# Demand Savings Analysis Solar + Battery Projects

**what we have learned from our operating portfolio**
**and**
**how to stress test financial models using performance data**

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there is a lot of excitement in the battery storage market!

behind the meter battery installations are expected to provide electricity bills savings by reducing electricity demand charges additionally, solar **plus** battery storage installations are expected to provide more savings by reducing both usage and demand charges as battery storage is a new market, there are varying methods in projecting combined solar plus battery storage installations this presentation is designed to describe how TerraVerde projects demand savings from battery installations when paired with a solar installation by relying on performance data from our operating portfolio we will first start with background information and work our way through a case study to assess the savings projection, we first need to understand how an electricity bill is calculated electricity costs are calculated based on the **rate schedule** applied to each utility electricity meter the rate schedule is primarily determined by the **usage profile** measured by the meter

rate schedule = func(**usage profile,**
**customer type,**
**$\textbf{voltage}_{\textbf{interconn}}$,**
**etc.**)

the usage profile is the measure of how fast, how much, and time of use of electricity to better understand all the details involved in a rate schedule you will need to thoroughly read the documentation provided by the electric utility the next slide shows the Southern California Edison TOU-GS3 rate schedule and all the components that need to be factored into calculating the electricity bill

## Schedule TOU-GS-3
## TIME-OF-USE - GENERAL SERVICE - DEMAND METERED

Sheet 3

(Continued)

### RATES

The rates below will apply to all customers receiving service under this Schedule. In addition, the customer will be charged the applicable rates under CPP, Option A, Option B or Option R, as listed below. Except for the customer's firm load that is designated as the Capacity Reservation Level (CRL), CPP Event Charges will apply to all remaining load during CPP Events and CPP Non-Event Credits will apply to all remaining load during CPP Non-Events, as described in Special Conditions 1 and 3, below.

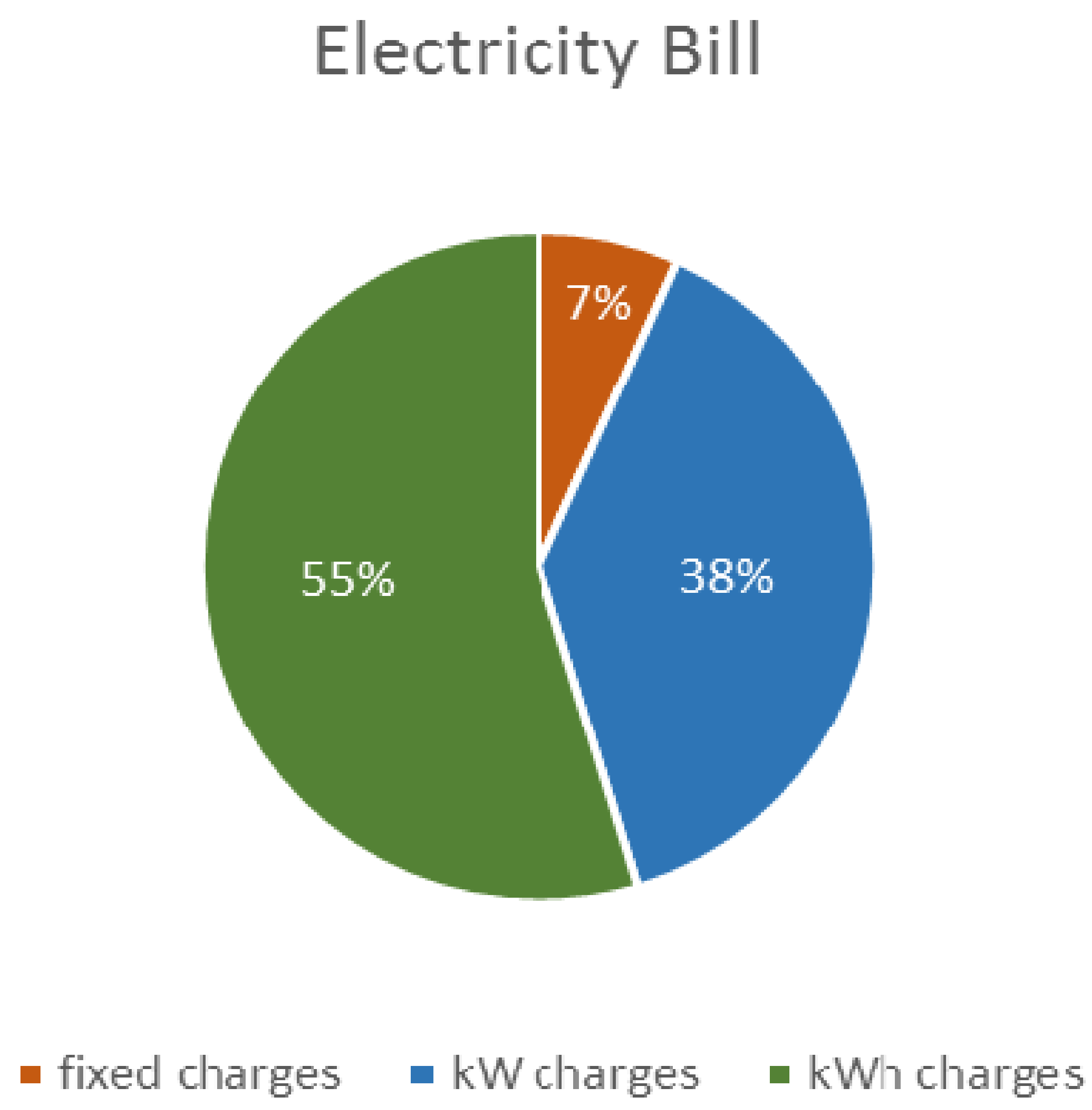
| | Delivery Service | | | | | | | | Generation[9] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Trans[1] | Distrbtn[2] | NSGC[3] | NDC[4] | PPPC[5] | DWRBC[6] | PUCRF[7] | Total[8] | UG** | DWREC[10] |
| **Option CPP** | | | | | | | | | | |
| Energy Charge - $/kWh/Meter/Month | | | | | | | | | | |
| Summer Season On-Peak | 0.00018 | 0.00302 | 0.00835 | 0.00028 | 0.00995 (R) | 0.00526 | 0.00024 | 0.02728 (R) | 0.10804 (R) | (0.00172) |
| Mid-Peak | 0.00018 | 0.00302 | 0.00835 | 0.00028 | 0.00995 (R) | 0.00526 | 0.00024 | 0.02728 (R) | 0.05913 (R) | (0.00172) |
| Off-Peak | 0.00018 | 0.00302 | 0.00835 | 0.00028 | 0.00995 (R) | 0.00526 | 0.00024 | 0.02728 (R) | 0.03584 (R) | (0.00172) |
| Winter Season On-Peak | | | | | | | | | | |
| Mid-Peak | 0.00018 | 0.00302 | 0.00835 | 0.00028 | 0.00995 (R) | 0.00526 | 0.00024 | 0.02728 (R) | 0.06073 (R) | (0.00172) |
| Off-Peak | 0.00018 | 0.00302 | 0.00835 | 0.00028 | 0.00995 (R) | 0.00526 | 0.00024 | 0.02728 (R) | 0.04064 (R) | (0.00172) |
| Customer Charge - $/Meter/Month | | 441.93 | | | | | | 441.93 | | |
| Demand Charge - $/kW of Billing Demand/Meter/Month | | | | | | | | | | |
| Facilities Related | 3.66 | 12.71 | | | | | | 16.37 | | |
| Time Related | | | | | | | | | | |
| Summer Season - On-Peak | | 0.00 | | | | | | 0.00 | 18.10 (R) | |
| Mid-Peak | | 0.00 | | | | | | 0.00 | 5.31 (R) | |
| Winter Season - On-Peak | | 0.00 | | | | | | 0.00 | 0.00 | |
| Mid-Peak | | 0.00 | | | | | | 0.00 | 0.00 | |
| Voltage Discount, Demand - $/kW | | | | | | | | | | |
| Facilities Related | | | | | | | | | | |
| From 2 kV to 50 kV | 0.00 | (0.20) | | | | | | (0.20) | | |
| Above 50 kV but below 220 kV | 0.00 | (6.71) | | | | | | (6.71) | | |
| At 220 kV | 0.00 | (12.71) | | | | | | (12.71) | | |
| Time Related | | | | | | | | | | |
| From 2 kV to 50 kV | 0.00 | 0.00 | | | | | | 0.00 | (0.32) (I) | |
| Above 50 kV but below 220 kV | 0.00 | 0.00 | | | | | | 0.00 | (0.91) (I) | |
| At 220 kV | 0.00 | 0.00 | | | | | | 0.00 | (0.92) (I) | |
| Voltage Discount, Energy - $/kWh | | | | | | | | | | |
| From 2 kV to 50 kV | 0.00000 | 0.00000 | | | | | | 0.00000 | (0.00104) (I) | |
| Above 50 kV but below 220 kV | 0.00000 | 0.00000 | | | | | | 0.00000 | (0.00232) (I) | |
| At 220 kV | 0.00000 | 0.00000 | | | | | | 0.00000 | (0.00234) (I) | |
| Power Factor Adjustment - $/kVAR | | | | | | | | | | |
| Greater than 50 kV | | 0.34 | | | | | | 0.34 | | |
| 50 kV or less | | 0.51 | | | | | | 0.51 | | |
| California Alternate Rates for Energy Discount - % | | 100.00* | | | | | | 100.00* | | |
| CPP Event Energy Charge - $/kWh | | | | | | | | | 1.37453 | |
| Summer CPP Non-Event Credit | | | | | | | | | | |
| On-Peak Demand Credit - $/kW | | | | | | | | | (11.44) | |
| Maximum Available Credit - $/kW** | | | | | | | | | | |
| On-Peak | | | | | | | | | (21.57) (I) | |
| Mid-Peak | | | | | | | | | (6.32) (I) | |

(Continued)

# the rate schedule components can be summarized into three categories:

- Usage or kWh charges
- Demand or kW charges
- Fixed charges

the ratio of three categories for the building in our case study are shown in the following pie chart


Electricity Bill
7%
38%
55%
fixed charges
kW charges
kWh charges

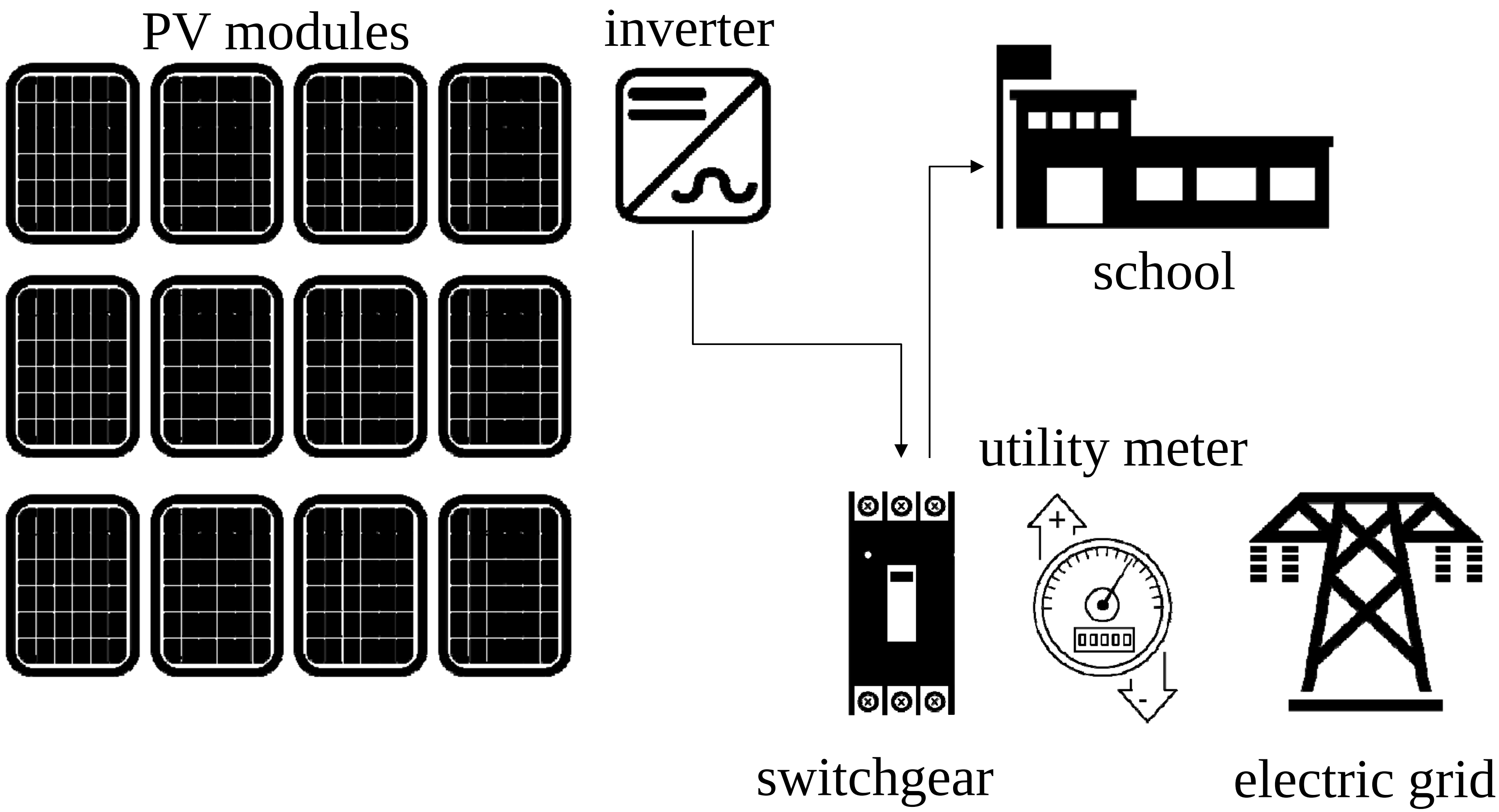
**usage charges** are the sum of total electricity drawn from the grid and measured in kWh

**demand charges** are calculated based on the maximum demand for each month measured in kW during any 15-minute interval

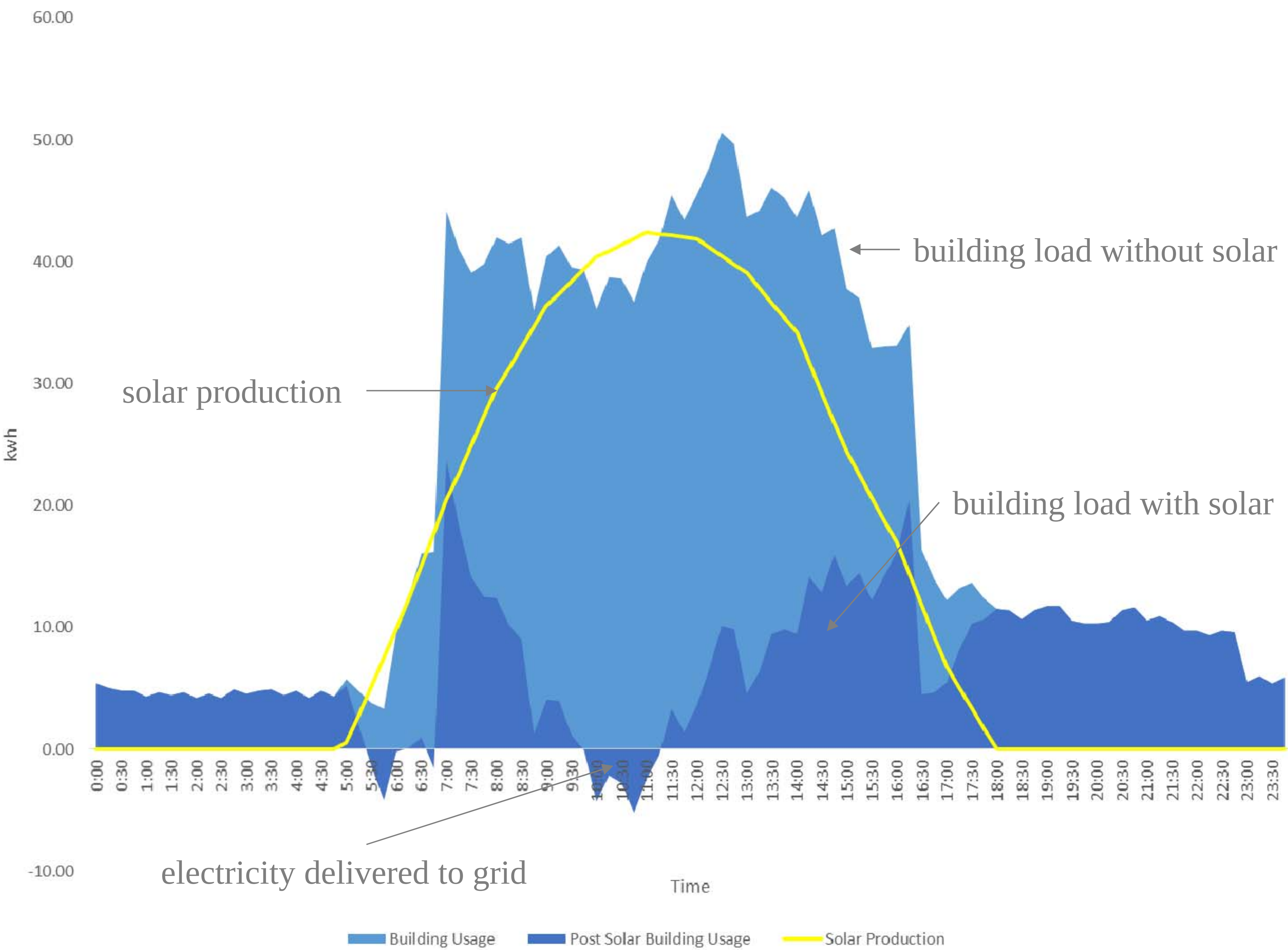
**fixed charges** are the sum of non variable costs including meter costs now that the basics of an electricity bill are covered, let’s jump into the analysis this presentation will walk through the following three savings analysis for:

- solar only savings
- battery only savings
- solar + battery savings

let’s start by showing a block diagram of typical behind-the-meter solar installation


PV modules
inverter
school
utility meter
+
-
switchgear
electric grid

the graph on the next slide shows the solar production and building load profiles for a typical school day



60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
kwh
building load without solar
solar production
building load with solar
electricity delivered to grid
0:00
0:30
1:00
1:30
2:00
2:30
3:00
3:30
4:00
4:30
5:00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
9:00
9:30
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11:00
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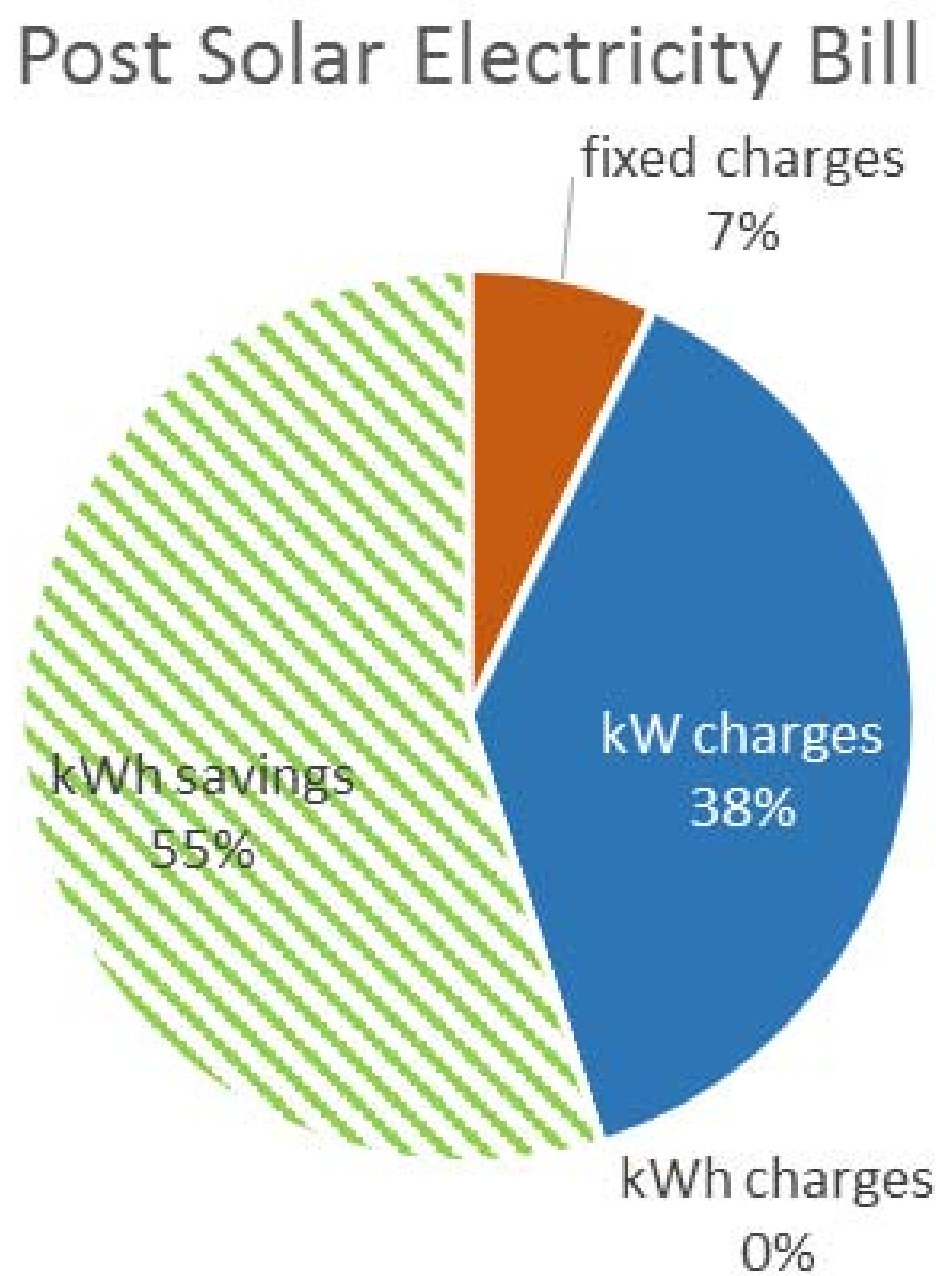
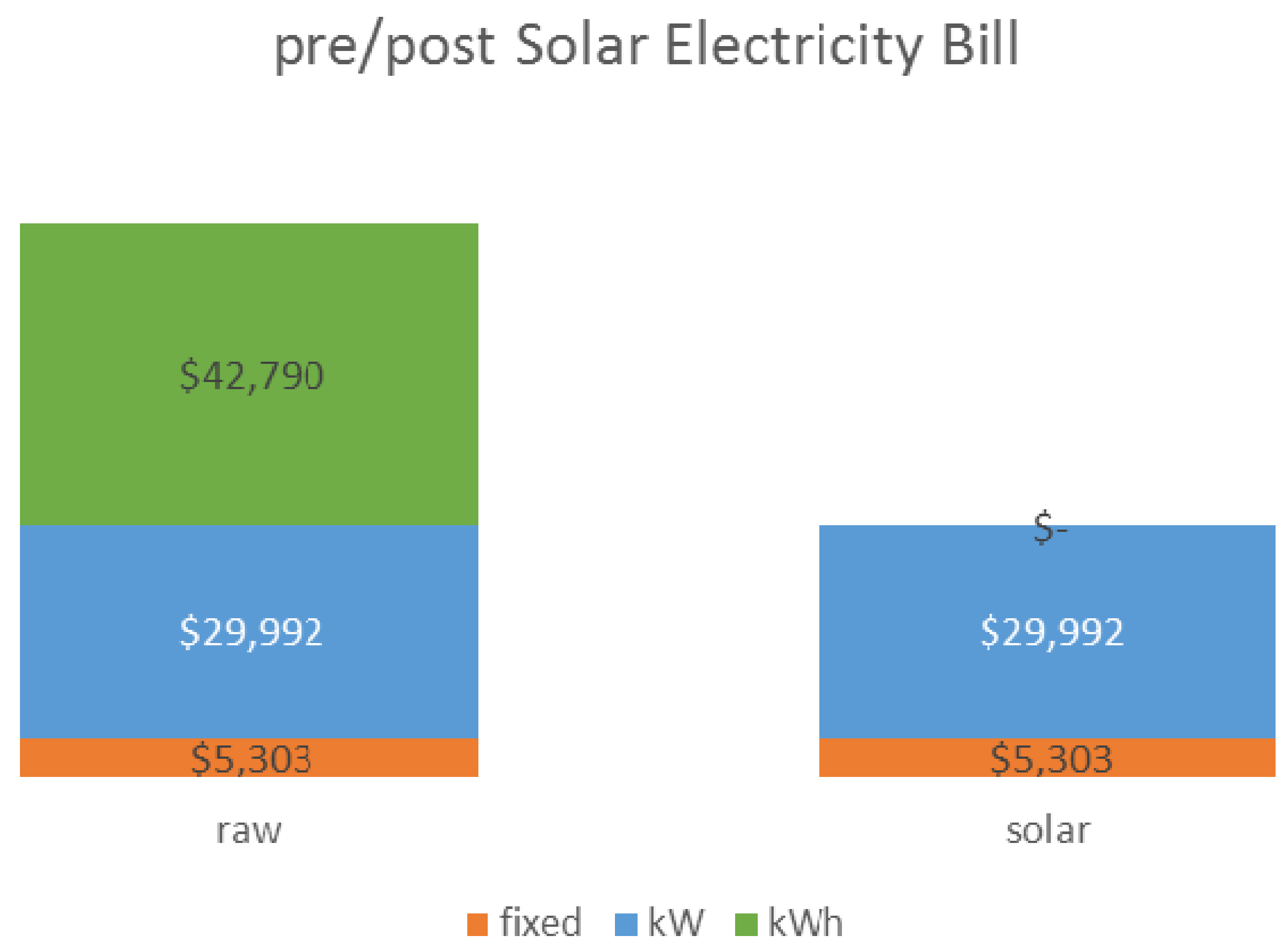
13:30
14:00
14:30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
Time
Building Usage
Post Solar Building Usage
Solar Production

the building load reduction **plus** the excess solar production delivered to the grid results in electricity bill savings which are shown on the next slide


Post Solar Electricity Bill
fixed charges
7%
kW charges
38%
kWh savings
55%
kWh charges
0%

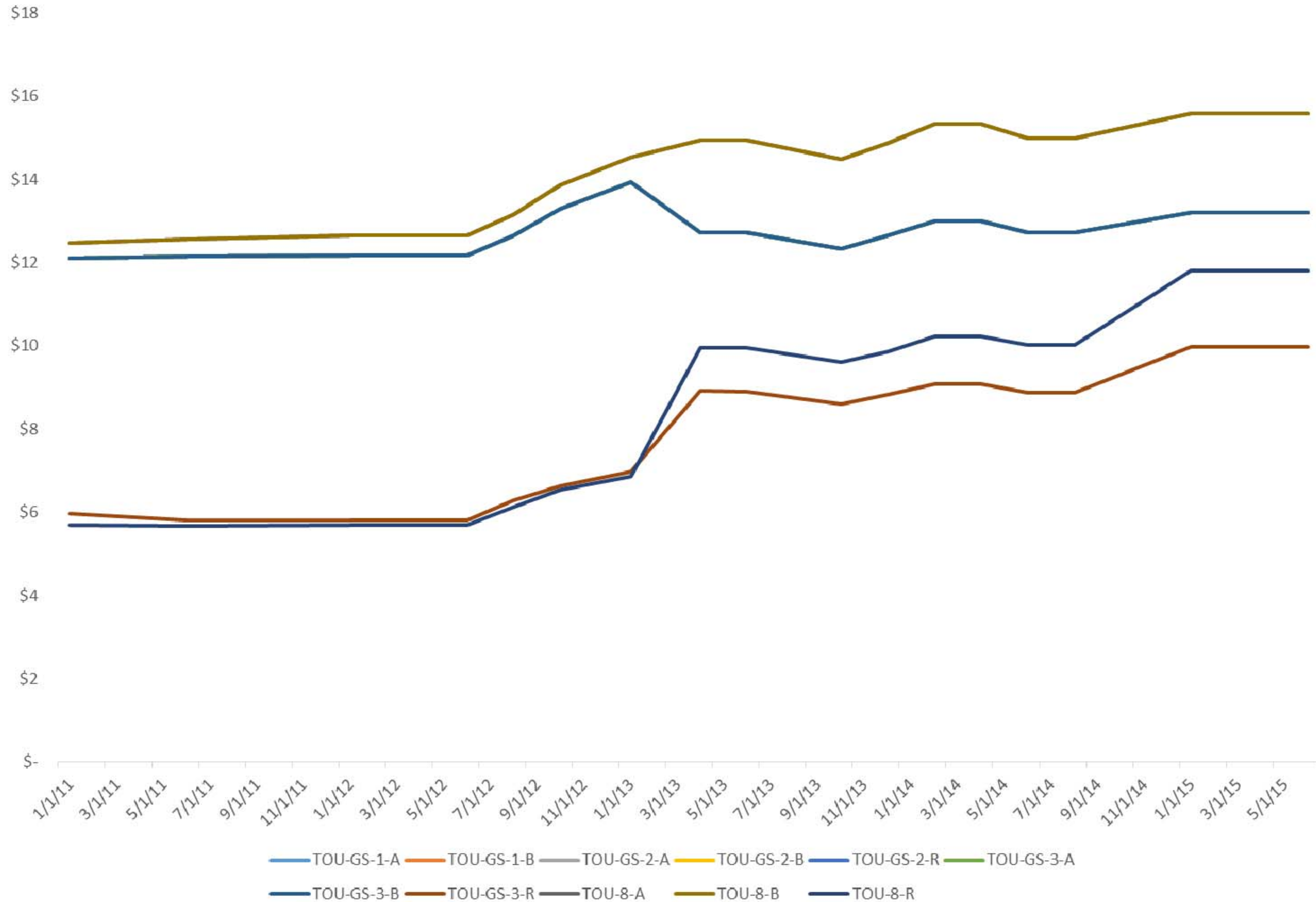
as shown on the last slide the solar installation is capable of reducing the entire usage (kWh) charges of the electricity bill solar installations are also able to reduce the instantaneous building demands, however demand (kW) savings are not accounted in savings projections due to intermittent nature of solar production why does the solar production **intermittency risk** prevent accounting for demand savings?

remember, **demand charges** are calculated based on the maximum demand (kW) for each month as measured during any 15-minute interval therefore, temporary cloud coverage during a typical operational day that reduces solar production would result in a demand spike measurement on the utility meter since the utility bills for demand charges for the one time highest 15-minute interval per month, the load spike during the could event would set the maximum demand for the month back to the bill, the next slide shows the electricity bill pre and post solar

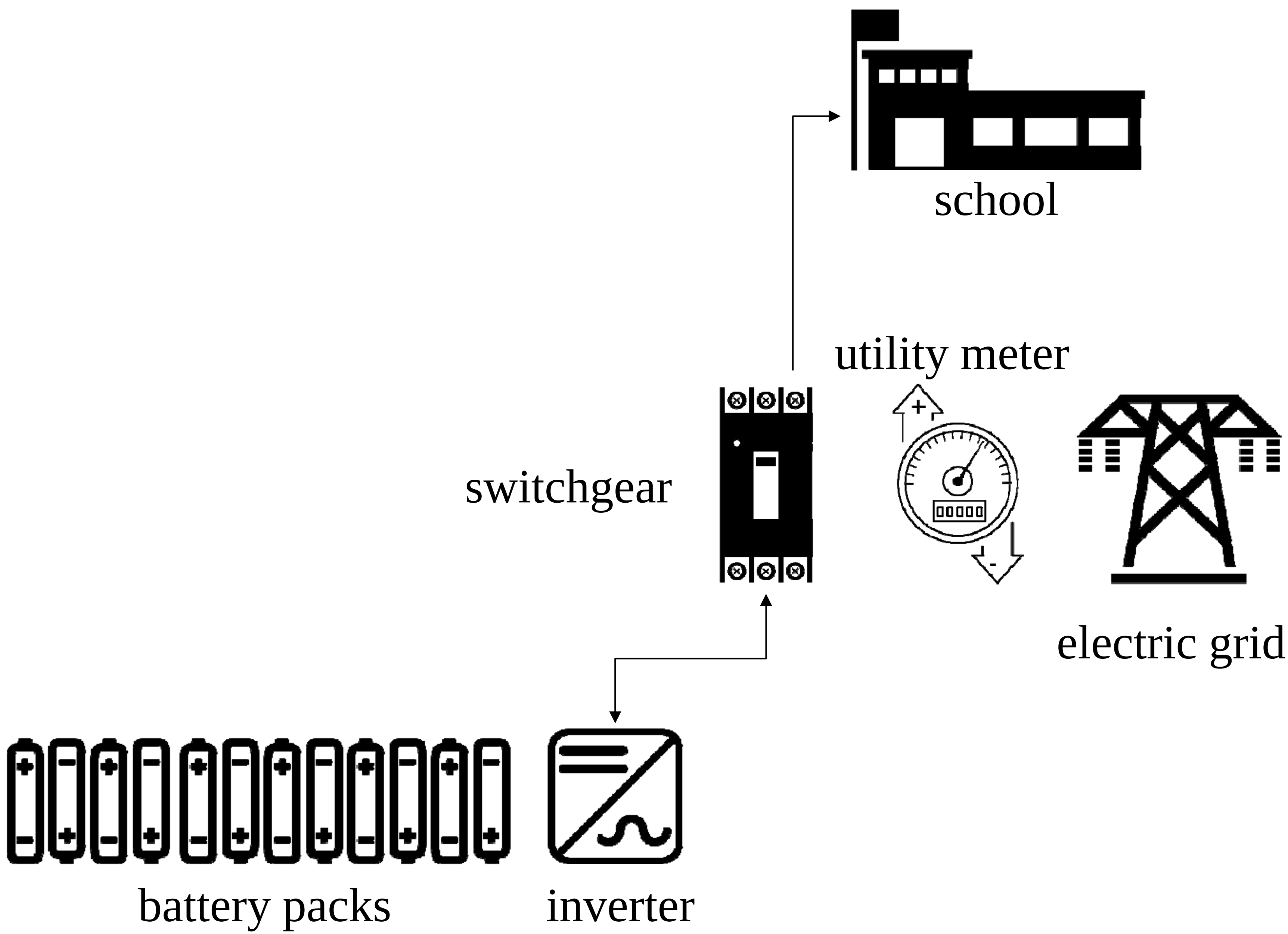

pre/post Solar Electricity Bill
$42,790
$29,992
$5,303
$-
$29,992
$5,303
raw
solar
fixed
kW
kWh

if all assumptions hold, the electricity bill would be reduced to $35,295 (sum of kW charges and Fixed charges) per year for the life of the solar installation unfortunately, the kW charges are expected to increase and as a result the post solar electricity bill will continue to increase the next slide shows the growth of the kW charges in SCE territory for a sample of the rate schedules

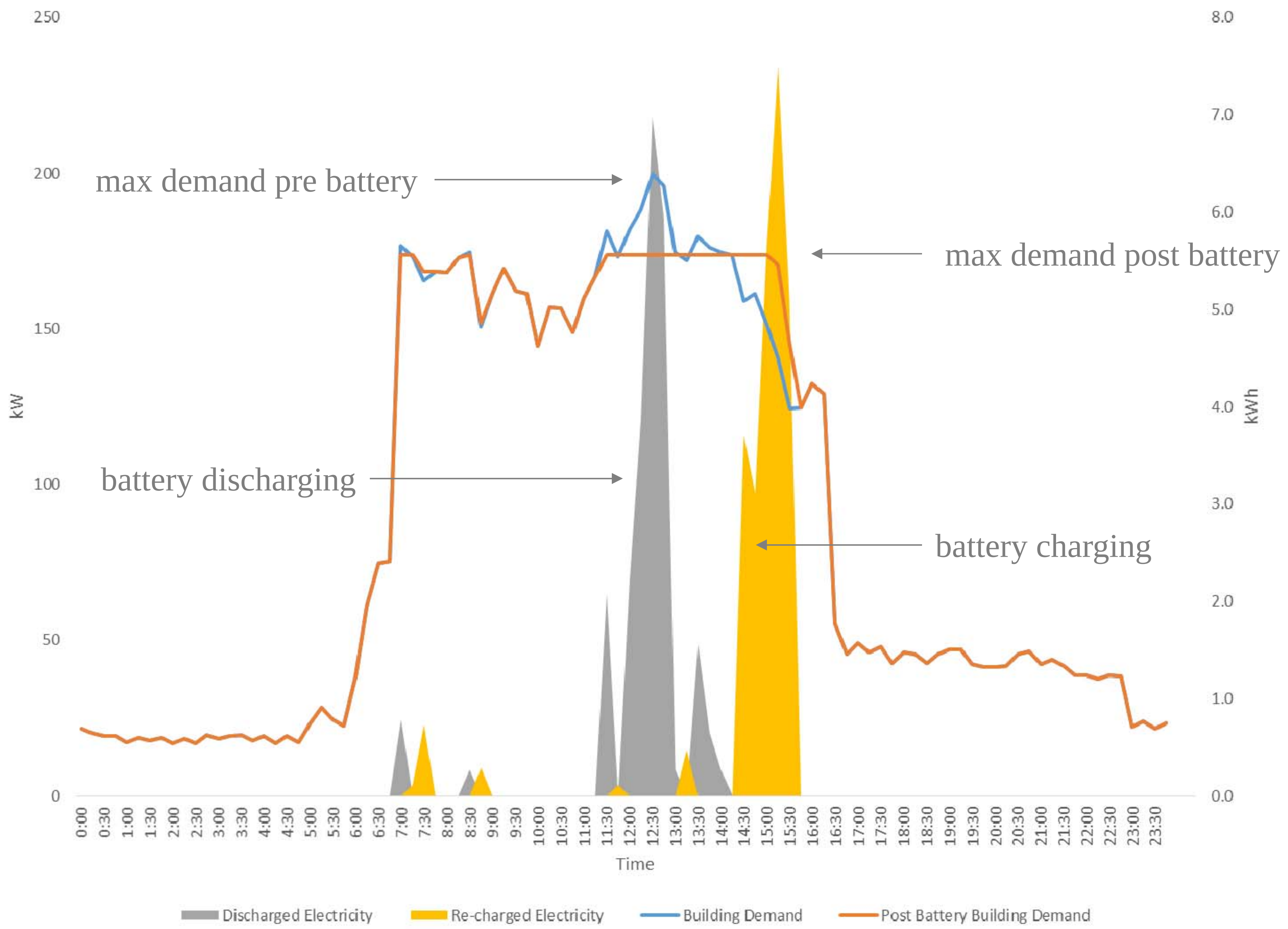
SCE Max Demand Increases (2011-2015)



to reduce the impact of kW charge increases and provide additional savings on the electricity bill we will look to battery storage systems before we see how a battery system complements a solar system, let’s first look at a stand alone battery system the next slide shows a block diagram of a behind-the-meter battery installation

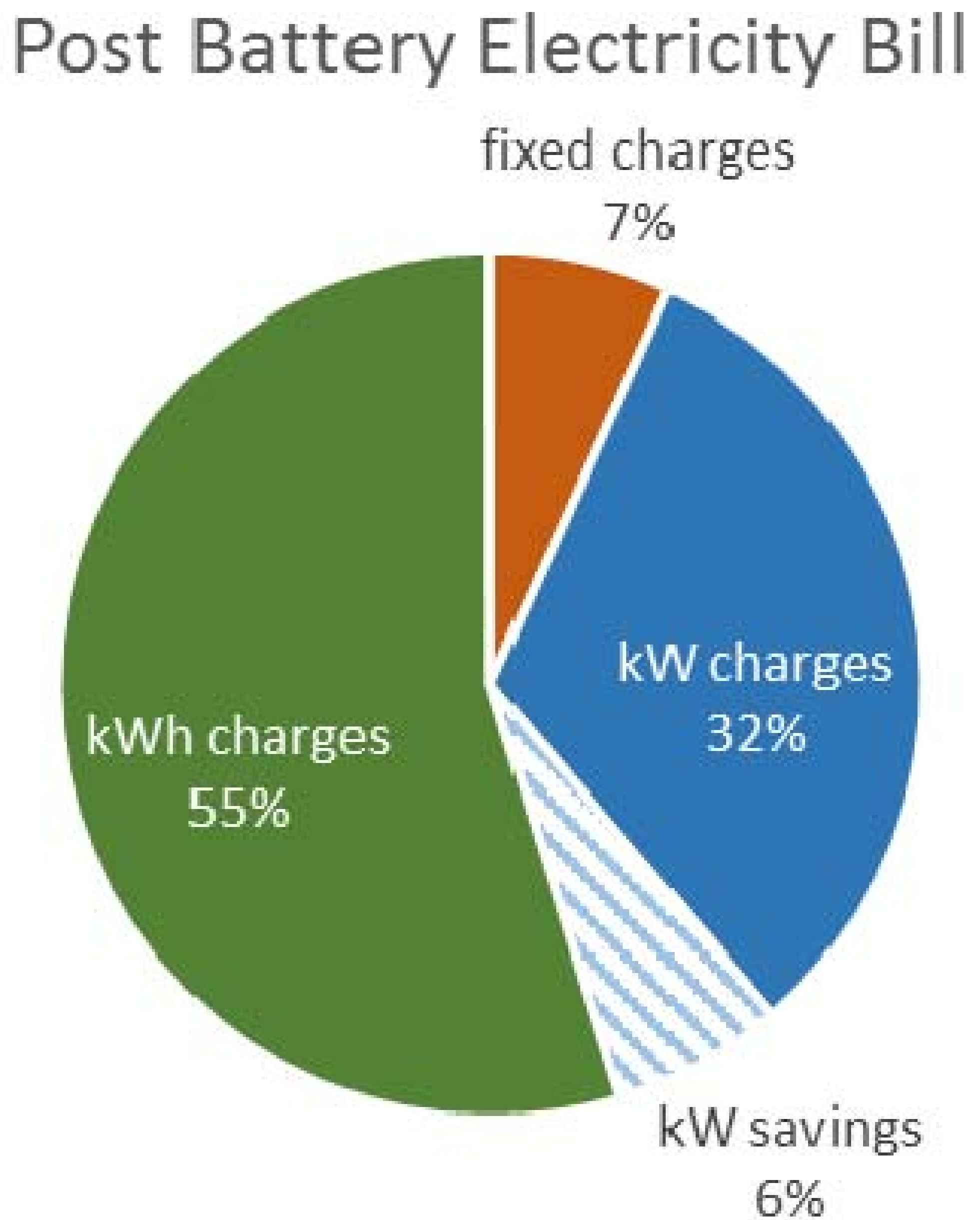

school
utility meter
switchgear
electric grid
battery packs
inverter

the graph on the next slide shows the charge/discharge and building load profiles for a battery installation

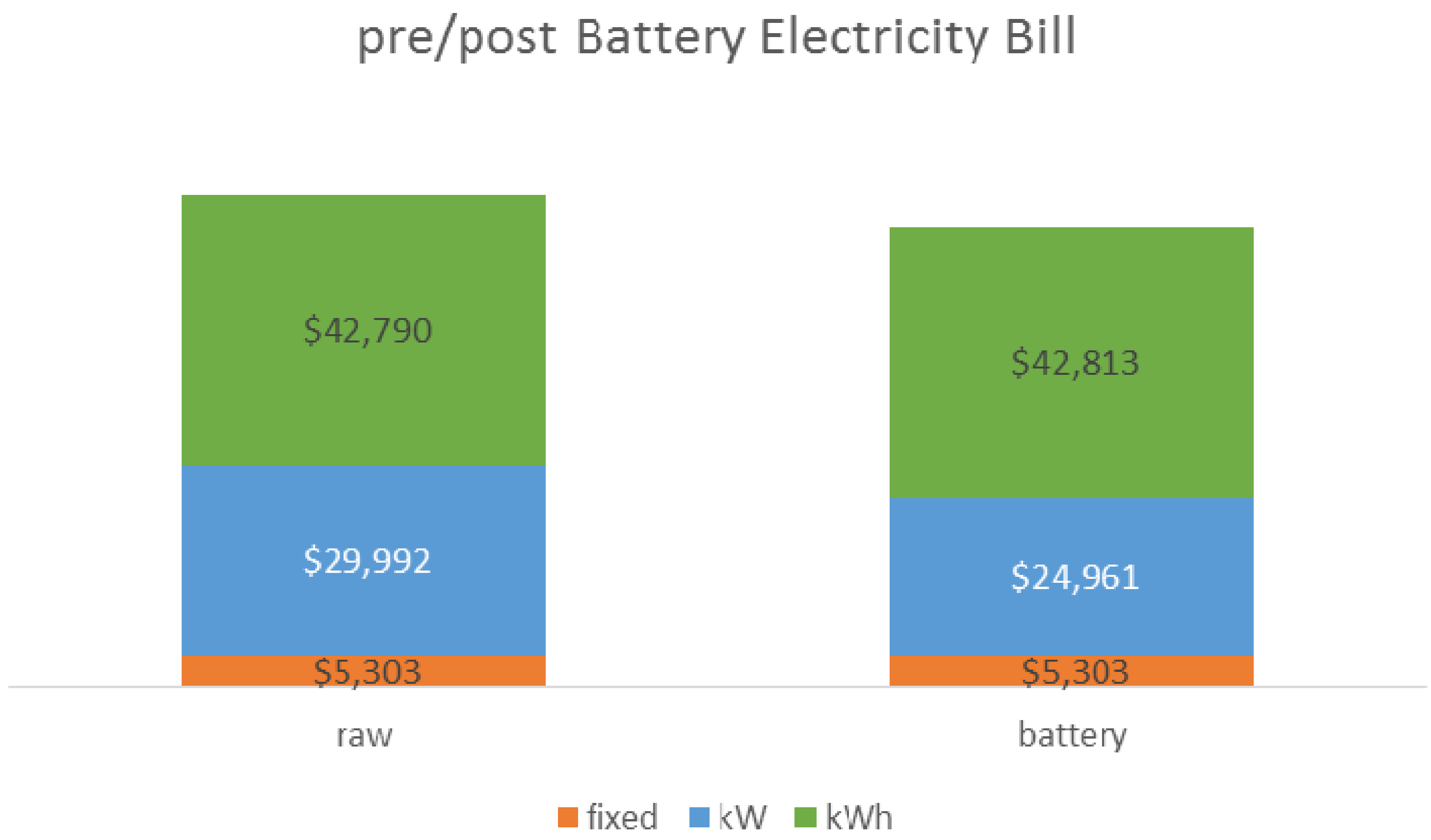


max demand pre battery
max demand post battery
battery discharging
battery charging
kW
kWh
Time
Discharged Electricity
Re-charged Electricity
Building Demand
Post Battery Building Demand

the building max demand reduction per month results in kW charge reductions as shown on the next slide

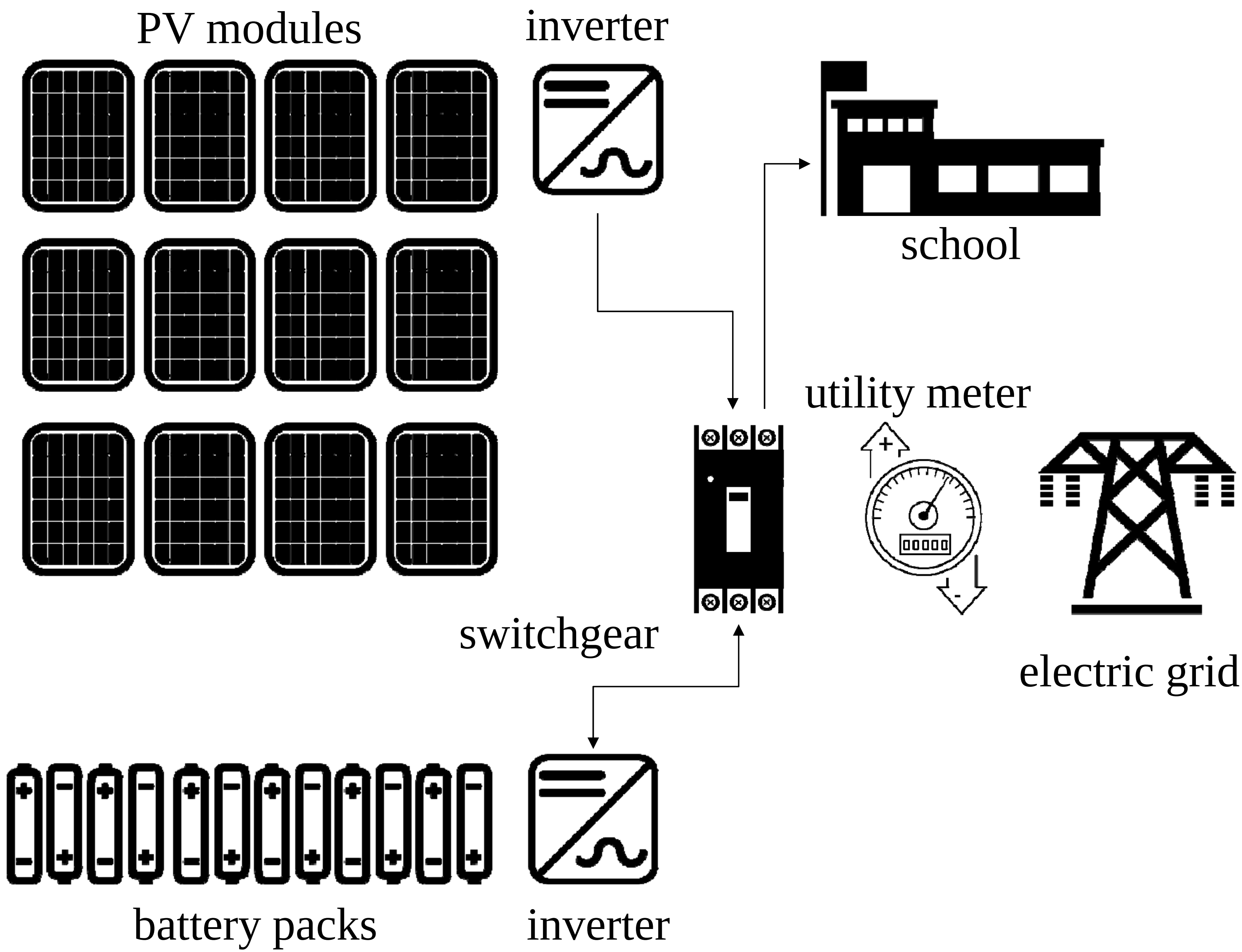

Post Battery Electricity Bill
fixed charges
7%
kW charges
32%
kWh charges
55%
kW savings
6%

the electricity bill savings as a result of demand reduction is shown next

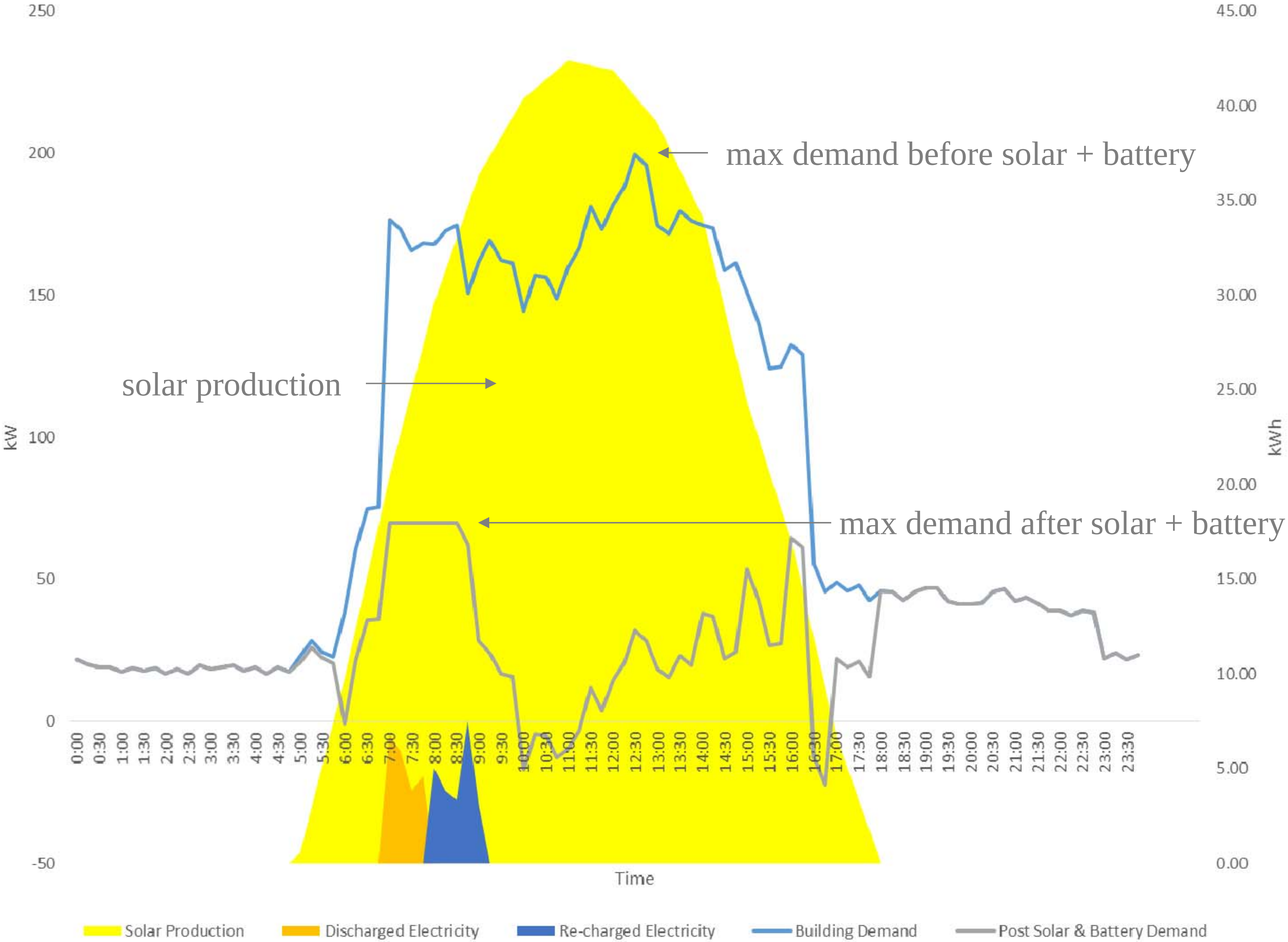

pre/post Battery Electricity Bill
$42,790
$29,992
$5,303
$42,813
$24,961
$5,303
raw
battery
fixed
kW
kWh

as shown on the last slide, the kW charges are reduced by $5,031 on an annual basis you may have noted a small increase in kWh charges; the increase is due to round-trip efficiency losses of the battery we have now covered the basics of stand alone behind-the-meter solar and battery installations let’s get into the exciting portion of the presentation and show what happens when solar and battery installations are paired!

again, we will start with a block diagram

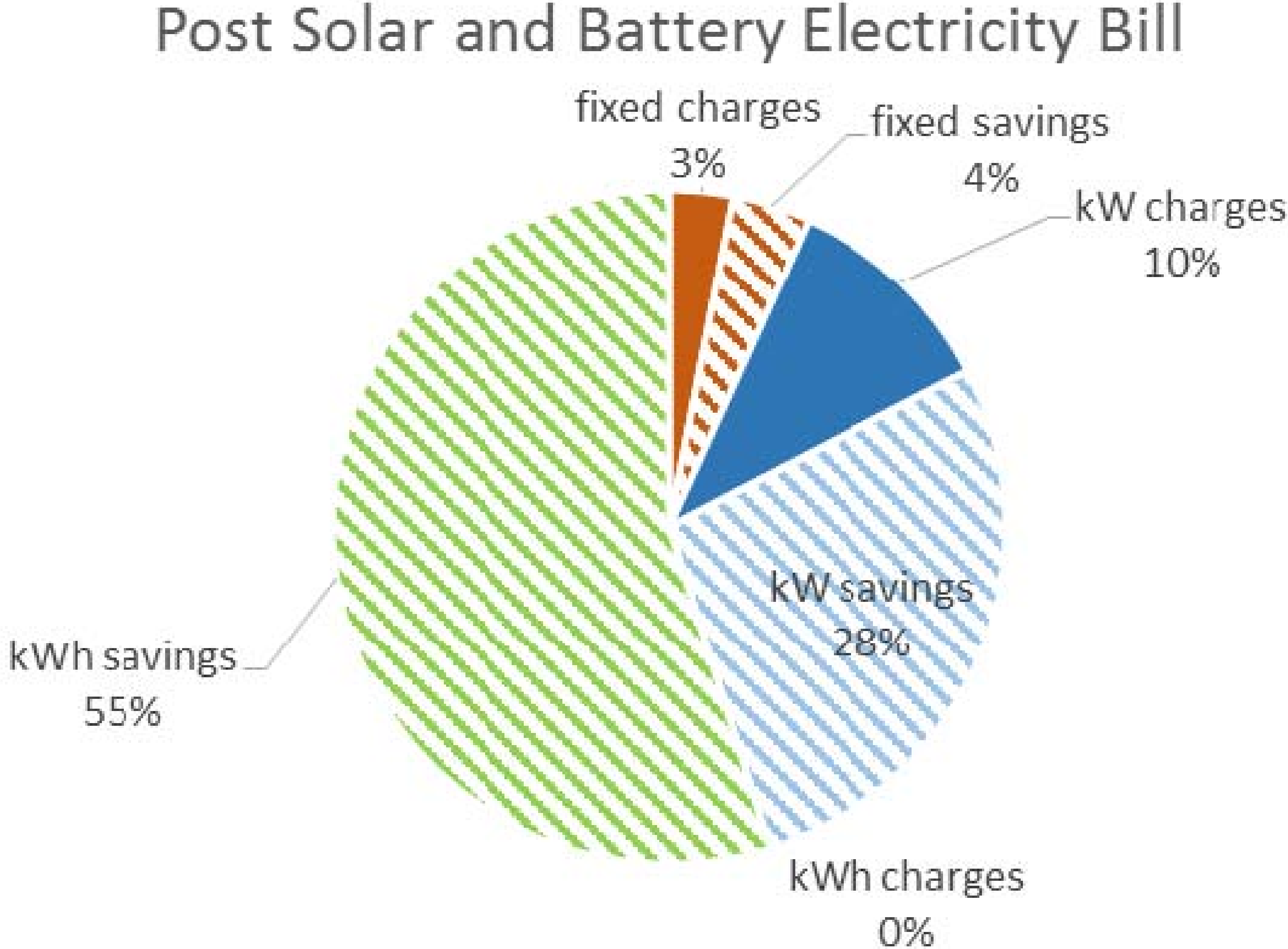

PV modules
inverter
school
utility meter
switchgear
electric grid
battery packs
inverter

and next is the demand and usage profiles of the same building for the same day; scroll back up to compare the profile differences

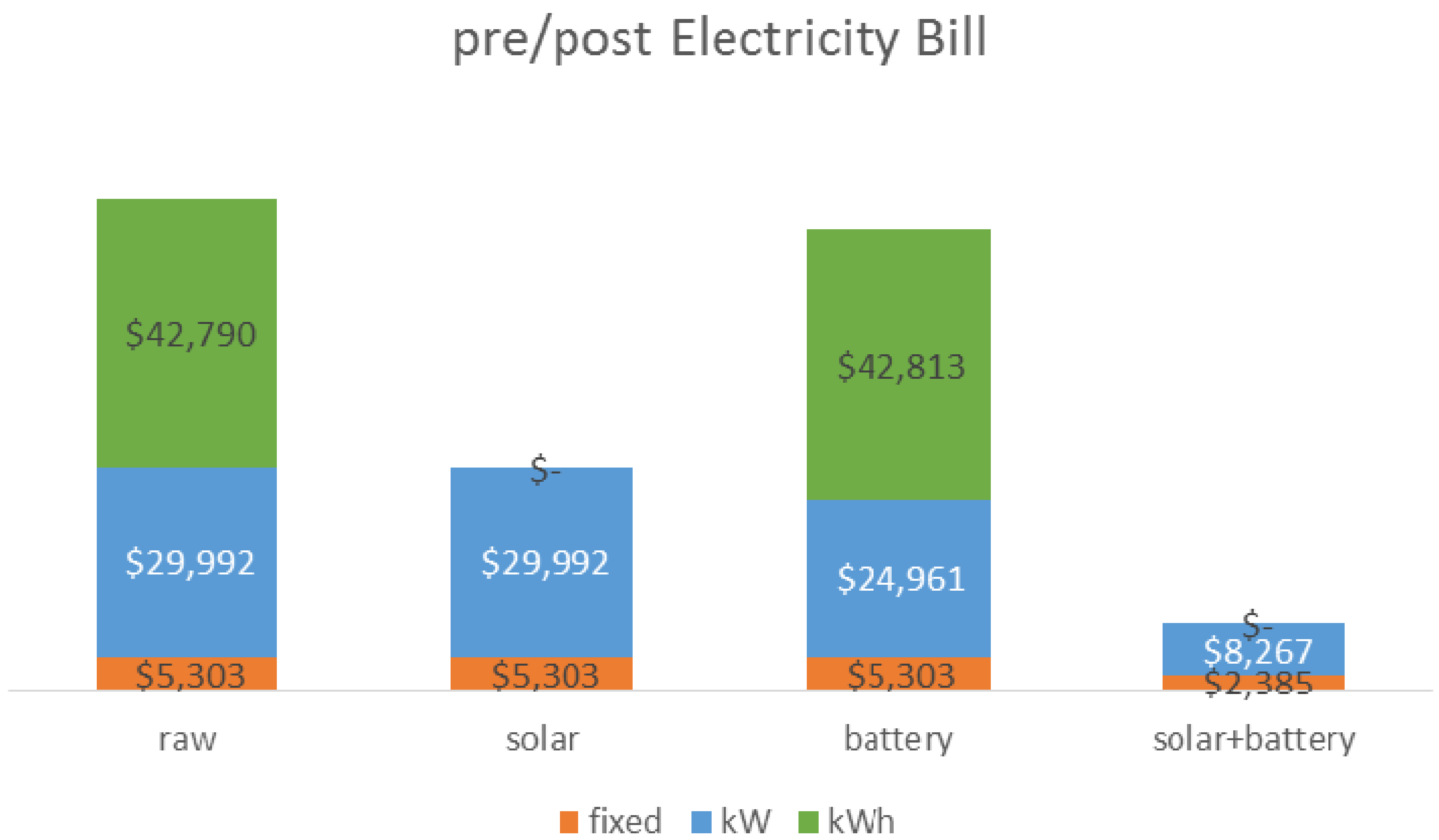


max demand before solar + battery
solar production
max demand after solar + battery
kW
kWh
250
200
150
100
50
0
-50
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0:00 0:30 1:00 1:30 2:00 2:30 3:00 3:30 4:00 4:30 5:00 5:30 6:00 6:30 7:00 7:30 8:00 8:30 9:00 9:30 10:00 10:30 11:00 11:30 12:00 12:30 13:00 13:30 14:00 14:30 15:00 15:30 16:00 16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00 20:30 21:00 21:30 22:00 22:30 23:00 23:30
Time
Solar Production
Discharged Electricity
Re-charged Electricity
Building Demand
Post Solar & Battery Demand

the next slide shows the reductions in kWh and kW charges as a result of solar and battery installations

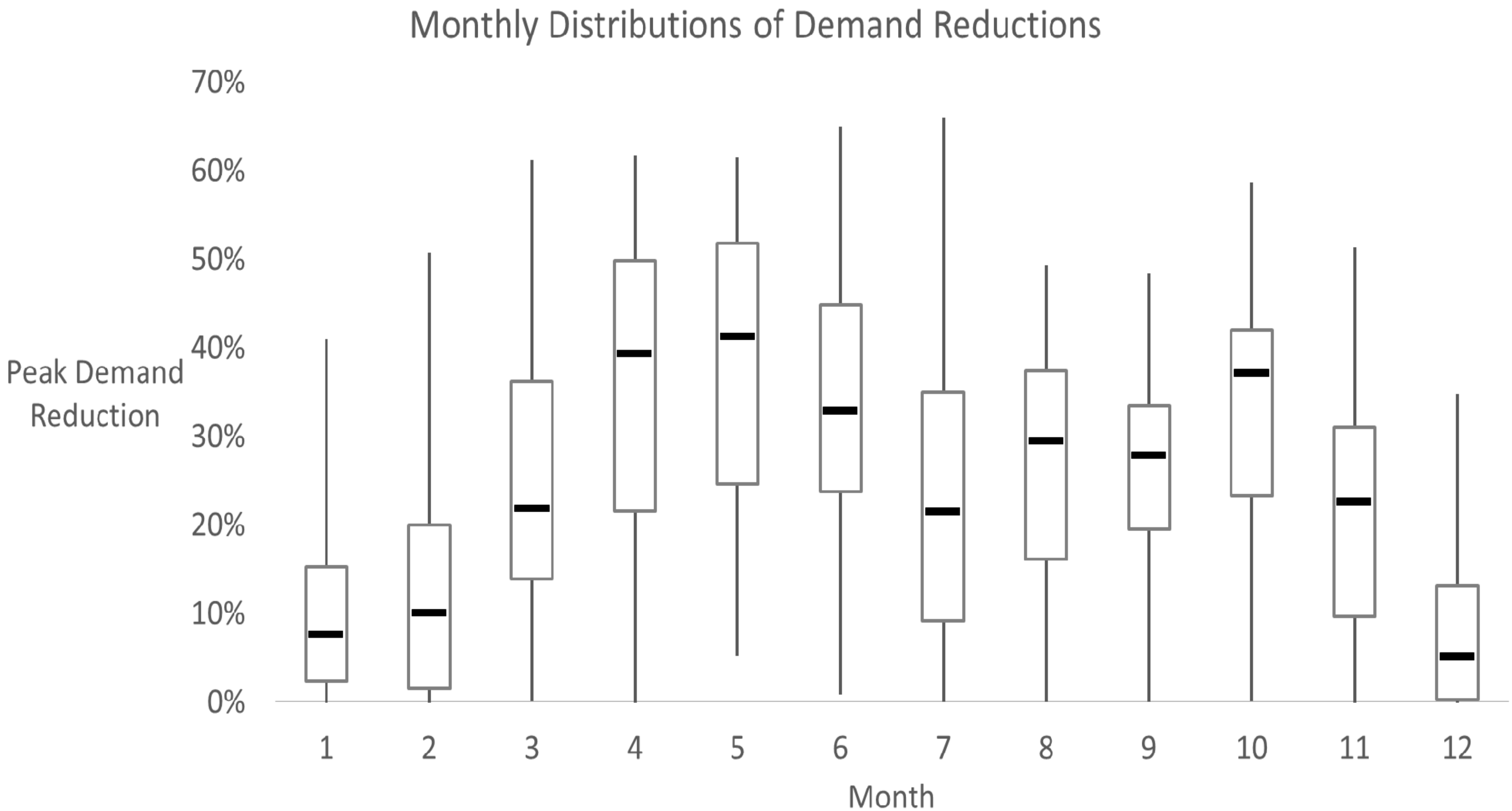

Post Solar and Battery Electricity Bill
fixed charges 3%
fixed savings 4%
kW charges 10%
kW savings 28%
kWh charges 0%
kWh savings 55%

you may have also noticed in reduction in Fixed charges which is due to rate schedule change in this scenario, the combination of solar and battery installations result in sufficient demand reduction to allow the building to switch from a GS3 to a GS2 rate schedule which has lower Fixed, kW, and kWh charges the next slide shows the electricity bill savings from solar and battery combination in comparison to previous scenarios

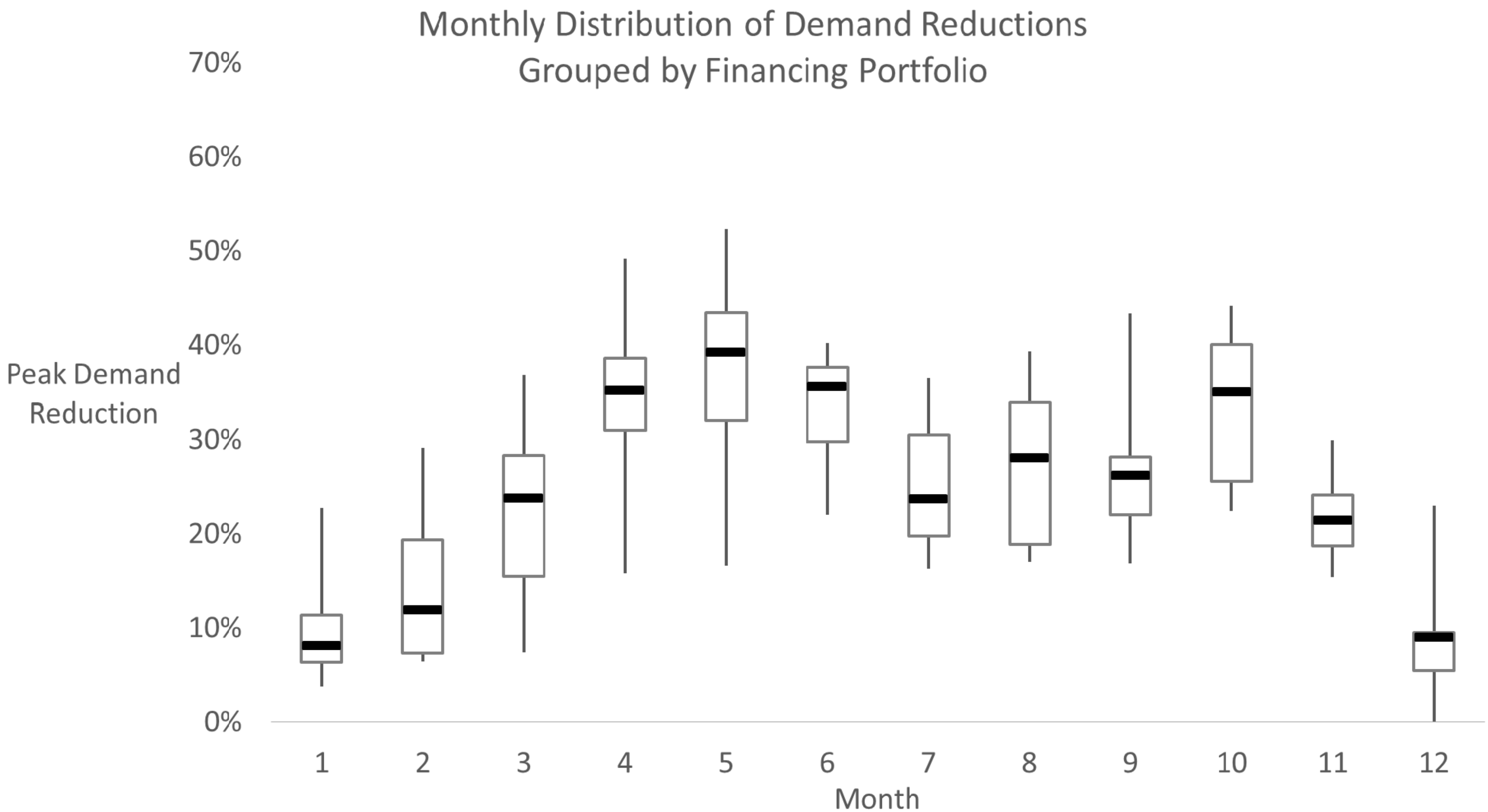


pre/post Electricity Bill
$42,790
$29,992
$5,303
$-
$29,992
$5,303
$42,813
$24,961
$5,303
$-
$8,267
$2,385
raw
solar
battery
solar+battery
fixed
kW
kWh

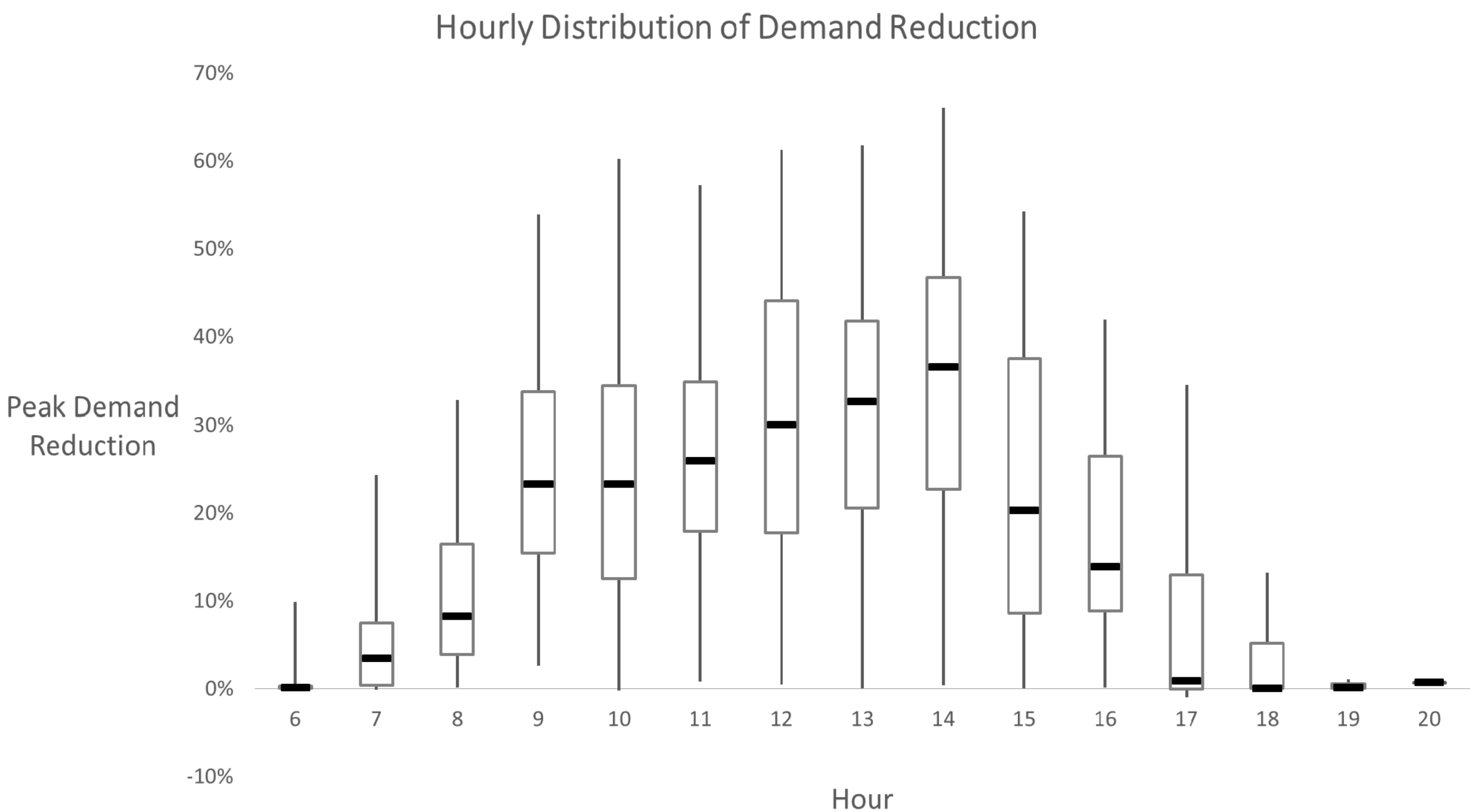
the savings exhibit a compelling argument for pairing solar with battery installations the remaining electricity bill is a fraction of the original bill while the opportunity and cost savings look attractive, it is critical to explore the assumptions behind the savings projections a key assumption explored in this presentation is the intermittent performance of solar installations and the impact on battery demand reduction when projecting demand reductions in solar plus battery installations, the model assumes typical year solar production the typical year solar model for this scenario would result in monthly demand reductions ranging from min 5% in December to max 66% in April that means solar production without the help of a battery is capable of creating demand reduction and therefore kW charge savings, **if typical performance is realized** per models this is a highly optimistic assumption which we are able to modify based on the performance data from our portfolio of operating solar installations the data presented is collected from the operating solar installations managed by TerraVerde the boxplot on the next slide shows the percentiles of max demand reduction, by month, for all of our portfolio sites



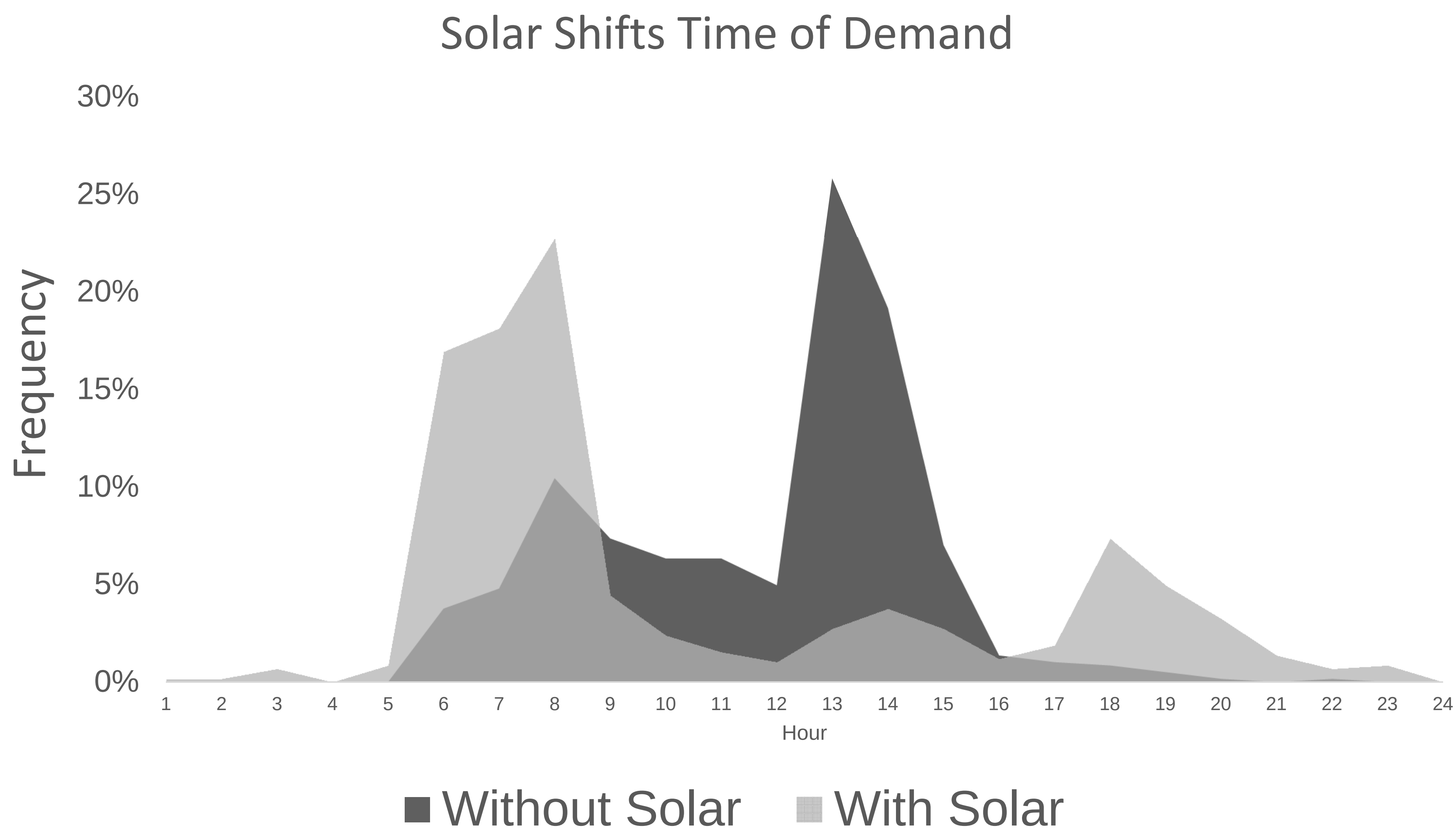

Boxplot range represent $0^{th}$, $25^{th}$, $50^{th}$ ,$75^{th}$ , and $100^{th}$ percentiles the following slide shows the same data but the sites are grouped by portfolio of financed projects



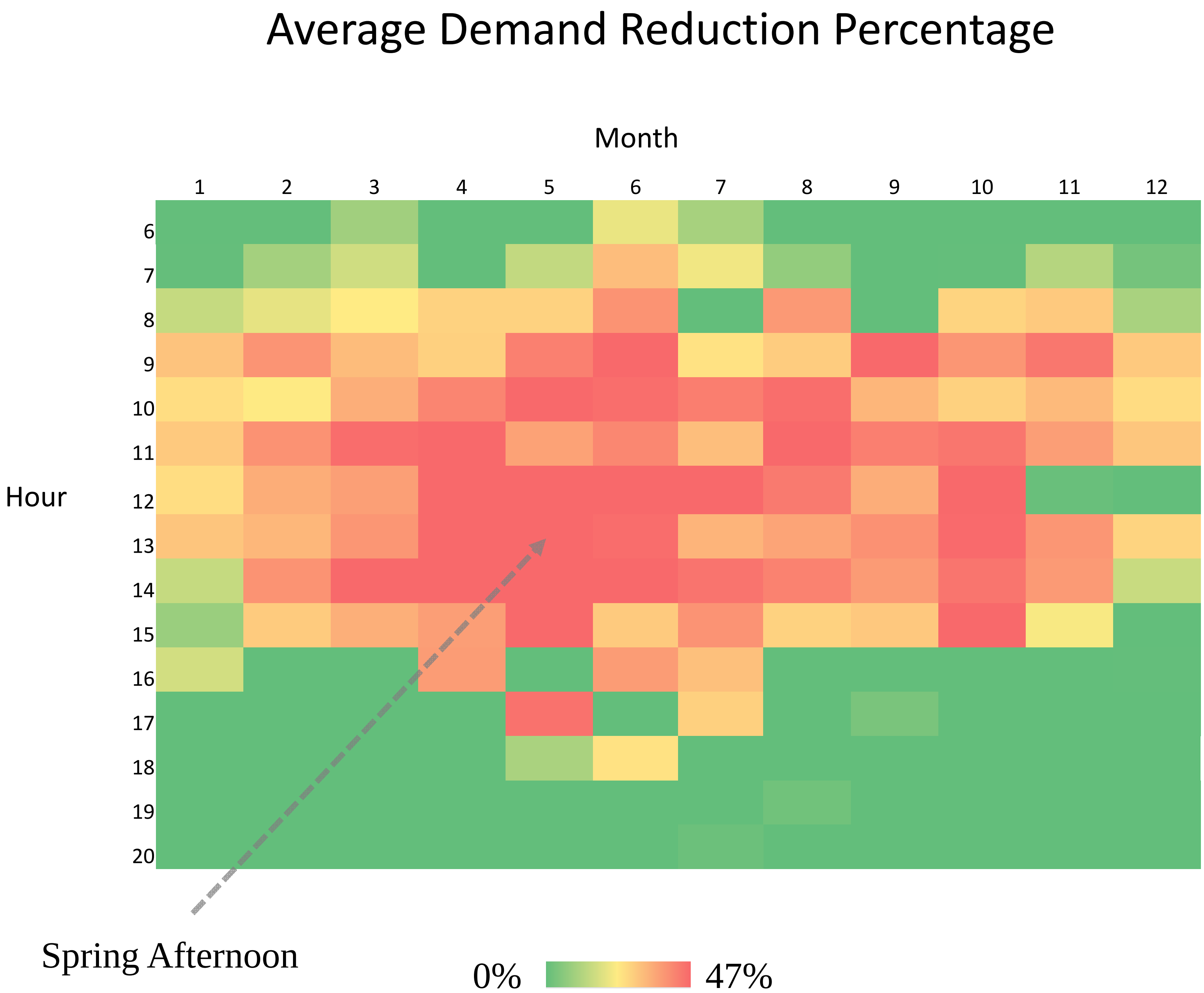

Boxplot range represent 0th, 25th, 50th ,75th , and 100th percentiles as shown from the last slide, the range of the average demand reduction gets much smaller when a portfolio of installations are evaluated the upcoming slide shows how much maximum demand decreases, depending on the hour when it occurs




Boxplot range represent 0th, 25th, 50th ,75th , and 100th percentiles the following slide shows what time of day maximum demand occurs with and without solar


Solar Shifts Time of Demand
Frequency
30%
25%
20%
15%
10%
5%
0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
Without Solar
With Solar

as seen on the previous slides, a solar installation is capable of reducing and shifting peak demand the following slide is a heat map showing the expected reduction in demand based on the month and hour it occurs

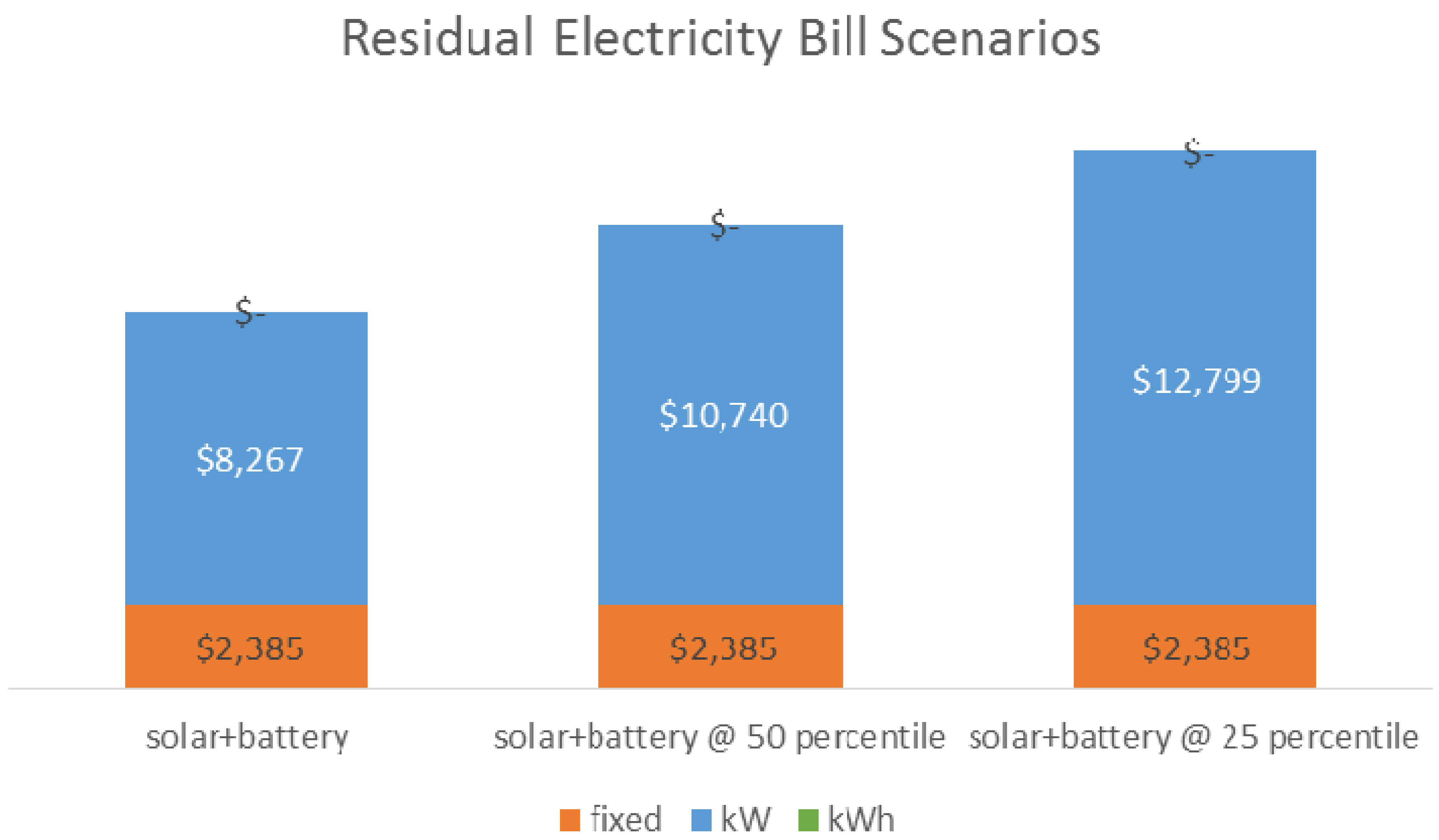


Average Demand Reduction Percentage
Month
1
2
3
4
5
6
7
8
9
10
11
12
Hour
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Spring Afternoon
0%
47%

# the peak demand reduction due to solar generation in our portfolio ranges from

| | |
|---|---|
| @25th Percentile | 5% to 32% |
| @50th | 8% to 39% |
| @75th | 9% to 43% |

as shown in the last slide, the peak demand reduction observed from operating solar installations is lower in most months than the modeled values based on TMY data therefore, to avoid over-estimating savings, we apply the 25th and 50th percentile limits to the post solar demand profile prior to testing the peak demand reduction using a battery installation the next slide shows the reduction in savings from the theoretical scenario assuming perfect solar performance per TMY data


Residual Electricity Bill Scenarios
$-
$-
$-
$8,267
$10,740
$12,799
$2,385
$2,385
$2,385
solar+battery
solar+battery @ 50 percentile
solar+battery @ 25 percentile
fixed
kW
kWh

as seen above, the residual electricity bill for the 25th percentile scenario is increased by $4,532 per year (43%) as compared to the TMY model savings the reduced ***projected*** savings from the combined solar and battery reduces the return on investment for the project while the reduced ROI is less attractive, it should be treated as a sound stress test of the financial models and part of the due diligence process in closing, we would like to remind you that the data presented here are from our operating solar portfolio with a system uptime of >99%

additionally, the portfolio presented is specific to California public school districts in various climate zones to perform a stress test on the financial return of solar and battery installations the analysis must be based on dataset collected from applicable buildings in similar climate zones finally, we need to emphasis for simplicity of presentation, we omitted to highlight other benefits of combined solar and battery installations including charge/discharge arbitrage and Demand Response opportunities

# About TerraVerde Renewable Partners

**Since 2009, TerraVerde has been California's leading independent solar energy advisor**

- Recognized leader in project development consulting services in Energy Efficiency, Solar, and Energy Storage
- Unique engagement model mitigates project risks during development
- In house engineering, structured finance, financial modeling, Design-Build & PPA contracts, owner's representative project management, and Asset Management
- Completed the first solar plus battery storage school project in California for Burton City Schools in Porterville and several more under installation and development



TerraVerde Renewable Partners

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