. Unlike the investor-owned utilities, MLPs have never had requirements about purchasing renewable energy in the past. The MA climate law issued in June 2022 changes that. It requires MLPs purchase 50% of their power from “non-carbon emitting” sources by 2030 and get to net-zero emissions by 2050. The NextEra power portfolio would not meet this requirement and thus PMLD will need to secure new contracts to purchase more non-carbon emitting power than they do now once our current contract ends. Currently PMLD does not purchase our own wind power, but instead exports that to the real-time market hour by hour at the prices available. This may change in 2028, assuming the wind turbines are still operational. They will be 19 years old by then and near end of life. It is not so easy to just buy wind or solar power to meet these non-carbon emitting requirement as you can only buy that power when it is being produced. PMLD could buy wind and solar when it is generated, but this leaves large gaps when it is neither windy nor sunny. The easy solution is to buy the remaining power from the real time market, but that power is not considered non-carbon emitting so it cannot work to fully meet our MA clean energy targets.

Power purchased from Princeton PV owners is about 1% of PMLD's power in 2022 and helps meet our climate goals. In the US new wind and solar power is the main source of new power being added to the grid and exceeds new natural gas power. As more solar is added without a corresponding way to consume or store that power what will happen in the future is the value of power during sunny days will plummet. I.e., the LMP price will be low during sunny days, but will jump up for high load days or for evening hours of 5-9pm. Commercial solar power would be available for PMLD to buy and if that happened the price for that power would likely be quite low if the massive solar PV build out continues until 2028. Wind and solar are less than 10% of the power on the grid today but may get up to near 50%. There will be wider swings in the grid (LMP) price of power and situations where grid operators would curtail solar power. LPM has occasionally gone negative in the past. When grid power goes negative, customers with LMP contracts would then be paid to consume power and penalized to export power to the grid. But only if you were paying LMP prices and not with our NextEra contract today. PMLD had a similar situation once with our wind turbines where they got a $15k penalty for not curtailing when ISO new England asked us to do so on a weekend. Today MMWEC can curtail our power during such an event from monitoring at their Stoney Brook plant. These events will be more common in 2028 as most new power will be wind and solar. What PMLD and other utilities, are working on is a way to store power when it is cheap and export that power when it is expensive. If this is not done within the town then utilities like PMLD will rely on others that install such energy storage. I've noticed that a few utilities are implementing time of day pricing. PMLD would need to install smart meters that would be needed if PMLD would implement time of day pricing. Such meters would have what is called AMI or Advanced Metering Infrastructure which would need to have an interface for the utility for billing and grid monitoring and a separate interface for the customer that would allow the customer to monitor and adjust power usage.

PMLD is currently working with MMWEC to allow a third party to finance, own, and operate a grid scale battery likely located near the wind turbines. Such a battery is intended to reduce our peak loads to save money on transmission and capacity charges that are figured based on the peak power consumption for a one-hour period each month. Current discussions are for a battery that can output 2-3MW and store power for up to 4 hours. There may be ways these batteries can be managed so they are normally charged from renewable solar or wind power.

Suffice it to say that PV owners can expect the price for exported power to be much lower than it is today once PMLD adjusts its power purchase agreements in 2028. PV owners in California and Hawaii where solar penetration is strong have seen requirements that new solar cannot be connected to the grid without also including battery storage. Adding battery storage to a PV system is expensive, even though it is eligible for solar tax credits of 30% for both the PV and battery systems. It is too early to tell how PV owners with batteries might be compensated in 2028 or if PMLD could implement smart meters with some form of demand response billing making customers more responsive to power price dynamics.

System design options

There are a wide range of options to add solar power to a residential home. There are many different manufacturers of solar panels, inverters, batteries, mounting systems that might be used to achieve the specific goals on a homeowner. In my case I installed a PV system of about 8kW which could produce about as much power as my all electric, (but very efficient) house would consumer over a year. I included an off grid inverter that would allow me to add batteries in the future but I never did that. I had a HERS rating of -3 which meant that my house was better than net zero. Net Zero was my goal and it was not related to economics or return on investment. My thought process was that while fossil fuels were wonderfully useful, they are artificially cheap due to multiple government subsidies, the largest being that we are all allowed to burn fossil fuels without paying for the damages they do to the environment which is at least $200 per metric ton of CO2. As an engineer that worked to make hydrocarbons, I wanted to see just how hard it would be to get to net zero and drastically cut my own consumption of fossil fuels. A year later I bought my first EV, a Tesla model 3, and this increased my power consumption, and I was no longer net zero. The big advantage of the EV was that I had a place to put the excess PV power. I could reduce exports and often drive the EV for very little power costs. My wife Claudia and I would use the EV most of the time and we put about 25,000 miles per year on it.

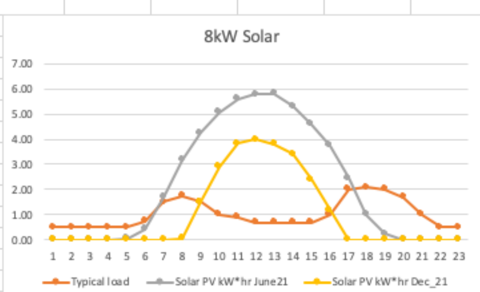
One of the key questions is how big should you make your PV system?
See the comments below to compare a few options.

Option 1: Yearly PV power equals the customer yearly power usage with a battery sized to meet your average daily load.

This option can capture PV power during the day and push it into the battery for use after the sun goes down. Additionally, this system can provide power to some or all the house when grid power is lost. Such a system could continuously provide backup power on sunny days but could fall short of daily power needs in winter months or cloudy days. A system like this may hit the minimum 200kw*hr power limit in summer months but would likely generate more power than the house uses in summer months and thus earn revenue from exported power.

Option 2 Yearly PV power equals the customer yearly power usage.

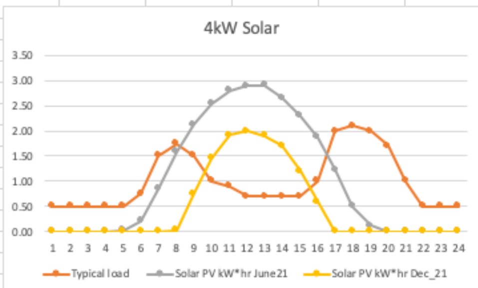
My experience with this option resulted in more than 50% of my PV power being exported as it was not coincident with my power load. With a normal off grid inverter when the grid goes down the PV system will not generate power. A separate generator could provide power during grid failures. Shifting some loads to the sunny part of the day can help, but the “always on” load every house has cannot be shifted and most people use power in the mornings and evenings when there is no sun. Some loads like electric water heating (especially a heat pump water heater that uses power more gradually), drying, cooking, and other loads may be shifted to the sunny part of the day to reduce exports and save the full retail rate on power. A large load like an EV can be charged during the sunny part of the day assuming it can be parked at home, and you can manage to charge it at the same rate you PV system is making power. That can be challenging to do manually, but doing this can significantly reduce power exports. There are some systems that can do this automatically, like the SPAN breaker panel or some systems with batteries like Tesla Power wall. In situations like this there may be some advantages to installing some PV panels to the southeast and/or southwest as that will flatten your daily PV production and better match your house loads. The graph below is using a typical MA load profile with morning and evening peak loads for a working family. The solar gain and loads are approximately as shown below for winter and summer days. Note the exported fraction of the solar power.



Summer Exports	71%
Winter Exports	69%

Option 3 Yearly PV power equals 50% of the customer yearly power usage

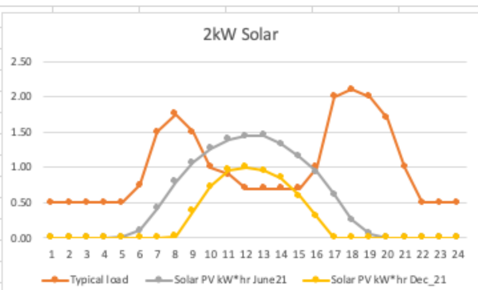
This arrangement will greatly increase the fraction of PV power that can be used consumed coincident with sunny days. There will still be some power that is exported on sunny days with a low house load, so your utility savings will be less than 50% of your previous bill. The graph below is using a typical MA load profile with morning and evening peak loads for a working family. The solar gain and loads are approximately as shown below for winter and summer days. Note the exported fraction of the solar power.



Summer Exports	52%
Winter Exports	47%

Option 4 Yearly PV power equals 25% of the customer yearly power usage

A small PV system will cost less, but there will be some fees that are the same as a larger system, like application fees, cost of a new meter, and maybe the inverter is a bit oversized as they may not be available for small sizes. The PV installer may not recommend this as it is a lower cost system. The graph below is using a typical MA load profile with morning and evening peak loads for a working family. The solar gain and loads are approximately as shown below for winter and summer days. Note the exported fraction of the solar power.



Summer Exports	27%
Winter Exports	13%

Option 5 – Community Solar

While there is no community solar option today, the Hubbardston Road Landfill site has about 7 acres that could be used for a commercial solar PV system to be developed by a third party. 7 acres will likely make a bit more than 1MW of power in bright sun and make roughly 1460 MWh annually. Commercial solar fields in Massachusetts can earn between $0.03 and $0.10 per kWh. With a willing developer and support from PMLD, it is possible the developer could offer a community solar option. A community solar project is a solar power generating facility that is owned and operated by a third-party developer. Individuals, businesses, and other organizations can subscribe to the project to receive credits on their share of the ownership. This could be a credit on their electricity bills for the portion of the power that is generated by their share of the solar panels.

Here are four financial models for community solar projects:

1 Subscription model: In this model, subscribers purchase a share of the solar project and receive credits on their electricity bill for the energy that is generated. This model is popular because it allows subscribers to participate in the benefits of solar energy without having to install solar panels on their own homes. The credits may not be fixed and could decline over time. This requires PMLD to buy the subscriber's power.

2 Lease model: In this model, a developer builds and owns the solar project and then leases the panels to subscribers. The subscribers pay a monthly lease payment, and they receive credits on their electricity bill for the energy that is generated. This model is popular because it allows subscribers to enjoy the benefits of solar energy without having to make a large upfront investment. This requires PMLD to buy the subscriber's power.

3 Power purchase agreements (PPAs): In a PPA, the project developer sells the electricity produced by the solar farm to the subscribers at a fixed price. This model is popular because it allows subscribers to lock in a fixed price for their electricity, which can protect them from rising energy costs. This requires PMLD to buy the subscriber's power.

4 **Share ownership:** In this model the subscriber owns a share of the project and can receive monthly payments from the developer according to the developers PPA with the buyers of the power. The utility is not involved with the subscriber. This is not really considered a commercial solar project and is more of an investment in a solar project.

Homeowners can receive a tax credit for their share of community solar. The amount of the tax credit depends on the size of the solar project and the number of subscribers. The federal solar tax credit is currently 22% in 2023 and then drops to 10% in 2024.

To qualify for the tax credit, homeowners must own a portion of the solar project. This can be done through a subscription model, a PPA model, or a lease model. The homeowner must also have a utility bill that shows that they are receiving credits for the solar energy that is generated.

The tax credit can be claimed on the homeowner's federal income tax return. The credit is claimed in the year that the solar project is completed.

Here are some of the requirements for claiming the tax credit:

The solar project must be located in the United States.
The solar project must be placed in service during the tax year.
The homeowner must own a portion of the solar project.
The homeowner must have a utility bill that shows that they are receiving credits for the solar energy that is generated.

Options 1, 2, and 3 require PMLD to issue a credit on the customer utility bill. To provide a credit, PMLD would need to purchase the all the subscribed power from PMLD customers and allocate credits based on ownership share and the total subscriber power production. To be simple this would be a fixed $ per kWh even if PMLD cost of power changes throughout the day.

PMLD philosophy for solar has been to compensate solar owners for the avoided cost (i.e., what it would otherwise cost PMLD for buying that power) and to make sure that PV owners pay a fair share of the overhead costs to keep the PMLD system maintained. PMLD power purchase agreements can be exclusive supply source, like the current NextEra contract and could limit the amount of community solar power purchased, although this is unlikely to be a limit at small scales. Subscribers would be mistaken to assume they could simply buy power from a community solar project at 3-10 cents per kWh to displace their PMLD rate of 24.75 cents. Subscribers have a normal meter and power consumed will be billed as before. The credit for their subscribed power would be figured separately and deducted from their monthly bill. It is likely that PMLD would be supportive of community solar, but it is unlikely there will be huge savings for subscribers. One factor is that unlike PV at a home, none of the PV power is coincident with load. PV homeowners can displace some of their expensive purchased power during the sunny part of the day, but subscribers cannot. The subscriber credit would need to factor this in.

References and resources

This residential solar guidebook (2022) from CEC provides some useful information.
https://goclean.masscec.com/downloads/MassCEC-Residential-Solar-GUIDE.pdf

PVWatts is a free program supported by NREL that computes the power production of a PV system. Very useful for planning how much power you might produce. It knows the weather in Princeton, and you just specify the size of the panels, mounting angle, and direction of your roof, PV panels, or windows.
https://pvwatts.nrel.gov/pvwatts.php

While most PV installations will provide a website that monitors the PV system The sense energy monitor is very helpful with great trending and the ability to identify loads based on the resistance and inductance signatures
https://sense.com/

Information on Solar farms:
https://8billiontrees.com/solar-panels/solar-farm-income-per-acre/

The PMLD web site has some useful information on policies, energy saving, and various incentive and rebate programs.
https://pmld.com/
https://pmld.com/policies-and-terms.html
https://pmld.com/electric-rates.htm

I have no connection with these suppliers, and these are only the suppliers that know off the top of my head – Keep in mind you will need a good electrician to integrate PV into your house and the supplier typically brings their electricians to the job as well as the PV panel installers on the roof. There are likely many other great suppliers, but some suppliers put together very boiler plate proposals without much detail and should be avoided.

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New England Clean Energy – https://newenglandcleanenergy.com/ Mark Durenberger – Out of Hudson Mark has installed PV in Princeton

Revision Energy - https://www.revisionenergy.com/ - Out of NH but may be able to handle complex applications.

PV squared – https://pvsquared.coop/ Out of Greenfield I picked them because I wanted SunPower panels and a specific Pika (no owned by Generac) inverter that could support off-grid with batteries that I never actually installed.

Author Rick Rys

For further questions email Rick Rys at: rys@r2controls.com