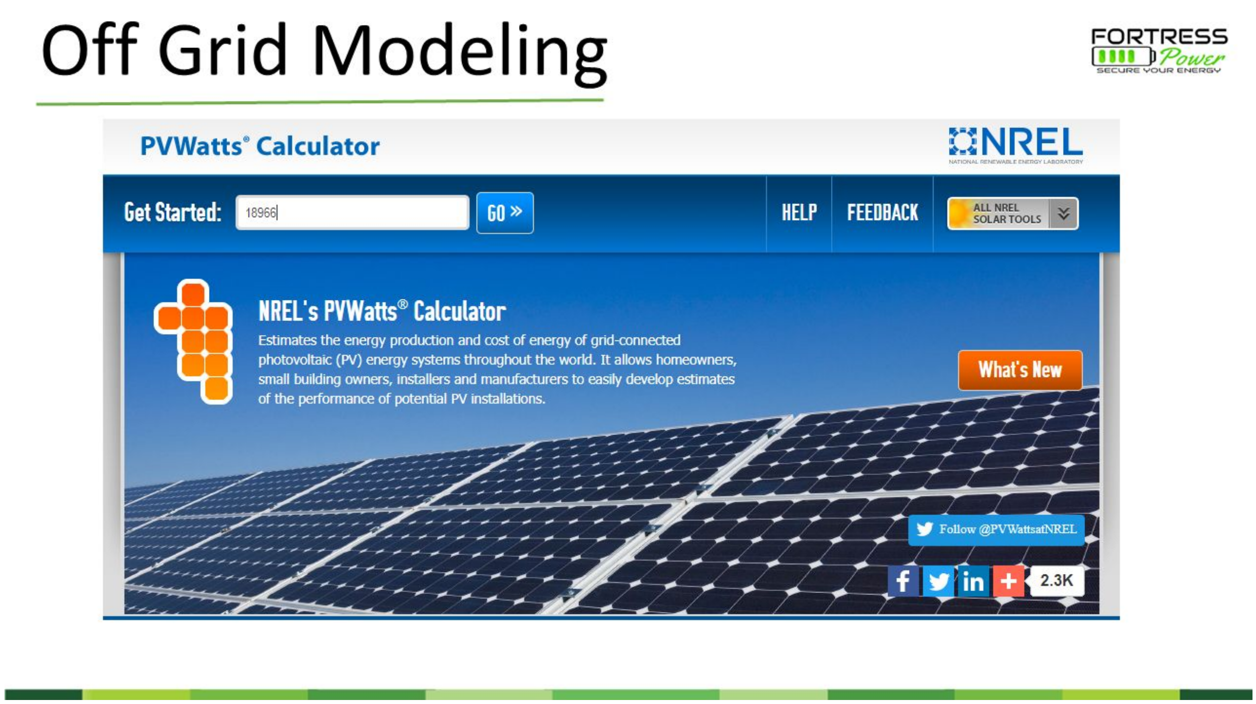
Solar Battery Capacity Tool

email sales@fortresspower.com before sharing

Check the Dealer Resources Page for the latest sizing tool version.

There are a lack of battery sizing tools on the market. Many that exist are complicated or more focused on the commercial market, which is a grid-tied market. Developing an off-grid sizing model can be done in a spreadsheet based on PVWatts, and this class will show you how. Along the way, various sizing considerations will be discussed for net-metering, variable rates, and zero outflow. Time-of-use rates and commercial demand modeling will be added into the model at a later date.



Like other design tools, this one starts with some PVwatts data. It's very easy to use. Just put in the zip code select go, and PVWatts adjusts its data based on local weather data. Move ahead to the system size screen and input a one kilowatt solar array for your area.

Off Grid Modeling

RESOURCE DATA SYSTEM INFO RESULTS

Go to system info

RESULTS

Print Results

1,334 kWh/Year*

System output may range from 1,282 to 1,386 kWh per year near this location. Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.02	80	10
February	4.04	95	12
March	4.72	121	16
April	5.60	130	17
May	5.96	141	18
June	5.98	133	17
July	6.38	144	19
August	5.84	131	17
September	5.23	115	15
October	4.07	99	13
November	3.21	77	10
December	2.71	70	9

Array Sizing Quick: Match winter / summer production with consumption from existing electric bills

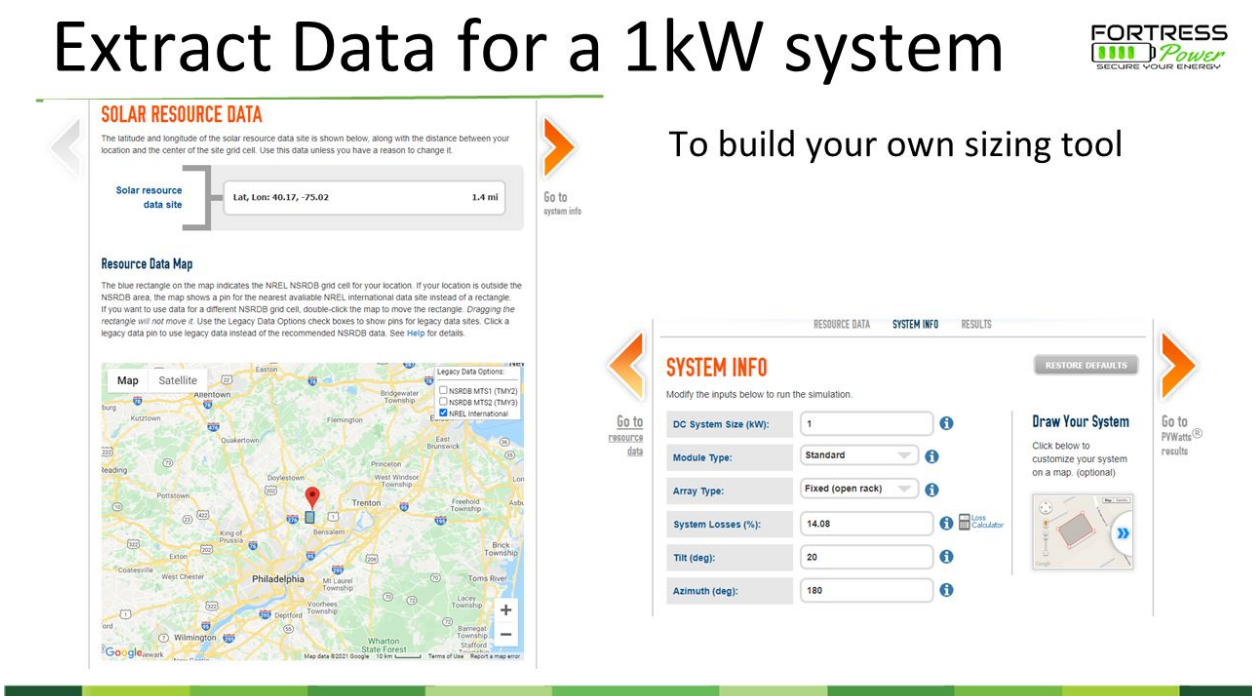
If you want to skip this class and just go with a quick and easy solar array size, a quick method of sizing off grid solar is to match up the monthly consumption with the monthly solar production. Many solar arrays without batteries will offset 100% of the annual site consumption, but in off-grid design, start by agreeing not to run out of power at the end of the month.

Do not be concerned with spring and fall weather, when the solar array is productive and the electric load is low. Those differences will vary between whether the building is gas or electric. An all-electric house will have a high winter morning load due to electric heat, whereas in summer weather, the heavy load will come in the middle of the day due to air conditioning. With gas, spiky load profiles due to cooking or laundry are non-existent. Spiky instant electric water heaters have a tremendously high load if only for a minute.

With off-grid sizing, match 12 months of electric bills up with the PVWatts data so that the monthly solar production always exceeds the monthly home consumption, and that is a great starting point for an off grid solar array. The most important design month might be January or August depending on the site location and other onsite energy sources. But an off-grid system should be reliable - and so there are times when an off-grid solar array produces a large surplus of electricity that doesn't get used.

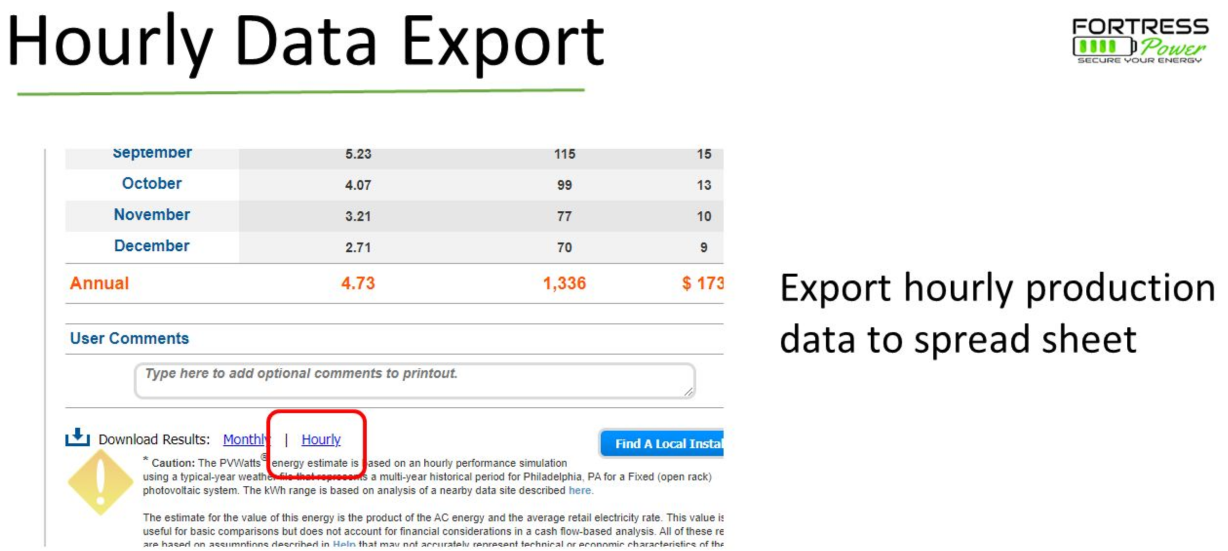
In the case of grid-tied solar, this surplus electricity is sold back to the grid. But there is a big difference between a 100% offset electric bill and a zero outflow solar array.

A grid-tied home with a zero outflow mandate might result in a small solar array and a large battery to operate efficiently. An off grid array might not care about efficiency as much, selecting the largest solar array the budget could afford and accepting a large amount of "stranded energy" won't get used. Grid-tied solar with good utility buyback might not need a large battery but could still benefit from a small battery for storage and electric rate optimization. ***Let's create a tool that displays how much electricity a solar array produces, how much electricity is consumed instantly on site, and how much is stored into a battery, and how much is either lost or sold back to the grid.***



Because our initial system estimate is based on monthly production and consumption, you might be concerned about times when there are multiple cloudy days in a row. Don't worry - PVWatts connects to local weather data so the weather will be considered!

Enter PVWatts data for a 1 kilowatt system and then extract the hourly data to copy and paste into the model. The 1kW size is to form a scalar in the model. We will be able to enter our own system size later, multiplying the PVWatts data by what we enter, so we don't have to run multiple PVWatts simulations.



Go ahead and visit PVwatts to grab the hourly solar production data for a 1kW array in your area. Put in your zip code and enter in a one kilowatt array.

The default values in PVwatts are fairly conservative. The values should be customized based on the direction the array is facing. East, West, or North facing solar will not produce as much as south facing, so if you know which direction the array will be facing, enter it in now. But it won't impact the overall model very much. The model will be conservative and the default PVWatts values are conservative already.

At the end of the PVWatts screen, scroll all the way down and export the data on an hourly basis. Don't select the monthly download, but rather the hourly download.

The spreadsheet becomes the basis for the model - this hourly data can be copy and pasted right into the sizing tool. This raw PVWatts data reveals valuable site data - the amount of sunlight in the air can reveal how many cloudy days are estimated in winter for example.

But planning for multiple days of storage isn't necessary - solar battery owners will either have access to the grid or a generator to recharge the batteries if they get low. That may sound like cheating, but such a configuration allows comfortable electrical consumption during normal system operation, and the user can scale back their electric use during true emergencies.

Multiple days of lithium battery storage is too expensive for most customers - a backup generator or grid power source is often the most cost-effective option to power through those cloudy days. Lead acid battery banks would be sized for four or five days worth of storage, but that much storage is needed for lead acid batteries to function reliably, at a very slow discharge rate. Lead acid needs a slow discharge rate, and so by having four or five days worth of storage, it has one.

But lithium iron phosphate batteries do not need such a large amount of storage to be used efficiently. They are a "two hour" discharge rate to work reliably for the long term. One day's worth of storage is more than sufficient to run off grid for most of the year. Smaller systems, with greater reliance on an external power source, might be preferable to grid-connected customers. And for off gridders, there will always be cloudy days. A generator plays a key role in off grid living, so let's create a tool that allows the user to evaluate solar and battery system size as a function of generator run time. Let's find the right amount of solar and batteries to eliminate the generator from running most days, and then determine how much additional solar or battery capacity is needed to reduce grid or generator use further.

PVWatts Download

FORTRESS Power SECURE YOUR ENERGY

	A	B	C	D	E	F	G	H	I	J	K
5	Long (deg W):	75.02									
6	Elev (m):	70.32									
7	DC System Size (kW):	1									
8	Module Type:	Standard									
9	Array Type:	Fixed (open rack)									
10	Array Tilt (deg):	20									
11	Array Azimuth (deg):	180									
12	System Losses:	14.08									
13	Invert Efficiency:	96									
14	DC to AC Size Ratio:	1.2									
15	Average Cost of Electr	0.129									
16	Capacity Factor (%)	15.2									
17											
18	Month	Day	Hour	Beam Irradia	Diffuse Irra	Ambient Tem	Wind Speec	Plane of Array Irra	Cell Temperature	DC Array Output (W	AC System Output (W)
19	1	1	0	0	0	-5	4	0	-5	0	0
20	1	1	1	0	0	-5	4	0	-5	0	0
21	1	1	2	0	0	-5	4	0	-5	0	0
22	1	1	3	0	0	-6	4	0	-6	0	0
23	1	1	4	0	0	-6	4	0	-6	0	0
24	1	1	5	0	0	-7	4	0	-7	0	0
25	1	1	6	0	0	-7	3	0	-7	0	0
26	1	1	7	0	0	-7	3	0	-7	0	0
27	1	1	8	655	41	-6	3	308.818	-0.144	269.925	258.614
28	1	1	9	827	55	-5	3	527.302	7.153	473.952	456.15
29	1	1	10	901	63	-3	3	678.329	13.37	605.06	582.27
30	1	1	11	927	67	-2	3	757.882	16.645	670.348	644.836
31	1	1	12	921	68	-2	3	758.289	16.865	670.263	644.754
32	1	1	13	895	63	-2	3	684.353	15.1	606.524	583.675
33	1	1	14	827	55	-2	2	542.224	13.495	475.816	457.948
34	1	1	15	678	41	-3	1	333.922	8.683	284.225	272.509
35	1	1	16	256	13	-4	1	85.113	-1.803	67.58	61.178
36	1	1	17	0	0	-5	1	0	-5	0	0
37	1	1	18	0	0	-5	0	0	-5	0	0
38	1	1	19	0	0	-5	0	0	-5	0	0
39	1	1	20	0	0	-5	0	0	-5	0	0
40	1	1	21	0	0	-5	0	0	-5	0	0
41	1	1	22	0	0	-5	0	0	-5	0	0
42	1	1	23	0	0	-5	0	0	-5	0	0
43	1	2	0	0	0	-6	0	0	-6	0	0

Input 1kW PVWatts data into PVWatts input tab…

How to adjust from 1kW to actual array size?

Building your{own energy model is the best way to learn valuable skills which are in demand by the workforce. But you can also make a copy of our sizing tool - but please do not distribute it without written permission.

Paste the hourly PVWatts data for a 1kW solar array into the PVWatts tab on the sizing tool spreadsheet. This tab feeds data on the rest of the sheet, such as taking a user-defined system size on the System Input tab, and then multiplying the PVWatts information by that system size. The results show up on the Hourly Energy Flow tab.

Adjusting for PV Size

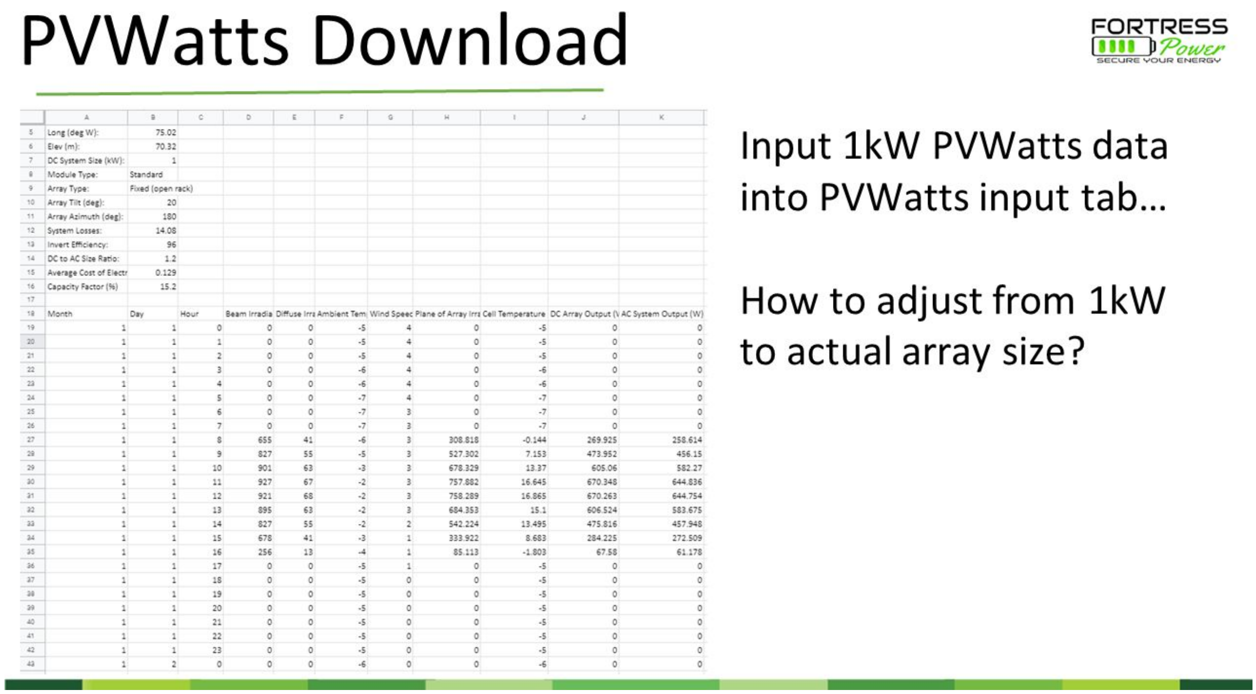
	A	B
1	Inputs	
2	Array Size (kW)	15
3	Battery Size (kwh)	37
4	eVault	2
5	eFlex	0
6	Generator Size (kW)	8

E2 `='PVWatts Input'!J19*'System Information'!$B$2/1000`

	A	B	C	E	L
1	Month	Day	Hour	Array Output (kw)	Estimated Consumption (kW)
2	01	01	00	0.0	0.5
3	01	01	01	0.0	0.5
4	01	01	02	0.0	0.5
5	01	01	03	0.0	0.5
6	01	01	04	0.0	0.5
7	01	01	05	0.0	2.0
8	01	01	06	0.0	3.5
9	01	01	07	0.0	3.5
10	01	01	08	4.0	3.5

PVWatts outputs its data by the watt, so that needs to be divided by a thousand to convert to kilowatts. The formula is copied throughout the new “Array Output (kW)” column to get the PV array output for each hour of the year, based on the system size entered into the “System Information” tab.

What if this were a commercial project, with PVWatts data needed in fifteen minute increments instead of hourly increments? To create that data, copy the PVWatts data four times and then re-sort the list by month, day, and hour of the year. The PVWatts data will then meet up with the 15 minute interval data. If the solar array has a 5kW power output for one hour,it will also have a 5kW power output for those 15 minute intervals within that hour. That isn’t quite the same as getting 15 minute solar data estimates, but that level of detail isn’t even considered in commercial design software, so we’ll ignore it too. This spreadsheet will be based on hourly PVWatts data, and 15 minute interval data will be added in a separate class.



	A	B	C	D	E	F	G	H	I	J	K
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23	1	1	4	0	0	-6	4	0	-6	0	0
24	1	1	5	0	0	-7	4	0	-7	0	0
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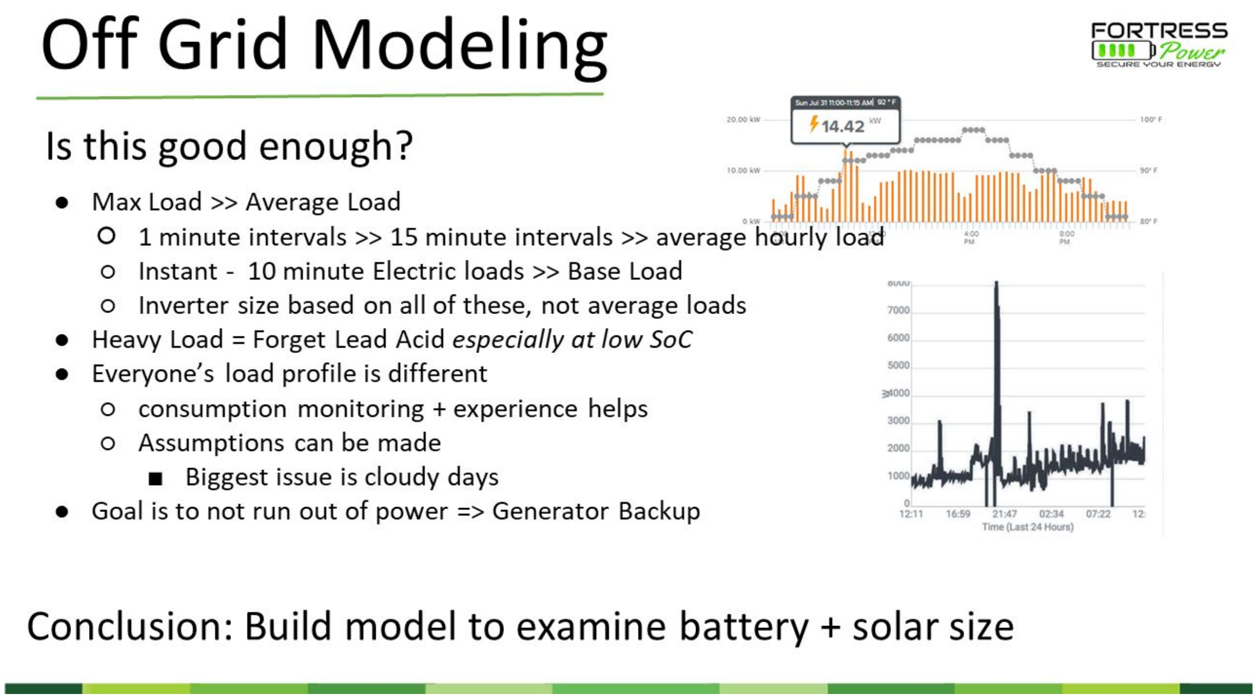
38	1	1	19	0	0	-5	0	0	-5	0	0
39	1	1	20	0	0	-5	0	0	-5	0	0
40	1	1	21	0	0	-5	0	0	-5	0	0
41	1	1	22	0	0	-5	0	0	-5	0	0
42	1	1	23	0	0	-5	0	0	-5	0	0
43	1	2	0	0	0	-6	0	0	-6	0	0

PVwatts is used all the time for systems without batteries, and PVWatts lacks information on hourly consumption of the building's electric use. How do you determine that?

Net-metering takes the intelligence out of the solar design process. If a one-for-one kilowatt hour credit is given for all system outflow onto the grid, the designer can simply look at 12 months of electrical data and 12 months of solar production, and adjust the system size until the two values match up, but none of that has much consideration for the hourly consumption or daily consumption or five-minute consumption of the home. In a sense, PVwatts and net-metering make solar design really simple. As net-metering policies phase out, design expertise is added back in.

Assumptions can be made about the electric load based on the 12 month electric bill history. Maybe these assumptions are not enough to determine the entirety of the system design - such as the maximum size of the battery inverter, but in terms of that power multiplied by a period of time, that time-based number, the kilowatt hour, is what is provided on most electric bills. Knowing how many kilowatt hours are consumed over a period of a month can then be broken down into average kilowatt hours consumed a given day, or further to a one hour average. In other words, take the electric use for the month, divide by the days in the month, and hours in a day, to get the average power demand for the month. At the very least, an hourly model can be made based on the average building load over the course of the month. That kind of model might be okay, if the battery bank is large enough, but we will make it more accurate by learning more about load profiles.



The building instant load may vary wildly from the building 15 minute average load profile, or even the real hourly profile, and more so from the average load for the month. But we know that at the end of the month, the site consumption and PVWatts production data balance out with a surplus. To a large extent, we can be more confident in our model because we are using lithium batteries, which are more responsive than lead acid batteries.

Sunny days have greater air conditioning loads than cloudy days, but there is also more solar production when those air conditioners are running.matching that consumption and production perfectly is tough, but there is an even greater when there are multiple days of cloudy weather conditions. This model is good enough to catch up on a five-day running average outside of extreme conditions, and remember the starting guess for the solar array size is to net out every month's consumption vs. production difference. The only way to make the data more accurate is to download hourly or better interval data, and we have a generator playing free safety to

account for any model inaccuracy. So this is about as good as it gets when modeling off grid systems based on 12 month consumption d
ata.

The average USA home uses 11,000 kwh of electricity per year. That will be a big difference between electric or gas, or the northern USA vs southern USA, and most solar customers tend to be on the high end of consumption, although there are extreme off gridders who are well on the low end of electrical consumption. At any rate, in class we will model a site that uses 15,000 kwh of electricity per year. This is typical of a medium sized, all-electric grid-tied home.

On this topic of interval data, commercial electric rates are often billed by the maximum 15 minute load of the entire building. That single point on a 15 minute interval graph of commercial load for the entire month can comprise 70% of a commercial electric bill in the most extreme cases.

But another kind of pitfall with interval data is not having enough resolution. Most commercial bills are based on 15 minute interval data, whereas PVwatts is based on hourly performance data. Without a battery, that one hour production could be meaningless to a commercial customer, if it all occurs within a 45 minute time frame, and a cloud sits on top of the solar array for the remaining 15 minutes. In that sense, battery models are more forgiving to errors in resolution than batteryless models. Or in other words, a solar array economic model without a battery is more likely to be incorrect than one with a battery. And also, as long as the model is close enough, remember that battery customers are not as concerned about payback as batteryless customers. A solar array without a battery can only reduce an electric bill. A solar array with a battery can provide reliable power throughout the day and night.

To improve the accuracy of the model, interval data can be useful. Sometimes the end user can log into their electric utility and download this 15 minute by 15 minute interval data, and that will provide a more accurate model than one hour average loads. But it's also worth pointing out that even more high resolution load profile data would guide the model further, to the point where even 15 minute interval data can be misleading.

A customer called into technical support convinced something was wrong with their inverter, but the inverter company was convinced there was something wrong with the battery. This inverter had a 9kW output, but whenever the customer would try to sell 7kW of power to the grid, the inverter would shut down the grid export. It turned out the customer had a 3kW load that would periodically turn on for a few seconds.The inverter would shut down the grid export in order to keep the load powered up, but that would result in inefficient grid sale. The proof was a 30 second long recording of the inverter screen - but even then it only recorded one of two instances where the grid export was halted. The less obvious instance was too fast, occurring in the matter of seconds, to be picked up on the inverter screen. The customer was perplexed that the inverter would not be smart enough to adjust itself and continue exporting power at an even 9kW by simply exporting a little less power. But an inverter doesn't know if a momentary load is a surge load which will vanish in 5 seconds or a continuous load which will remain on or even escalate further. And while there are solutions to slow down certain loads, they are inefficient, like driving a car with the parking brake on. Pre-charge circuits that suppress loads are not something you do for loads that come on routinely. Well pumps and air conditioners do not lend themselves as good to surge loads as garage doors and elevator lifts.

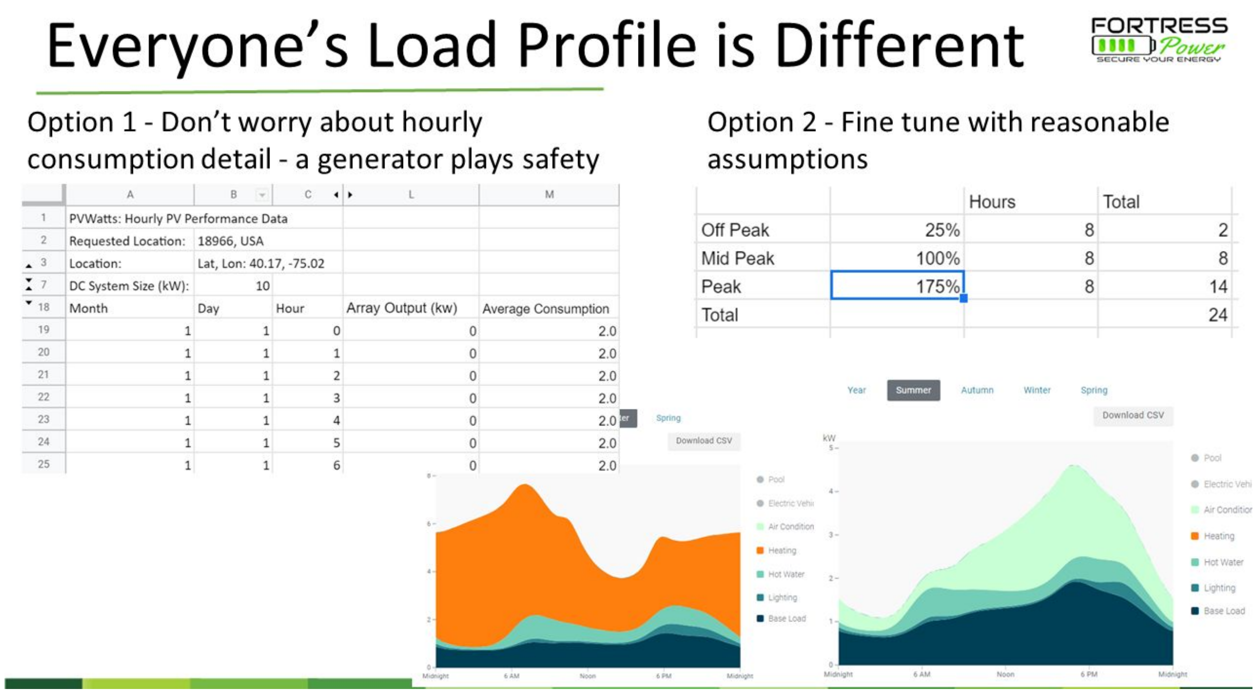
i'm not concerned about five or six second loads - while there are unusual cases of surge loads being 10 times greater than continuous loads, many inverters can surge for five or six seconds. But loads like hair dryers or electric water heaters or microwaves can surge for a few minutes, well beyond the timescale included in the surge capability of an inverter, but that 5 minute surge level may not show up on a 15 minute or hourly interval data.

So if you really want to nail your off-grid design, buy consumption meters - either as an add-on to the battery inverter monitoring system or as a 3rd party consumption meter such as Sense, and start taking a close look at the building electric load on a 5 second basis. Just looking at the load is one of the better things you can do for battery project planning. And remember that loads on 40 amp breakers which only reveal 10 amps of power likely have other internal components which are only used a few times a year, such as ice defrosting or comfort heating. So even 15-minute data can be somewhat misleading.

This model is really for battery capacity sizing where the biggest concern is not running out of energy - other models, such as consumption modeling or performing a load calculation by counting up all the appliances and estimating the real time maximum load are more concerned with instantaneous power. Power is instantaneous, and energy is power multiplied by time, and that's another topic for another day. For this class, we're looking at energy rather than power. We're not going to worry about how many loads we are running at once. Instead we are looking at how we don't run out of power after a string of cloudy days.

Well, there isn't much to do about cloudy weather and all but the most ardent environmentalists will see the value in having a generator backup system for five percent of the year. It's efficient to use some fossil fuel - it will dramatically reduce the required battery bank size for the application. To the point where even a biodiesel system could be considered over a larger battery bank! The goal of an off grid system for a building should be to substantially reduce reliance upon either the grid or a generator charge, but that may include tolerating small amounts of grid charge, and even optimizing the design for that value. The path to 100% renewables is not taking every building offgrid, but by reducing the reliance of the grid as much as practical.

Coming back down to earth, there are some things we can do to make our energy model better fit the varying load structures of the site. A building in Canada may not have air conditioning. A building in Mexico may not only use heat to defrost an air conditioner.



Aurora Solar, a solar design software, has a load profile modeler that is pretty fun to play with, and I've seen some similar tools on electric utility websites. The load profiles vary based on the season - for example winter will have electric heating with a higher load in the morning and evening, whereas summer would have escalating air conditioner loads during the hottest times of day before tapering off at night.

Even though these are site specific, they are still general trends that certain groups of customers follow. You can assume a gas heat home will not have the heavy winter loads of an electric heat home. A home with gas cooking will not have the electrical spikes of an induction burner. The model can be fine tuned for this.

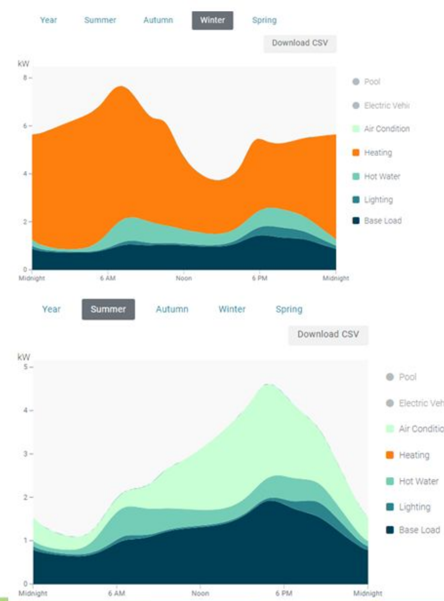
If we have an average load, we know there will be times of day when the building runs at below the average load, and then other times when the building is above the average load, and yes other times when the building load is just average.

So to make a more accurate model, we guess at the load profile. Aurora's tool will ask for a series of electrical devices and adjust the load profile accordingly. In our model, we will assume that spiky loads with a 75% premium will occur for eight hours a day, and below average loads with a 75% discount will occur for eight hours a day. Average loads will be assumed for eight hours a day. The end result is the same consumption as assuming the average load occurs for 24 hours a day, but it more accurately models what is actually occurring to the load during that 24 hour period, and more importantly, how that load relates to solar production.

In fact the assumptions in this model are perhaps too conservative. There are examples of peak loads being 5-6x that of baseloads. So this model will include a tuner adjustment which can increase or decrease the amplitude of the loads without more hard-coded forms for modification, using a baseline factor of 100%. A flat load profile would decrease this percentage whereas a spikier load profile would increase the percentage. If building your own data, remember that as long as the 24 hour average load equals the 24 hour combined total of peak and off peak loads, the numbers will balance out. There's always 24 hours in a day. So in the spreadsheet there is a little table to check to make sure that your assumptions are correct in case of custom modification. So for these eight off-peak hours,and these eight mid-peak hours, and these eight peak hours, at these percentage differences, it will sort itself out compared to the 24 hour average load.

Weather varies consumption

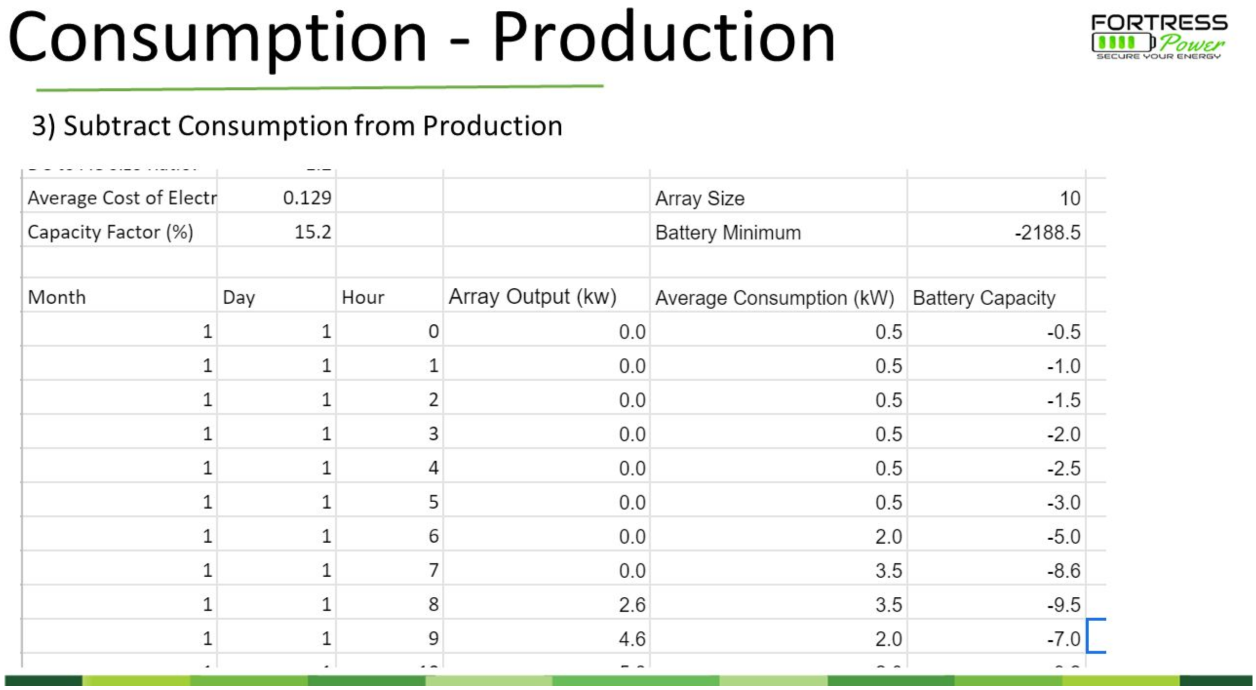
	Months	Weather Type	Consumption (kwh)
13	Months	Weather Type	Consumption (kwh)
14	January	Winter	1500
15	February	Winter	1000
16	March	Spring-Fall	800
17	April	Spring-Fall	800
18	May	Summer	800
19	June	Summer	1000
20	July	Summer	1500
21	August	Summer	2000
22	September	Summer	2000
23	October	Spring-Fall	1500
24	November	Spring-Fall	1000
25	December	Winter	1500
26	Total		15400
27			



The weather can also be adjusted. Mexico would be modeled as mostly summer months, triggering summer load profiles. Winter months would be more common to Canada. But these seasonal load profiles are impacted by gas vs. electric appliance selection, so in the spreadsheet there is a page that shows how the peak, mid peak, and off peak consumption hours are distributed based on the season of the end user - requiring manual adjustment. These seasonal load profiles are also linked to whether the load profile is based on a gas or electric load profiles. And so our load profile picture is assumed, customizable and adjustable from within the system input tab.

Remember how this model incorporates weather data from PVWatts? Well weather data is only accurate to about 10% and we’re already introducing error by modeling the system based on monthly electric bills. The load profile data similar impacts the model by a couple percentage points. We don't have to worry about 1% inaccuracies when the model is already 10% inaccurate. The model will still serve enough role to find the most cost-effective configuration of solar array size, battery size, and generator run time.

And because this model includes a generator, we are not creating energy emergencies for the customer, but rather providing them with a clean power resource which reduces or eliminates their grid reliance. The key point here is that an off grid system should not create an energy emergency for the customer. That might mean not getting rid of fossil fuels entirely, but allowing them to play a rare 2nd fiddle.



Consumption - Production

3) Subtract Consumption from Production

Average Cost of Electr	0.129			Array Size	10
Capacity Factor (%)	15.2			Battery Minimum	-2188.5
Month	Day	Hour	Array Output (kw)	Average Consumption (kW)	Battery Capacity
1	1	0	0.0	0.5	-0.5
1	1	1	0.0	0.5	-1.0
1	1	2	0.0	0.5	-1.5
1	1	3	0.0	0.5	-2.0
1	1	4	0.0	0.5	-2.5
1	1	5	0.0	0.5	-3.0
1	1	6	0.0	2.0	-5.0
1	1	7	0.0	3.5	-8.6
1	1	8	2.6	3.5	-9.5
1	1	9	4.6	2.0	-7.0

Back to earth - how do we take the PVwatts solar production model and add off-grid sizing capability to it? Now that the array output from PVWatts is determined and the 12-month electric bill is broken into hourly consumption increments, based on load profile assumptions, we can create a model of energy in vs. energy out and where that energy goes.

If the accounting is summed up correctly, there's no reason why we can't build our own off-grid model in a spreadsheet. There are limits. If building consumption is subtracted from solar production, the simple assumption is that the battery is infinitely large - an argument put forward by net-metering critics who argue the electric grid is being used as an infinitely large battery.

Well, our battery is not infinitely large, so we need to set a largest battery size, requiring a formula that says if the solar production minus building consumption is greater than the battery bank capacity, then the battery can only fill up to its maximum capacity, and the remaining energy is either lost because the battery is full, or sold back to the utility because the battery is full. That energy is modeled later.

Max Battery Capacity

4) Guess the battery size (and model the upper battery limit).

14	Invert Effici	96				
15	DC to AC Si:	1.2			Array Size	10
16	Average Co:	0.129			Battery Size	80
17	Capacity Fa	15.2			Battery Minimum	-2876.8
18						
19	Month	Day	Hour	Array Output (kw)	Average Consumption (kW)	Battery Capacity
20	1	1	0	0.0	0.5	79.5
21	1	1	1	0.0	0.5	=IF(N20+L21-M21>N16,N16, N20+L21-M21)
22	1	1	2	0.0	0.5	78.5
23	1	1	3	0.0	0.5	78.0
24	1	1	4	0.0	0.5	77.5
25	1	1	5	0.0	0.5	77.0
26	1	1	6	0.0	2.0	75.0
27	1	1	7	0.0	3.5	71.4

For now, start with a guess as to the battery size. The model will show a minimum battery size amount, and the guess can be adjusted to make sure the minimum battery size is not negative.

An hourly energy flow tab is created to visually inspect the model to ensure proper system functionality. I've always found it useful to be able to verbally describe what is happening to the system as reflected on a power flow model, and in this example it's midnight at 1am and the solar array isn't doing anything at all, but a small amount of off-peak electricity is being consumed. So that amount of consumption is subtracted from the battery starting capacity and eventually the sun also rises, and the solar array turns back on, and the battery fills back up to its maximum size, where it stops charging, and any extra energy is either sold back to the electric grid or lost as stranded electricity.

In an off-grid setting , it's very common to overproduce more electricity than what is being consumed, such as during the spring or fall or on sunny days. The goal is to keep the battery full, and that implies necessitates some wasted energy at the top.

Wise off gridders will load shift, doing laundry and even cooking during the day for example, and that is okay for some. To count this stranded electricity, which otherwise remains as increased voltage within the solar array itself, is that when the batteries are full, any excess is counted as either sold back to the grid or lost.

Add a generator

5a) Add a generator to reduce battery capacity.

	A	B	C	L	M	N	O	P
11	Array Tilt (d	20						
12	Array Azimu	180						
13	System Loss	14.08						
14	Invert Effici	96			Array Size (kW)	30		
15	DC to AC Si	1.2			Battery Size (kwh)	80		
16	Average Co	0.129			Generator Size (kW)	8		
17	Capacity Fa	15.2						
18					Battery Minimum	-37.6		
19	Month	Day	Hour	Array Output (kw)	Average Consumption (kW)	Battery Capacity	Generator On	
20	1	1	0	0.0	0.5	79.5	=IF(N20<N15*0.2, N16,0)	
21	1	1	1	0.0	0.5	79.0	0	

Similarly, an infinite battery doesn't exist and the sun isn't on all the time. The model can determine the largest battery size and solar array size to run fully autonomously, but it can also compare that against the use of a gas generator. In either event, recognize that as a model based on average consumption and average weather data, it is not a model robust enough for extreme conditions. This hindrance is offset by the assumption that the battery will not be cycled deeply and regularly by more than 80% of its total capacity. That extra 20% will be used during those extreme times - but at all other times the grid or generator charge will be turned on. When those charging resources do not work, that extra 20% will still be available. But the maintenance issues associated with draining a battery down to 0%, and then trying to discharge it even further without damage, while being more fun than an actually damaged battery, are less fun than keeping the battery within an operating range that will ensure a healthy and long life.

That was a long-winded way to say a column is added to the model to indicate that the generator will run whenever the battery hits a certain depth of discharge. The model will assign a default value of 20% to indicate that if the battery is at a 20% state of charge, the generator or grid charge will turn on.

Off Grid Modeling

5b) Count generator run time and date.

=COUNTUNIQUE(S2:S8761)

Month	Day	Hour	Array Output (kw)	Estimated Consumption (kW)	Battery Capacity	Generator Output	Generator Run Date
01	01	00	0.0	0.5	36.5	0	
01	01	01	0.0	0.5	36.0	0	
01	01	02	0.0	0.5	35.5	0	
01	01	03	0.0	0.5	35.0	0	
01	01	04	0.0	0.5	34.5	0	
12	31	21	0.0	2.0	14.5	0	
12	31	22	0.0	0.5	14.0	0	
12	31	23	0.0	0.5	13.5	0	
Totals			20914	15400		2280	142

Correspondingly, another column tracks the date that the generator runs and counts the total number of days the generator runs. Most off-gridders want to avoid a generator in order to obtain peace of mind. They understand the practicality of a generator on site, but don’t want to rely upon the generator running every single day to get by. Being able to quantify that value to the customer is valuable. A customer on the fence about buying one eVaults or two can be quantified into how many days per year a generator will need to be run. That helps guide the customer to deciding about adding the additional budget.

Generator run time has a cost - whether it is the cost of transporting the fuel to the property, or the cost of the gas itself. If the client is fine with the risk of running the generator for most days out of the year, the cost of fuel itself can be the reason to increase the battery capacity. To determine that number, the hours of generator run time are also counted, with the assumption that the generator is run at full capacity. A whole different discussion could be explored about the inefficiencies of running a generator at less than full capacity - the same is true of solar and battery electronics. For now let’s be satisfied with a spreadsheet that reveals how many hours total and unique days a generator or grid charge will need to be applied to the system to keep the electric load running 24/7.

The reality is that if the grid needs to be relied upon for an hour each day, there will be many days when the home runs completely off grid, and that during a real emergency, the energy consumption can be reduced by the end user such that the home functions fully off grid. But being 100% offgrid takes that reliability factor and kicks it up into a whole new ball game regarding battery sizing and budget. At any rate, a good model will guide the designer to make the best design for the application.

Off Grid Modeling

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6) Simulate various models to determine best size.
-> no generator = large batteries
-> small battery = less "100%" offgrid days

Inputs		Reports	With Battery	Without Battery
Array Size (kW)	15	% PV Generation Stranded or Grid Outflow	37.4%	66.7%
Battery Size (kwh)	37	% PV Instant Consumption	33.3%	33.3%
eVault	2	% PV Stored	27.5%	0%
eFlex	0	% PV Lost due to battery system inefficiency	1.8%	N/A
Generator Size (kW)	8	% Grid or Generator Consumption	15%	55%
Grid/Generator Start %	20%	Minimum Battery Capacity	2.8	N/A
Battery System Efficiency	94%	Grid/Generator Days	142	365
Load Profile	Electric	Generator Run Time (hours)	285	
Load Profile Range	Wide	PV generation (kwh)	20914	20914
Outflow adjustment factor <-- use wisely	0%	Annual Consumption	15400	15400

Remember the solar array size is initially selected to offset 100% of the client's winter or summer electric bill. The maximum battery bank size is guessed at, and the generator or grid charges the battery when the battery gets down to a 20 percent state of charge.

Every single hour of the day is counted, so we know how many hours the generator runs. And if the model were expanded, that generator run time could be ascribed a hard cost based on the cost of fuel and fuel transport. The number of days required for the generator to run will impact the client's peace of mind, and so to determine the best array size and battery size, it is simply a matter of running multiple configurations to determine how those factors are impacted.

An 8 kilowatt array with a large battery results in 34% of the site energy coming from the grid or generator, with the generator running for at least an hour per day for about 2/3rds of the year. The array size and battery bank size can be adjusted to determine which decreases grid reliance. Both are important, and by running multiple simulations, the optimal configuration is determined. Effectively, run a bunch of different system sizes through the model to determine which model reduces grid reliance the most within the project budget, and that is the configuration to use.

In this 8kW solar, 18.5 kwh battery example, next step forward would be examine double thing battery size to 37 kilowatt hours, reducing grid reliance from 34% to 14% while running the generator once out of every three days - perhaps for an hour or two as shown in the Hourly Energy Flow tab.

Off Grid Modeling

H	I	J	K	L	M	N	O	P	Q	R
Simulations	A	B	C	E	D	F	G	I	L	M
Array Size	8	16	16	24	16	16	24	24	32	40
Battery Size	56	19	37	37	56	74	56	74	148	130
Grid/Gen %	34%	30%	14%	9%	8%	6%	4%	2%	0%	0%
Grid/Gen Days	218	254	136	106	76	51	35	21	0	0
Grid/Gen Hours	651	5571	263	174	163	120	76	48	0	0

7) Simulate various models to determine best size.

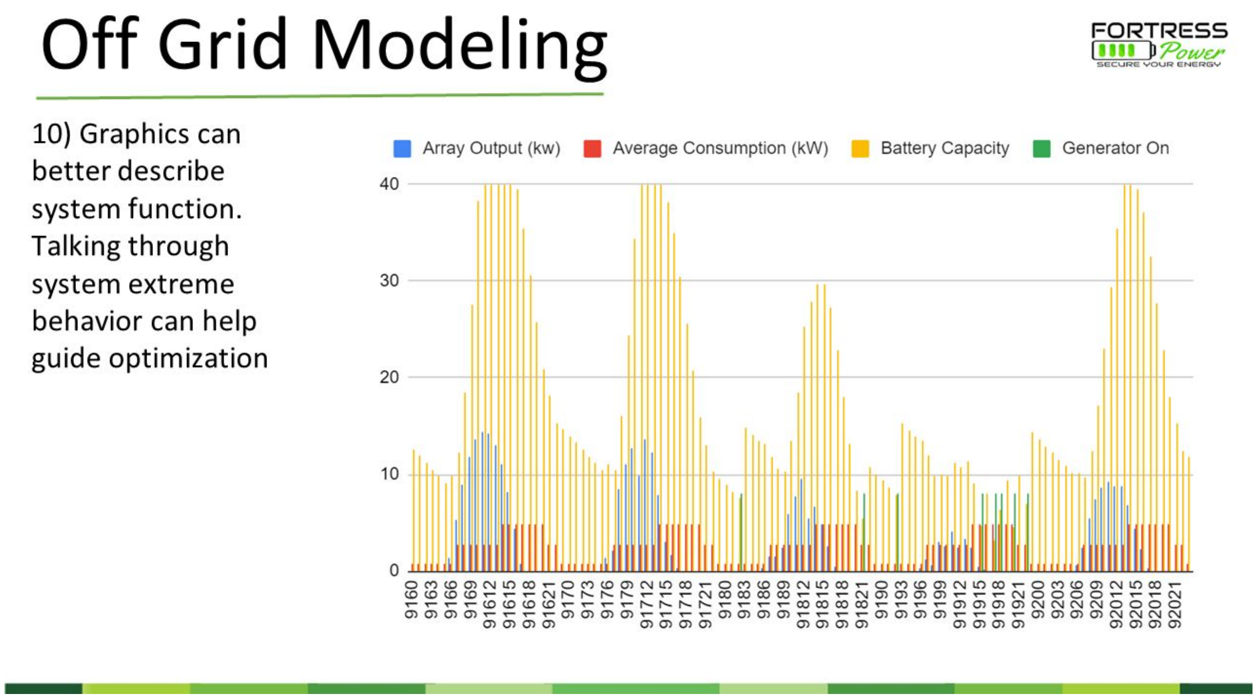
Perhaps it is better to increase the solar array size instead. Increasing the array size from 16 kW to 24kW reduces grid reliance by 9% which is still pretty good. Where a similar reduction in grid reliance can be achieved by increasing the battery size or solar array size, consider which increase will reduce the required number of days the generator will run. Running the generator

30 days out of a previous 136 by increasing the battery bank will bring the client more peace of mind than running the generator 50 out of the previous 136 days by increasing the size of the solar array, if it comes down to a splitting the decision.

The client may get down to a 5% grid reliance, but insist on eliminating generator charges entirely. That might be the right decision, but it is useful to put it in terms of buying two versus four 418.5 kilowatt hour batteries. The client, in the quest to reduce fossil fuels entirely from the project site, might be dismayed by diminishing economic returns. Or the application may be so important as to necessitate the increased budget for the larger battery. For most, there will be a point where some generator or grid reliance is worth the reduction in project budget. It's the opinion of the class author that a generator run time of around 5% is an acceptable target for most off-gridders, and off-gridders restricted by budget are smart to accept increased generator reliance in order to afford a top shelf battery.

A system configuration which does not require the generator for this example would be a 40 kilowatt array with 130 kilowatt hour battery bank, or something around that point. The system cost could be reduced by over 60% to have an application that relies on a grid or generator for 9% of the time, rather than 100% or 0% of the time. Grid management and energy efficiency, even if it means reconnecting with nature to determine that less energy should be used on an overcast day vs. a sunny day, can overcome the remaining deficit as required by the budget.

Within the hourly energy flow tab, the system information is available and can be depicted on a chart. Graphing out the simulation and associating a solid narrative to the graphic to describe system behavior is a great process to understand what is going on in the model, which can help the designer determine if more battery or solar capacity is needed.



Here in red is the system consumption. It is obvious the array output is not necessarily matched up with site consumption and that touches on economic issues associated with the time value of electricity. This extra solar power needs to be stored in the battery bank or sold back to the grid or lost. Many solar customers bemoan terrible utility buy back rates and it is economic to add a battery to reduce this amount, only to a point. Some utility buyback, even at a lousy rate, is acceptable. The starting point in that conversation is to estimate how much electricity is instantly consumed on site, versus what is needed to be stored in a battery or sold back to the utility. Generator usage is displayed as well. The generator is running when the battery bank is at a low state of charge - evidence that the model is working as it should.

Per the PVWatts data, solar product is a function of sunny days versus cloudy days. in this period of partly cloudy weather, the day starts with an already low battery bank capacity and the generator or grid charge is run more often. If you can describe how the model looks and why it should look that way, then you can be more confident in any adjustments you make to the model.

There's an invite to our chat community in the 0password-protected dealer resources section of the Fortress website. Copies of the model are available there, as well as live interactive chat with our technical support team. Fill out the dealer application on the Fortress website and then go to the dealer section or just send tech support an email at sales@fortresspower.com to get setup.

Residential Net-Metering

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- Respect minimum battery capacities
  - 1 eVault per battery inverter
  - 2-3 eFlex per battery inverter
- Backup (50A) vs. Whole House Backup (200A)

A	B	C	D	E	F
Inputs			Reports	With Battery	Without Battery
Array Size (kW)	8		% PV Generation Stranded or Grid Outflow	19.4%	46.5%
Battery Size (kwh)	18.5		% PV Instant Consumption	53.5%	53.5%

Now, most battery customers are not off grid customers, but instead are grid tied so how Does what we just learned apply to the grid market? We previously discussed net-metering, and the general rule to net-metering design is that solar outflow is valued at near retail pricing and so there's less economic incentive for batteries. Instead the desire for backup power drives the sale. Unless there is some peak rate optimization to take advantage of, the most economic solution to battery storage is to follow the minimum battery capacity guidelines of the inverter manufacturer. What that really means is in net-metered territories, bidding them the smallest battery configuration possible is acceptable, provided both you and your client understand what that means. The main thing to watch out for with net metered customers is to respect the minimum battery capacities of the inverter systems being installed to avoid an undersized battery.

For example, on an 8 kilowatt inverter, using the 2 hour rule of thumb means that the battery bank should be around 16 kilowatt hours. That’s about three e-flexes or one eVault. If selling two battery inverters of up to 9kW in size, regardless of brand, the battery bank capacities should be at that 2:1 ratio, discussed in the first battery class. Two 8kW battery inverters will need twice the eVauts as 1 battery inverter, resulting in two eVaults or six eflex. Not because they inverters won’t run on smaller batteries, but because that capacity is actually needed for the inverter to supply its full capacity, which the inverter will try to do whenever subject to surge loads, because surge loads are not governed by software settings but by physical limitations of how fast electricity wants to travel to ground. In other words, for those rejoining the conversation, electricity is less controllable than the shackles of mere software impositions.

Battery inverters themselves are capable of sending surge currents to undersized batteries that can in worst cases damage the batteries and in hopeful cases, trigger the battery BMS in a way that a 10-year warranty can continue to be honored! Don't try to build a hot rod with expensive batteries by running the batteries outside of specification. And also understand the larger the inverter, the more rapid the charge can be applied on the battery, and so the larger the battery required! Don’t rely on software settings to control an electrical system - that’s not how code works and it’s not how electrical design works. Most software does not govern 5s or less surge flow and the customer load only creeps upwards over time.

At any rate, with net metering, a large battery isn’t necessary. There is no penalty for grid outflow, and so selling the minimum battery capacity for the inverter is appropriate. A net-metered system with whole house backup would require a larger battery, not to reduce outflow onto the grid, but because whole house backup systems require more inverter capacity than simple net-metered systems. In other words, supplying whole house backup will increase the minimum capacity size in order to deliver it reliably. More on that later.

Zero-Outflow Modeling

7) Count instant consumption, outflow, and “stranded” energy for further analysis

A	B	C	E	L	M	N	O	P	Q	R	S
Month	Day	Hour	Array Output (kw)	Estimated Consumption (kW)	Instant Consumption	Solar Outflow	Amount Stored	Grid Outflow / "Stranded Energy"	Battery Capacity	Generator Output	Generator Run Date
01	01	00	0.0	0.5	0.0	0	0	0.0	129.0	0	
01	01	01	0.0	0.5	0.0	0	0	0.0	128.5	0	
01	01	02	0.0	0.5	0.0	0	0	0.0	128.0	0	
01	01	03	0.0	0.5	0.0	0	0	0.0	127.5	0	
01	01	04	0.0	0.5	0.0	0	0	0.0	127.0	0	
12	31	21	0.0	2.0	0.0	0	0	0.0	110.3	0	
12	31	22	0.0	0.5	0.0	0	0	0.0	109.8	0	
12	31	23	0.0	0.5	0.0	0	0	0.0	109.3	0	
Totals			44616	15400	7783	36833	7573	29260		24	2

Getting back to the model, it's a good idea to confirm how the system is behaving. It is fairly easy to add a new column to the model to track system outflow - which is how much of the solar energy is not stored in the battery or instantly consumed by the load. The spreadsheet already has columns for how much the array is producing and what the estimated instant consumption is. The difference will be how much solar is outflowing from the array, either to the grid or the battery. So if we assume all the surplus energy is charging the battery to 100% first, before selling back to the grid, the result of subtracting how much the battery was charged from the solar outflow is how much energy will either be sold back to the grid or left stranded, unused.

Examining the formula, take the solar array output, subtract the consumption, and if it is a non-negative number, then add it into the battery bank. A limit is placed to not charge the battery more than its maximum size, and if the battery is charged full, the remainder is stranded electricity.

Residential Zero Outflow

1) Determine how much solar is not being consumed by load
   a) this needs to go into the grid or the battery
   b) off-grid = “stranded electricity”

p	Array Output (kw)	Average Consumption (kW)	Solar Outflow	Grid Outflow / "Stranded Energy"
	0.0	0.5	=IF(M20-N20>0,M20-N20,0)	0
	0.0	0.5	0	0
	0.0	0.5	0	0

Dividing the total stranded electricity by the total produced electricity will give a benchmark of system efficiency, useful in right sizing off grid batteries or determining system value when grid buy back rates are less than what the utility charges the customer for grid inflow.

It's useful to point out that without a battery, a small solar array will still outflow almost half of its power onto the grid, and a large solar array designed to offset 100% of the site consumption can outflow about 75% of its total system production onto the grid. The utility has a valid point that a 100% solar powered grid driven by net-metering results in infrastructure that can’t handle all the solar outflow. And while we aren’t close to a 100% solar grid, if every single house on a particular street had solar, it could easily overload that local distribution circuit. Long story short, utilities don't have an interest in supporting net-metering policies and a counter reaction is to implement very discounted utility buy back rates or zero outflow mandates.

Residential Zero Outflow

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2) Determine how much can be stored in battery
   a) when battery is full, remainder is sold back to grid or lost as “stranded electricity” ie. offgrid

	D	M	N	O	P	Q	R	
10								
11						Array Size (kW)	20	
12						Battery Size (kwh)	40	
13						Generator Size (kW)	8	
14						Generator Run Time (hours)	158	
15						Battery Minimum	3.2	
16						Grid Outflow / Stranded Energy	12	
17						Offsite Utilization	46.61%	
18								
19	Timestamp	Array Output (kw)	Average Consumption (kW)	Solar Outflow	Grid Outflow / "Stranded Energy"	Battery Capacity	Generator On	4 H
20		0.0	0.5	0	0	39.5	0	
21		0.0	0.5	0	=IF(O21-(R12-Q20)>0,O21-(R12-Q20),0)		0	
22		0.0	0.5	0	0	38.5	0	

Zero outflow mandates state that if connected to the electric grid, you're only allowed to charge from the grid and not to outflow onto the grid. So in a zero outflow model, the amount of stranded electricity modeled is wasted, with a value of zero, rather than being sold back to the grid. Retail pricing savings only applies to the instant consumption of the array, and avoided cost buyback rates actually look like a good deal in comparison to getting nothing at all for any grid sell back. Battery economics tremendously improve in these design circumstances, because the cycle cost of using the battery to store surplus electricity is less than the difference between retail priced electricity and zero.

Residential Zero Outflow

3) Increase battery size or reduce array size until onsite utilization is 100% or stranded electricity percentage is acceptable.

	A	B	C	D	E	F
1	Inputs			Reports	With Battery	Without Battery
2	Array Size (kW)	8		% PV Generation Stranded or Grid Outflow	9.4%	46.5%
3	Battery Size (kwh)	55.5		% PV Instant Consumption	53.5%	53.5%
4	eVault	3		% PV Stored	35.0%	0%

Now that the model is complete, run simulations to determine how much electricity is stranded or sold back to the grid, to determine the optimal solar array and battery size. If one configuration shows that 46% of the system electricity is either stranded or solid, then increasing the battery size or decreasing the solar array size will move that percentage closer to zero. Keep adjusting the model until it is within an acceptable range.

After running multiple simulations, a 4kW with a 18 kilowatt hour battery bank results in only 1% of the system energy being stranded. An 8kW array with the same battery would result in 20% of the electricity sold back to the grid or stranded. Without a battery, that number would be 45-50%.

Residential Zero Outflow

3) Increase battery size or reduce array size until onsite utilization is 100% or stranded electricity percentage is acceptable.

Array Size (kW)	20
Battery Size (kwh)	40
Generator Size (kW)	8
Generator Run Time (hours)	158
Battery Minimum	3.2
Grid Outflow / Stranded Energy	12
Offsite Utilization	46.61%

Timestamp	Array Output (kw)	Average Consumption (kW)	Solar Outflow	Grid Outflow / "Stranded Energy"	Battery Capacity	Generator On
	0.0	0.5	0	0	39.5	0
	0.0	0.5	0	=IF(O21-(R12-Q20)>0,O21-(R12-Q20),0)		0
	0.0	0.5	0	0	38.5	0

Ultimately, zero outflow situations reward smaller solar arrays and larger batteries. Economic analysis can be applied to these numbers if it can be determined what the effective rate is for grid outflow versus retail price for on-site consumption. Multiply the percentage outflow by the buyback rate (which may be zero) and then the instant consumption plus stored battery energy multiplied by the retail energy price to get the total value of the system.

Residential Zero Outflow

Most solar without batteries is outflow!

15 minute data ***can be much*** less accurate than 5 minute data…

Consider load shifting / contactor relays

Sell value and avoiding a bad deal from the utility rather than simple payback

A	B	C	D	E	F
Inputs			Reports	With Battery	Without Battery
Array Size (kW)	4		% PV Generation Stranded or Grid Outflow	0.8%	22.1%
Battery Size (kwh)	18.5		% PV Instant Consumption	77.9%	77.9%
eVault	1		% PV Stored	20.0%	0%

A	B	C	D	E	F
Inputs			Reports	With Battery	Without Battery
Array Size (kW)	8		% PV Generation Stranded or Grid Outflow	19.4%	46.5%
Battery Size (kwh)	18.5		% PV Instant Consumption	53.5%	53.5%

A	B	C	D	E	F
Inputs			Reports	With Battery	Without Battery
Array Size (kW)	8		% PV Generation Stranded or Grid Outflow	10.4%	46.5%
Battery Size (kwh)	37		% PV Instant Consumption	53.5%	53.5%
eVault	2		% PV Stored	33.9%	0%

The solar battery market is fascinating because there are many regions within the United States which do not have net metering, but instead have utility buy back rates at something closer to 20% of retail energy price. The retail price of energy in Michigan may be 15 cents but after announcing the end to net-metering, the instant outflow buyback rate could be 3 cents. It only requires a small bit of value modeled for grid outage avoidance to have the economic payback of the batteryless and battery system be the same.

Anyone who has been through a long duration grid outage will recognize it had a monetary loss associated, through the inability to work at home or the food in the freezer. Rural grids can lose power frequently, if only for short durations. The loss of power can be more economically damaging for a commercial business, especially one with large refrigerators.

Effective Generation Rate

Economic Analysis

$$\frac{\text{Onsite Utilization} \times \text{Retail Energy Rate} + \text{Offsite Utilization} \times \text{Buyback Rate}}{\text{Total System Production}} = \text{Effective Generation Rate}$$

The point is a higher priced battery project can also have a higher effective generation rate because it better matches up with utility policy.

In a net-metered market, the battery may not be particularly economic, and so the minimum battery configurations acceptable. But in a zero outflow or avoided cost buyback market, it may be more cost effective to have a small solar array and a rather large battery, compared to a large solar array. This is actually encouraging, because many homes can fit a small solar array on the roof, but the total project size is too small for installer interest. The “small solar array, large battery” configuration opens up more job sites in a community.

Avoided Cost Buyback Economics

	A	B	C	D	E	F
1	Inputs			Reports	With Battery	Without Battery
2	Array Size (kW)	8		% Stranded / Grid Outflow	14.9%	46.5%
3	Battery Size (kwh)	18.5		% Instant Consumption	53.5%	53.5%
4	Generator Size (kW)	8		% Stored	29.7%	0%
5	Grid/Generator Start %	0%		% Lost due to storage inefficiency	1.9%	0%
6	Total Storage Inefficiency	94%		% Grid or Generator Consumption	38%	61%
7	Load Profile	Electric		Effective Generation Rate	$0.13	$0.09
8	Load Profile Range	Wide		PV generation (kwh)	11154	11154
9	Solar Budget (Total) / $/W)	$20,000				
10	Solar Budget $/W	2.5		Project Budget	$34,800	$20,000
11	Battery Budget (Total)	$14,800		Adjusted Budget (Tax Credit / Grid Outages)	$20,752	$14,800
12	Battery Budget ($/kwh)	$800		Annual Cost Savings	$1,433.59	$1,024.11
13	Tax Credit	26%		***Simple Payback Year***	***14.8***	***14.5***
14	Total Cost Savings due to grid outages / avoided interconnection cost	$5,000				
15						
16	Peak Rate ($/kwh)	$0.15				
17	Peak Consumption %	100%				
22	**Effective Utility Buyback Rate ($/kw**	**$0.03**				

Battery economics are further improved by time of use rates or other variable rate structures. This is not yet modeled into the sizing tool, and gets into the realm of commercial design software like EnergyToolbase. It requires additional hard coding, intimate knowledge of the site electric rate structure, and someone who can competently read an electric bill. Interval data is all the more valuable for a proper time-of-use analysis.

At the same time, can the model perform some basic time of use analysis as is? It already shows how reliant the customer is on the grid, with the remainder coming from the solar array and battery storage. So if the client peak rate consumption is less than what is being stored in the battery, then the battery is well sized to take advantage of time-of-use rate structures for even better economics.

In other words, if the battery stores 30% of the site energy, and the peak rate time frame applies to 30% of the site consumption, then the vast majority of the peak rate time can be avoided by use of the battery. In this circumstance, a small solar array may be more cost-effective than a large one!

TOU Rates

$120 electric bill at $0.12/kwh x 1000 kwh/month
- $60/month -> assume solar-battery generates 500 kwh/month @ $0.12/kwh
- $30/month -> assume remaining consumption is offpeak @ $0.06/kwh

$30 Electric Bill

Total Savings: $90

Solar/Battery generates at $0.18/kwh effective

$120 electric bill at $0.12/kwh x 1000 kwh/month
- $40/month -> assume solar effective rate is $0.08/kwh due to bad buyback
- $0/month -> assume no savings due to TOU rate

$80 Electric Bill

Solar Effective Rate is $0.08/kwh

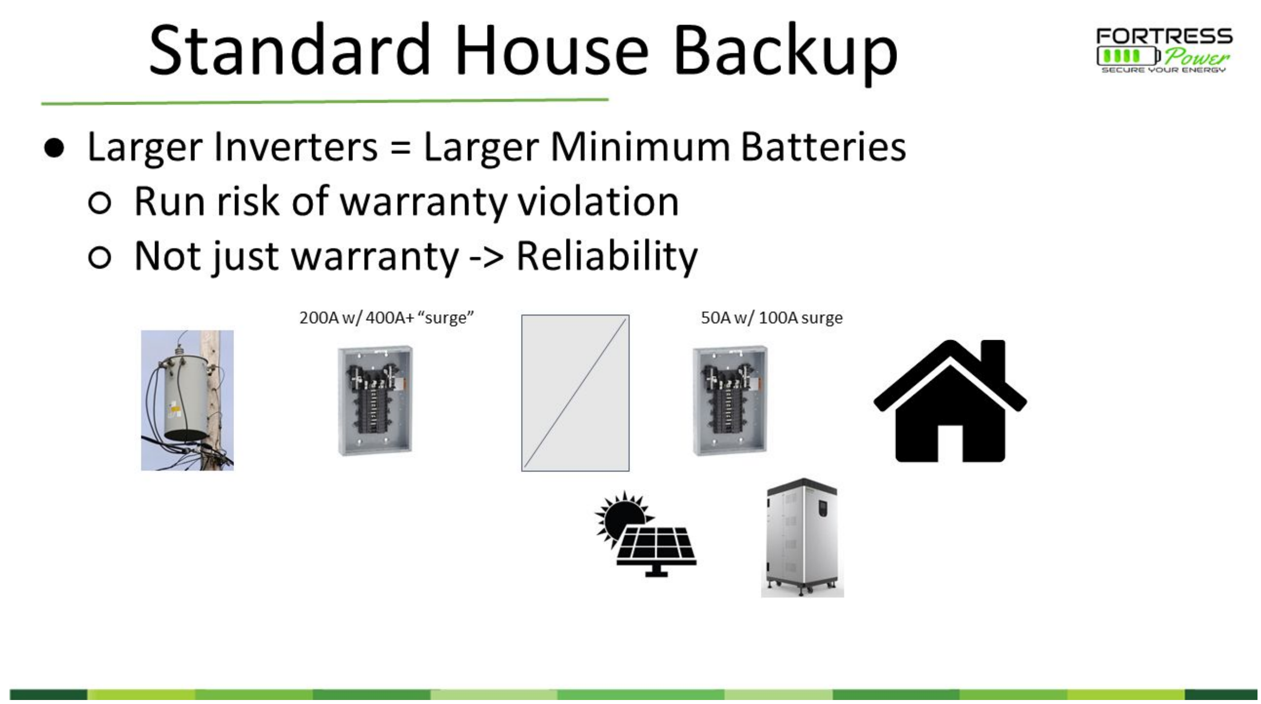
Say for example the electric bill is $120, billed at 12 cents per kilowatt hour for a thousand kilowatt hours a month. Let's look at how a 4 kW array kilowatt array, only powering 50% this home, will lower the bill by 75%, all without reliance upon a net-metering policy.

The sizing tool tells us there is no outflow in the system, so the battery has eliminated any outflow onto the grid. This model works without a good utility solar buyback rate. Let’s also assume the peak rate option is for 50% of the day, the amount offset by the solar battery. Usually peak rates are for much less than this amount, so this is a conservative example.
The building still has 50% of its power come from the grid, but that electricity comes from the off-peak rate. Because the customer can economically avoid the peak rate, they gain access to this discount off peak electricity. So the solar battery doesn't just save the customer for the energy that's coming out of it, but the system also lowers the customer’s electric rate from the grid itself.

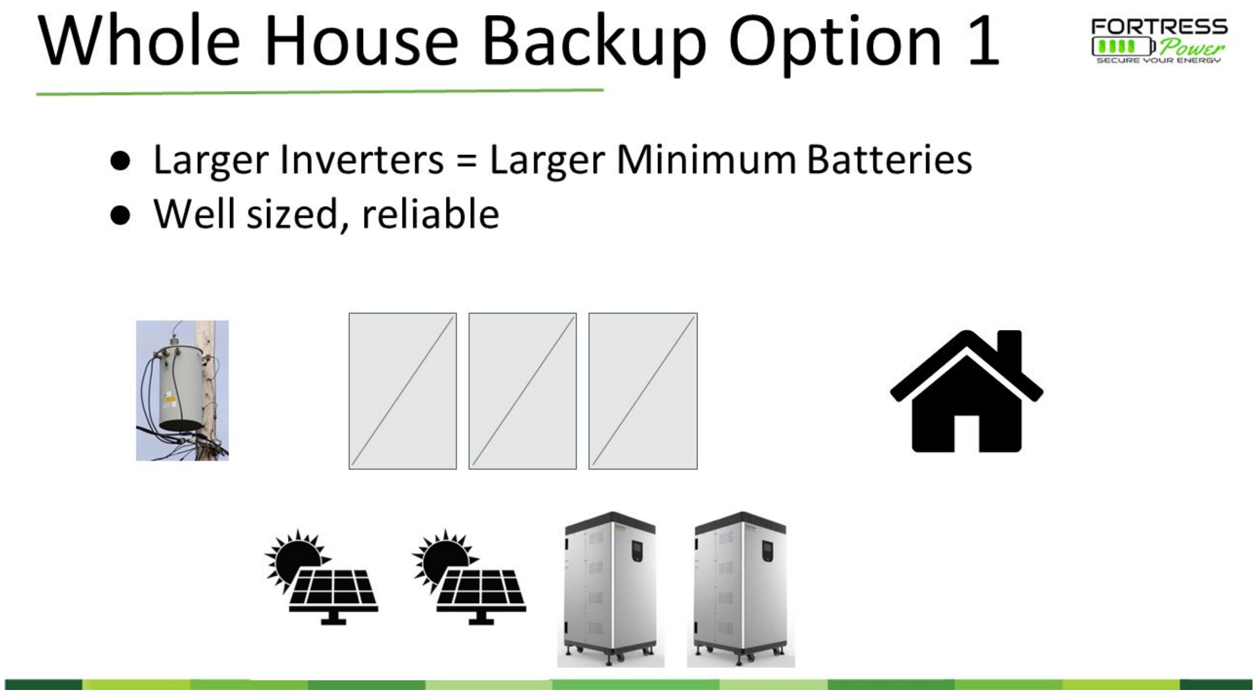
Residential Variable Rates

- Like net-metering in rewarding smaller systems
- Smaller than “zero outflow”
- Battery Size = Peak Consumption

Because the battery is saving the customer money not only for the energy it produces, but also for the portion of energy that comes from the grid itself, it achieves an above retail price effective generation rate, which is higher than what a net-metered array can produce. And that means there are electric rate structures out there, independent of net-metering policy, where a more expensive system with a battery can have a better customer payback than a less expensive system without a battery. The takeaway here is go to the utility website and see if they have extreme time of rate structures available, because if it does, then you can sell many solar batteries, including systems with small solar arrays and large batteries. And lastly, if you're in an area where there is no net metering at all, the only way to put together any sort of economic project is to include a battery.



Whole house transfer capabilities warranty more detailed discussion than what time allows. The key note is that most battery inverters are only 8kW. A volt time and amp is a watt, and a residential home is at 240V, so that 8kW inverter has a 33 amp capability. Whereas a whole house has a 200 amp service panel. It would need six 8kW battery inverters to have an equivalent service! Due to minimum battery sizes, that would require about 111 kwh of battery storage capacity. Many backup generators are 20kW or about 80A, and 80A lithium iron phosphate solar battery requires about 37 kwh of But even a smart home with 150A electric service (plus additional amps during the day from AC-coupled solar) is less than what some all electric homes need.



Customers who desire whole house backup but have limited budgets are put in a difficult position. Is it better to back up the whole house with not enough power and try to manually adjust electricity use during a disaster? Or is it better to design a reliable system that works when the power goes out, even if it means only powering a portion of the home?

Whole House Backup Option

One approach installers are experimenting with are supply-side taps, which transfer the home from a 200A main service to backup service fed by the critical load side of the battery inverter. This costs about the same as retrofitting a critical load panel - is it as good a solution?

NEC loosely implies the smallest residential electric service should be 100A, based on a 100 A minimum service disconnect. It is possible to show load calculations for less than 100A load, as well as interval data, but expect jurisdictional pushback if arguing that a 30A inverter can power a 200A electric service as a code compliant generator. NEC 702 governs optional standby generators, and it clearly indicates that automatic transfer equipment must be able to supply the full load. While there are devices to automatically restrict the individual breakers on the service panel on site, installing such a system costs as much, if not more than wiring a critical load panel.

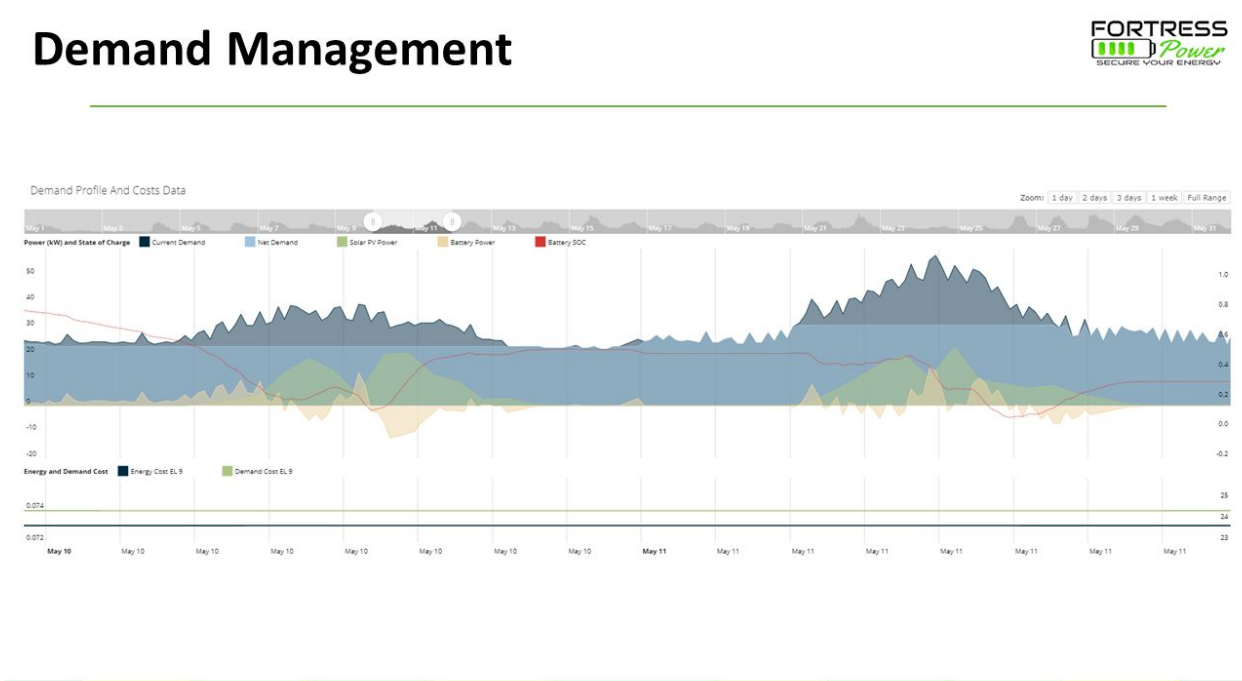
Residential Variable Rates

- Like net-metering in rewarding smaller systems
- Smaller than “zero outflow”
- Battery Size = Peak Consumption

A solar installer may feel comfortable flipping breakers and rebooting inverters and batteries during blackouts, in the pursuit of whole house backup power on a budget. Some of our competition pursues this idea as well, because it is what the customer wants. But based on field experience, customers do not like learning how to restart their system during an emergency conditions that might cause a grid failure, and technical support infrastructure in those circumstances is not so readily available. Unless the customer is extremely comfortable with servicing their system, with an aim towards battery or inverter expansion within the first year of operation, my recommendation is to stick with the critical load mentality when installing one or two battery inverters especially with minimum battery capacity sizes.

Undersizing a solar backup system is a risk that is costly to fix, but it is possible to plan the site so that some inverters and batteries can be installed initially, and others can be added within the first year of system operation if needed. It is a simple matter of planning enough space for the entire project (including the parts not installed), and selecting a battery combining balance of system material that allows for easy additions. And there is a little more design flexibility regarding undersizing as the system grows. Multiple inverters and multiple eVaults for example, do not necessarily have to follow a 1-to-1 ratio on larger systems, such as 4 SolArk on 3 eVaults.

But to avoid problems, putting the master bedroom outlets, kitchen wall outlets and refrigerator, some interior and exterior LED lighting, the internet and security system, a 4kW hot water heater, and the garage door on a critical load panel fed by a single 8kW battery inverter is a great entry point for a grid-tied residential battery system. All but the smallest air conditioning mini split systems will require a larger battery and at least two battery inverters. Remember the goal of the system is to deliver reliable electricity to a customer who is inexperienced with power outages or energy management. Using a transfer switch to power an entire house with a single battery inverter is not going to be as reliable as a proper critical load panel.



The last topic in this presentation is commercial demand management, which warrants a followup class. It is possible to modify this model for demand management but when I actually do professional demand management models, I use EnergyToolbase because it is professional software. They make cash flow models that will make a CFO smile, and it takes a lot of computing power to crunch the numbers. This example load is very flat - the best commercial demand customers have very spiky load profiles where a project may just cut off the very tip of the demand load profile. Like solar with time of use, targeting a smaller portion of the commercial electric bill can be much more cost-effective than offsetting the entire bill. The great news is that every commercial customer with a high demand charge can benefit from a battery, even if it’s a residential sized battery. Demand management can have the best payback in the industry, so if you're already installing residential battery banks, consider getting into the small commercial market as well in markets where demand charges are high.