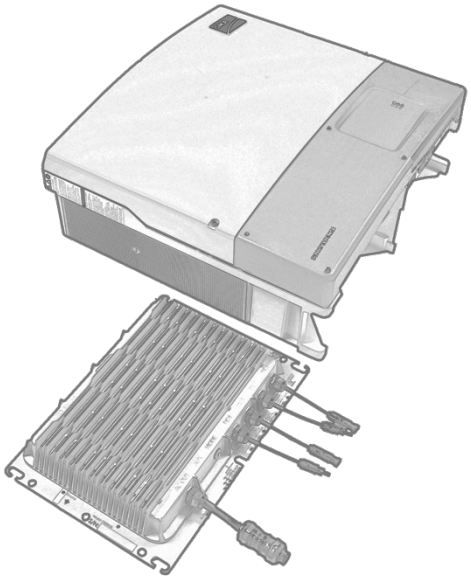
HiQ Solar BOS Cost Comparison

9 March 2016, v1.0

This paper contains 3 case studies that are used to compare Balance of System (BOS) costs between a HiQ Solar based system, and one designed using a competitor's inverters. It is common in our industry to make unsubstantiated and biased claims about cost savings; for this reason we have done the following:

- Used bids generated by a well respected and unbiased customer rather than doing it ourselves; these were given to us without any remuneration given or expected
- We present two different bid tools, one proprietary that is used internally by the customer, and the second a new web-based tool from PVBid[1] applied to a subset of cases
- We are presenting enough detail that assumptions are explicit and can be discussed



All cases are based on Commercial rooftop systems of varying sizes and 3-phase voltages. We have taken the cost of the inverters out of the comparison so that BOS costs may be directly compared.

The overall conclusion is that in these bids, HiQ inverters save between 5 and 7 ¢/W for 480V systems, without including any difference in the cost of the inverters themselves. The gain at 208V is considerably higher. We expect similar differences compared to other string inverter brands. These savings are on the low end of what we hear anecdotally from customers.

[1] www.pvbid.com

Contents

1. Overview

We hear from installers that they save considerable BOS costs using our products. In an effort to quantify these savings we worked with a reputable and well-known installer based in California. The comparisons revolve around 3 sites that were bid last year. We asked them to extend these bids to compare several additional scenarios including different 3-phase voltages and bid tools.

The systems and variants are shown in Figure 1. Two systems are medium sized rooftop installs, both at 480V. The third and smallest is a 56 kW system that has been reworked to cover 208V as well as 480V. This final system has been modeled with PVBid as well as the Customer Proprietary Cost Model (CPCM). The overall intent is to pick some typical examples that are useful. Note that these were not chosen to be favorable to either inverter system manufacturer, and are based on real bids that were submitted last year.

		Voltage	Size (kW STC)	Racking	Inverters Used	Stacking	Module Type	Module Qty
System A	HiQ	480V	447.3 kW	Flush mount	46x HiQ 8k	122%	Canadian Solar 315W	1420
	Brand S				16x Brand S 24k	116%		
System B	HiQ		359.1 kW	Ballasted	38x HiQ 8k	118%		1140
	Brand S				12x Brand S 24k	124%		
System C	HiQ	208V	56 kW	Ballasted	8x HiQ 5.75k	122%	Canadian Solar 320W	176
	Brand S				4x Brand S 9k, 2x Brand S 6k	117%		
	HiQ	480V			6x HiQ 8k	117%		
	Brand S				2x Brand S 24k	117%		

Figure 1: Summary of systems examined

The HiQ Solar systems use either the TrueString™ 480V 8 kW inverter or 208V 5.75 kW inverter. For our competitor, Brand S, the primary inverter used is the very popular 24 kW model except for the 208V cases that use smaller single-phase products.

2. Notes and Assumptions

- The models include labor and material costs, but no sales tax, profit or commissions (or inverters)
- Brand S is the alternative inverter chosen by the installer but is broadly representative in BOS terms with many 3-phase inverter systems from other manufacturers
- The cost of the inverter in each model was zeroed out in order to make BOS cost differences explicit. However additional costs such as string combiners (Brand S) and AC Splice box costs (HiQ) are included in the models
- The models assume that the HiQ inverter is array-mounted, and the Brand S inverter is wall-mounted away from the array and next to the breakers etc. While large 3-phase string inverters can be array-mounted, and HiQ inverters can be mounted away from the array, these were not modeled
- HiQ's TrueString inverter has both AC and DC connectors certified as the means of disconnect. The installer in question benefits from this on the DC side, allowing savings compared to the Brand S inverter. However, on the AC side, it is assumed that the breakers are within sight of the Brand S inverter and therefore no individual AC disconnects are required, nullifying a HiQ advantage. It is also assumed that the 2014 NEC rapid shutdown requirements are not in force in the jurisdictions of these projects.
- The installer has a rule to never use wire smaller than #10
- The installer never exceeds 125% stacking ratio
- Monitoring is not mandatory but was included in all bids. For Brand S 3-phase units, if 4 or fewer units are used, Ethernet cables may be directly connected to the inverter(s) and the cost of an Brand S communication gateway can be avoided
- In general the costs of modules, interconnection, racking and non-construction costs show no difference between cases for a particular system. A couple of cases show minor differences but these are not significant and are ignored. Most of the results focus on the factors that are inverter-related
- The ballast racking cases (Systems B & C) use wire trays for string wiring, conduit everywhere else. The flush mount example (System A) uses conduit everywhere
- Because the smaller HiQ inverters are combined together using the proprietary AC Splice boxes, the number and cost of breakers is usually similar for both inverter brands

3. System Component Layouts

The broad cost categories are visible in the upper (HiQ) and lower (Brand S) system layouts shown in Figure 2, drawn also to highlight layout differences.

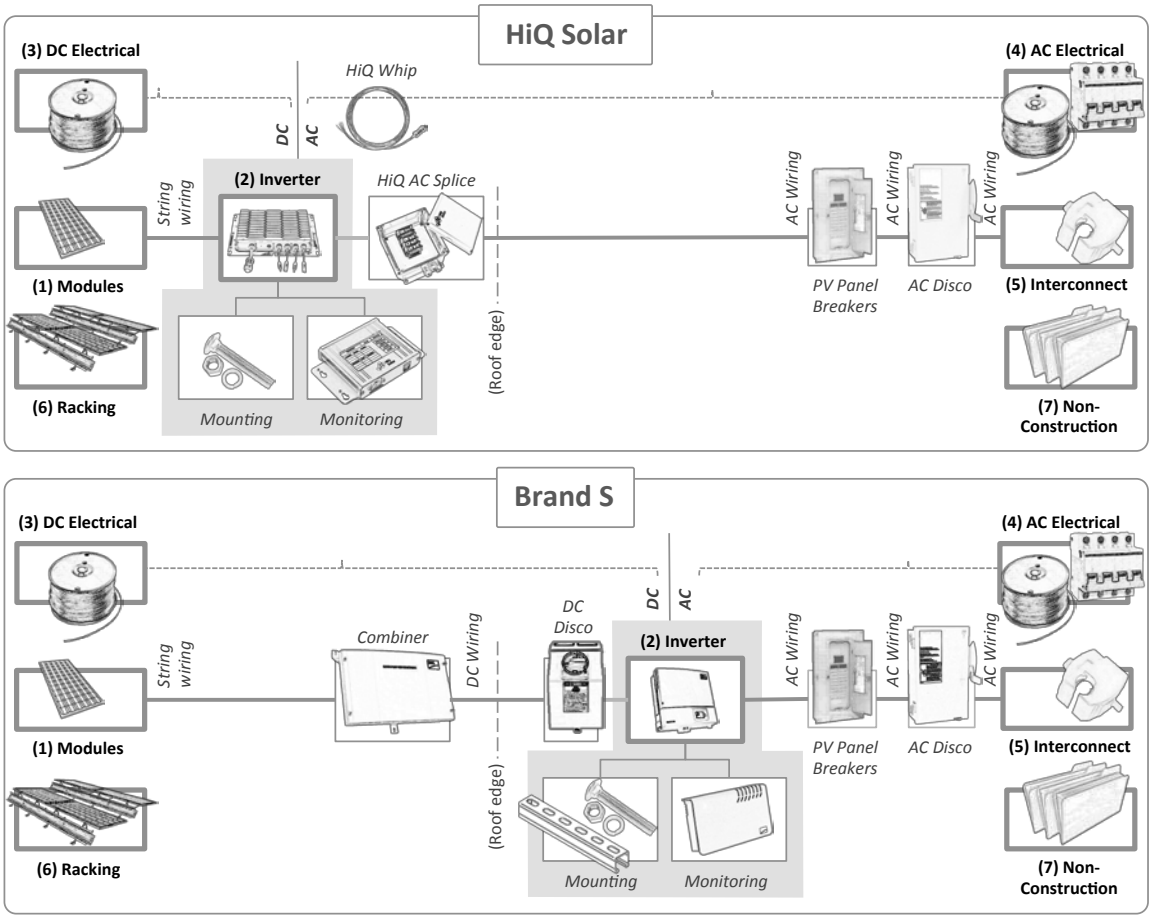


Figure 2: Basic layouts for systems using inverters from each comapny

These 7 category buckets were used throughout. As noted earlier, (1), (5), (6) and (7) do not have significant dependence on inverter type. The items included in each cost bucket are explained in Section 4.

A notable difference between the scenarios depicted in Figure 2 is in the location of the inverters for each case, and the consequent difference in AC and DC-side costs.

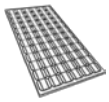
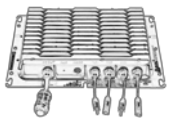
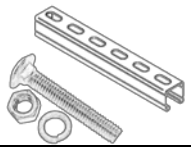
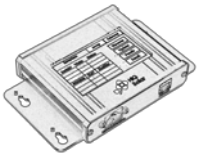
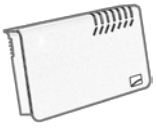
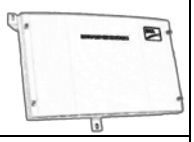
- With HiQ the modeled systems have very short DC string wiring, the inverter mounted at the array; three inverters are combined together on the AC side using the HiQ AC Splice to allow a long run of 208 or 480V wiring in conduit to the AC panel location.
- The Brand S system has longer runs of 1,000V DC string wiring to a Brand S string combiner mounted near the edge of the roof, then thicker gauge DC wiring over to where the Brand S DC disconnect is located along with the inverters, breaker etc. Obviously in the Brand S case the AC runs are very short.

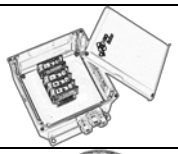
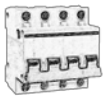
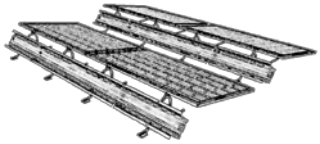
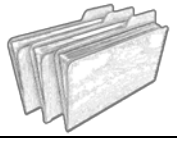
As stated earlier, either system may be mounted differently, although these weren't modeled:

- The HiQ inverter can be mounted significant distances from the array like a conventional string inverter, for example down in an electrical room, if desired
- The Brand S inverter can be array mounted. However, this requires the additional cost of a mounting cradle, and if the AC panel is not within sight of the inverter, the addition of individual AC disconnects. When mounted in this way the inverter is exposed to sunlight that it would not normally be, with possible detrimental effects on LCD displays etc.

4. Cost Categories

The output from both tools used in this exercise was sorted into categories, detailed below.

<table>
<tr><th></th><th>HiQ Solar</th><th>Brand S</th></tr>
<tr><td rowspan="3">1. Modules
  </td><td colspan="2">Module cost, plus installing modules on racking</td></tr>
<tr><td colspan="2">Mobilization, including warehouse work, lifting equipment to get materials to the site roof, daily setup and clean up, but not crew travel</td></tr>
<tr><td colspan="2">Safety, including generating a safety plan, putting up safety equipment on site such as covering skylights, marking the roof edge etc.</td></tr>
<tr><td rowspan="3">2. Inverters
 
  </td><td>Install inverter – usually means bolting to racking for HiQ  </td><td>Install inverter – mounting strut etc. to suitable wall structure, mounting inverter to that  </td></tr>
<tr><td colspan="2">Cost of inverter - zeroed out for this analysis of BOS for easy comparison. Does not include costs of disconnects and combiners which are included in other categories</td></tr>
<tr><td>Monitoring – in all modeled cases means adding optional HiQ Gateway, and misc. wiring  </td><td>Monitoring – varies depending upon configuration, sometimes wiring (and possibly a router) only, sometimes includes a Brand S communications gateway  </td></tr>
<tr><td rowspan="3">3. DC Electrical</td><td>String wiring to the inverter. (Wire trays included in elsewhere Racking category)  </td><td>String wiring to the string combiner on the edge of the roof. (Wire trays included elsewhere in Racking category)  </td></tr>
<tr><td></td><td>Installation and cost of the combiner box  </td></tr>
<tr><td></td><td>Wiring from combiner to the inverter, including conduit  </td></tr>
</table>

	HiQ Solar	Brand S
		Cost and installation of the Brand S DC disconnect 
	Grounding the array	
4. AC Electrical	Cost and labor of proprietary HiQ AC Splice box 	
	HiQ proprietary AC Whips 	
	Wiring from inverters to Panel PV, including conduit 	
	Install Panel PV 	
	Wiring from Panel PV to DC Disconnect, including conduit 	
	Install AC disconnect 	
	Install circuit breakers 	
		Install gutter when using more than 2 inverters on the wall
5. Interconnect	Install Line Side Tap 	
	Install wiring between interconnection and AC disconnect, including conduit 	
6. Racking	Install racking (either flush mount or ballasted), install ballast if appropriate, install slip sheets, seismic anchors, wire trays. Includes cost of roofing subcontractor 	
7. Non-Construction	Engineering, project management, permitting, interconnection paperwork, crew travel, system commissioning 	

The three specific systems are described in more detail in the next sections.

5. Example System A, 447 kW 480V

5.1. Overview

The first system is a lumber business consisting of two buildings; it is the largest system examined and is illustrated in Figure 3.

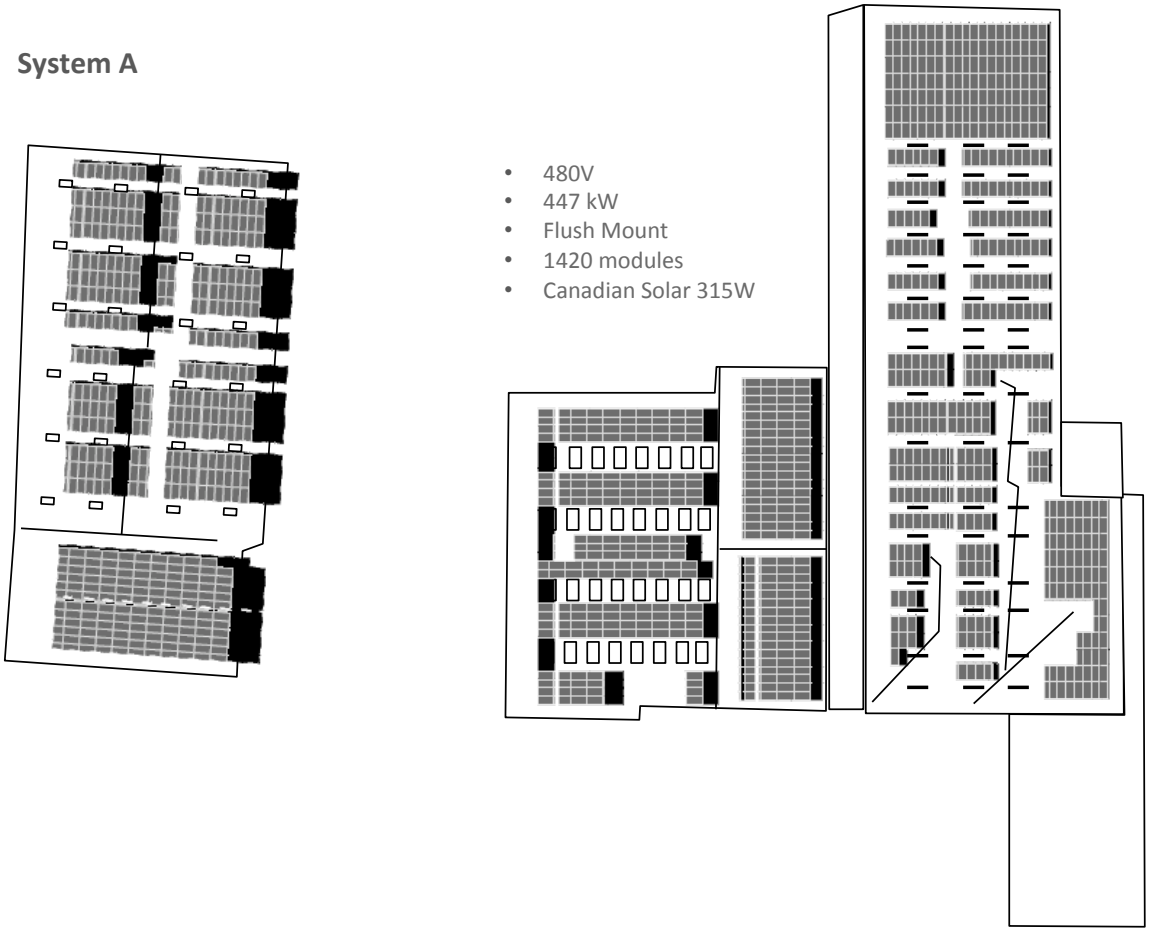


Figure 3: System A plan view

The next sections follow a common format. For each example examined, there is a table showing cost categories, and the HiQ systems compared to the Brand S system. The topmost system shows the data in absolute dollars. The next table shows the same data normalized cents per Watt for easier comparison between systems. Finally the bottom table shows the subtraction between the two system numbers. A negative number is a benefit to HiQ, a positive number a benefit to Brand S.

More details on system costs are given in tables in the appendices.

5.2. System A - Cost Comparison Summary Tables

CPCM - System A, 480V				
$$$ - Total Cost			HiQ	Brand S
1	Modules		394,832	395,080
2a	**Inverters**	**Mounting**	**2,342**	**4,070**
2b		**Monitoring**	**750**	**3,150**
3	**DC Electrical Equipment**		**30,704**	**80,468**
4	**AC Electrical Equipment**		**46,837**	**16,318**
5	Interconnection		4,462	4,462
6	Racking		92,815	92,815
7	Non-Construction		44,258	44,302
Total			**617,001**	**640,665**
Hours			*2,120*	*2,215*

CPCM - System A, 480V				
¢/W - Cost per Watt			HiQ	Brand S
1	Modules		88.3	88.3
2a	**Inverters**	**Mounting**	**0.5**	**0.9**
2b		**Monitoring**	**0.2**	**0.7**
3	**DC Electrical Equipment**		**6.9**	**18.0**
4	**AC Electrical Equipment**		**10.5**	**3.6**
5	Interconnection		1.0	1.0
6	Racking		20.8	20.8
7	Non-Construction		9.9	9.9
Total			**137.9**	**143.2**
Watts			447,300	447,300

CPCM - System A, 480V			
¢/W Delta			HiQ vs Brand S
1	Modules		(0.1)
2a	**Inverters**	**Mounting**	**(0.4)**
2b		**Monitoring**	**(0.5)**
3	**DC Electrical Equipment**		**(11.1)**
4	**AC Electrical Equipment**		**6.8**
5	Interconnection		-
6	Racking		-
7	Non-Construction		(0.0)
Total			**(5.3)**
Hours			*(95)*

Figure 4: System A - Cost Comparison Summary Tables

5.3. System A - Cost Comparison Commentary

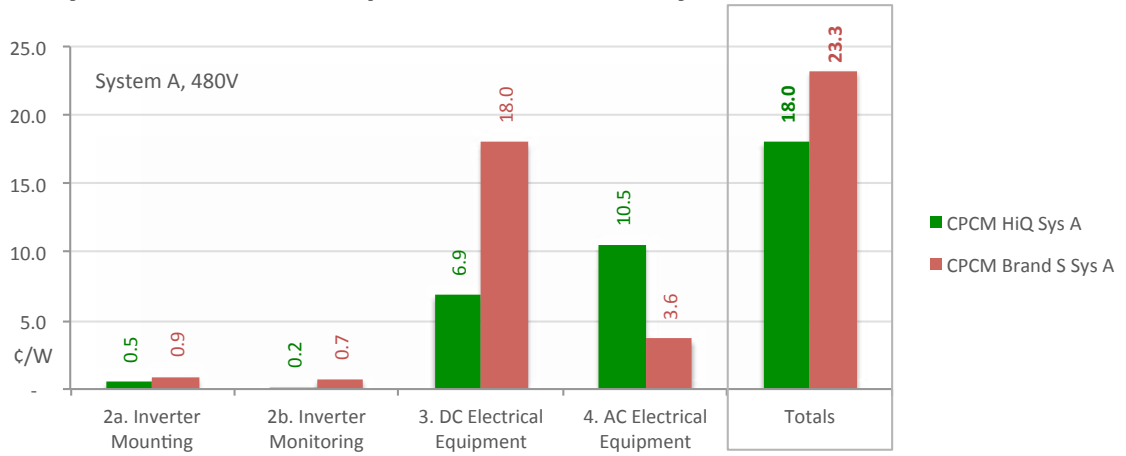


Figure 5: Graph of System A costs in ¢/W

A comparison graph is shown in Figure 5. The following notes apply to the bid:

- Flush mounted racking was used, with conduit used throughout rather than wire trays – all other cases use wire trays for string wiring
- With a large number of both inverters, both systems use communication gateways; for Brand S this also means RS485 cards added to each inverter
- With 16 Brand S wall-mounted inverters, a gutter is assumed for wiring containment between inverters
- The HiQ system avoids the cost of the DC string combiner and the DC disconnect switch. However, it does require HiQ AC whips and AC Splice boxes that the Brand S does not. On balance the difference in cost favors the HiQ approach
- **The net benefit is 5.3 ¢/W in using TrueString inverters in this example, excluding inverter cost**

	HiQ String Sizing		Brand S String Sizing	
Modules	1420		1420	
Wattage	315		315	
Inverters	46		16	
AC Rating	8000		24000	
Strings	92		76	
	# Strings	Length	# Strings	Length
Length 1	40	16	11	20
Length 2	52	15	32	19
Length 3			31	18
Length 4			2	17

Figure 6: String sizing calculations for System B

As a side note, Figure 6 is an example of the string sizing calculation that was performed on System A by the original designer. It is obvious that the HiQ situation is much simpler to design, with single strings on each inverter input and only two different (or frequently just one) string length to worry about. This carries through to installation also, with the added complexity of keeping track of four different string lengths in wire trays and making sure they get to the right string combiners without error adding time and complexity to the process with Brand S. This appears to be an extreme example but illustrates the point.

6. Example System B, 360 kW 480V

6.1. Overview

The second system is a machine shop shown in Figure 7.

Figure 7: System B plan view

6.2. System B - Cost Comparison Summary Tables

CPCM - System B, 480V

	$$$ - Total Cost		HiQ	Brand S
1	Modules		316,416	315,812
2a	**Inverters**	**Mounting**	**1,898**	**3,653**
2b		**Monitoring**	**933**	**2,550**
3	**DC Electrical Equipment**		**26,103**	**81,513**
4	**AC Electrical Equipment**		**48,997**	**15,823**
5	Interconnection		4,669	4,666
6	Racking		95,982	95,707
7	Non-Construction		32,702	32,763
Total			**527,701**	**552,486**
Hours			*2,039*	*2,154*

CPCM - System B, 480V

	¢/W - Cost per Watt		HiQ	Brand S
1	Modules		88.1	88.3
2a	**Inverters**	**Mounting**	**0.5**	**1.0**
2b		**Monitoring**	**0.3**	**0.7**
3	**DC Electrical Equipment**		**7.3**	**22.8**
4	**AC Electrical Equipment**		**13.6**	**4.4**
5	Interconnection		1.3	1.3
6	Racking		26.7	26.7
7	Non-Construction		9.1	9.2
Total			**147.0**	**154.4**
Watts			359,100	357,840

CPCM - System B, 480V

	¢/W Delta		HiQ vs Brand S
1	Modules		(0.1)
2a	**Inverters**	**Mounting**	**(0.5)**
2b		**Monitoring**	**(0.5)**
3	**DC Electrical Equipment**		**(15.5)**
4	**AC Electrical Equipment**		**9.2**
5	Interconnection		(0.0)
6	Racking		(0.0)
7	Non-Construction		(0.0)
Total			**(7.4)**
Hours			*(115)*

Figure 8: System B - Cost Comparison Summary Tables

6.3.**System B - Cost Comparison Commentary**

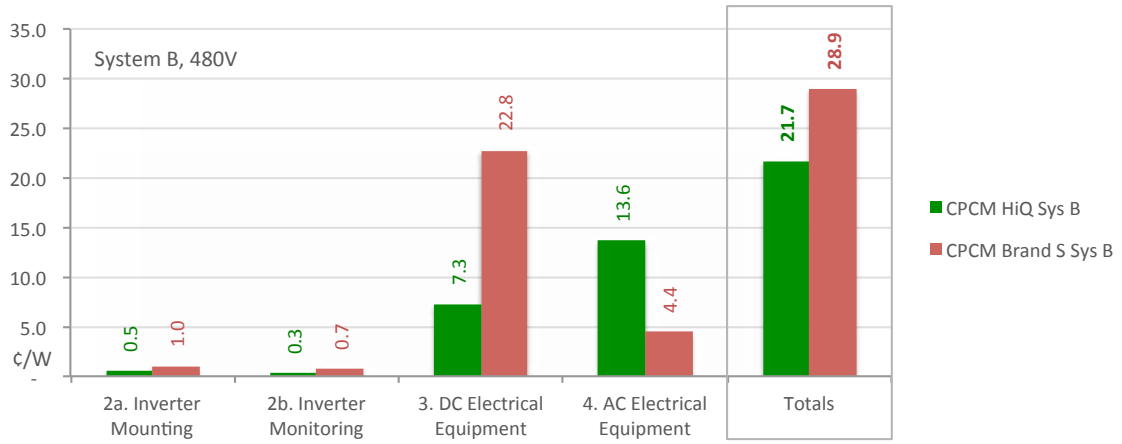


Figure 9: Graph of System B costs in ¢/W

As with System A earlier, a comparisons of cost categories for System B is shown graphically in Figure 9.

- This project used ballast mount racking, with wire trays used for DC string wiring, conduit everywhere else
- With a large number of both inverters, both systems use communication gateways etc. at similar cost in materials and labor except for the extra RS485 cards added to each Brand S inverter to allow communication with their gateway
- With 12 wall-mounted inverters, a gutter is assumed for wiring containment between Brand S 3-phase units
- The HiQ system avoids the cost of the DC string combiner and the DC disconnect switch. However, it does require HiQ AC whips and AC Splice boxes that the Brand S does not. On balance the difference in cost favors the HiQ approach
- **The net benefit is 7.4 ¢/W in using HiQ in this example, excluding inverter cost**

7. Example System C, 56 kW 480V & 208V

7.1. Overview

This project is a hardware store, and is the smallest system modeled; it has been laid out separately for 480V and 208V, and is shown in Figure 10. The 208V system is based on use of two different sizes of Brand S single-phase inverters, specified to ensure the phases remain within 6kW of balance.

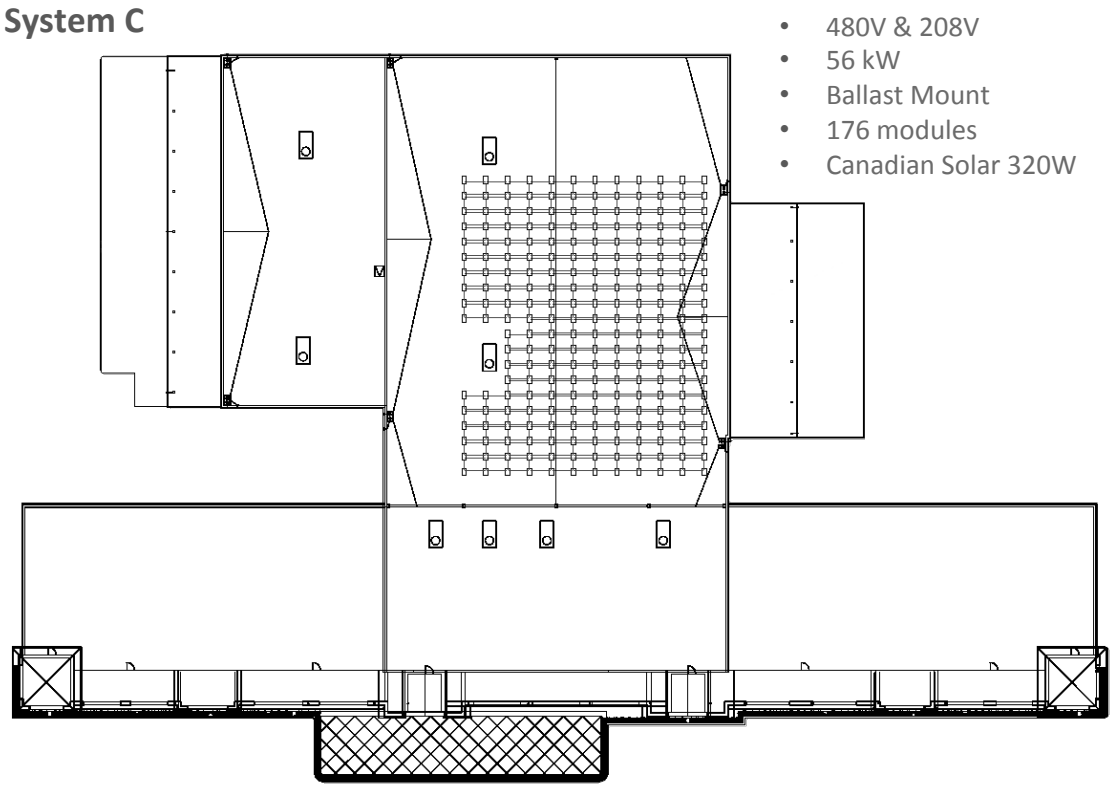


Figure 10: System C plan view

More details on wiring lengths, sizes, and conduit are given in the appendix contained in Section 14.

7.2. System C - 480V Variant – Cost Comparison Summary Tables

Note that this variant, along with the next one, has been modeled in the Customer Proprietary Cost Model (CPCM) and also PVBid.

System C, 56 kW, 480V

	$$$ - Total Cost		CPCM System C - 480V		PVBid System C - 480V	
			HiQ	Brand S	HiQ	Brand S
1	Modules		46,407	46,405	45,376	45,376
2a	**Inverters**	**Mounting**	**504**	**546**	**420**	**605**
2b		**Monitoring**	**925**	**350**	**860**	**205**
3	**DC Electrical Equipment**		**2,091**	**7,828**	**2,020**	**8,245**
4	**AC Electrical Equipment**		**5,988**	**3,498**	**4,814**	**2,957**
5	Interconnection		1,063	1,777	1,702	1,702
6	Racking		15,230	15,230	17,082	17,082
7	Non-Construction		18,494	18,482	18,325	18,325
Total			**90,701**	**94,115**	**90,599**	**94,497**
Hours			*484*	*483*	*487*	*487*

System C, 56 kW, 480V

	¢/W - Cost per Watt		CPCM System C - 480V		PVBid System C - 480V	
			HiQ	Brand S	HiQ	Brand S
1	Modules		82.9	82.9	81.0	81.0
2a	**Inverters**	**Mounting**	**0.9**	**1.0**	**0.8**	**1.1**
2b		**Monitoring**	**1.7**	**0.6**	**1.5**	**0.4**
3	**DC Electrical Equipment**		**3.7**	**14.0**	**3.6**	**14.7**
4	**AC Electrical Equipment**		**10.7**	**6.2**	**8.6**	**5.3**
5	Interconnection		1.9	3.2	3.0	3.0
6	Racking		27.2	27.2	30.5	30.5
7	Non-Construction		33.0	33.0	32.7	32.7
Total			**162.0**	**168.1**	**161.8**	**168.7**

System C, 56 kW, 480V

	¢/W Delta		CPCM HiQ vs Brand S 480V	PVBid HiQ vs Brand S 480V
1	Modules		0.0	-
2a	**Inverters**	**Mounting**	**(0.1)**	**(0.3)**
2b		**Monitoring**	**1.0**	**1.2**
3	**DC Electrical Equipment**		**(10.2)**	**(11.1)**
4	**AC Electrical Equipment**		**4.4**	**3.3**
5	Interconnection		(1.3)	-
6	Racking		-	-
7	Non-Construction		0.0	-
Total			**(6.1)**	**(7.0)**
Hours			*2*	*0*

Figure 11: System C - 480V Variant – Cost Comparison Summary Tables

7.3. System C - 480V Variant – Cost Comparison Commentary

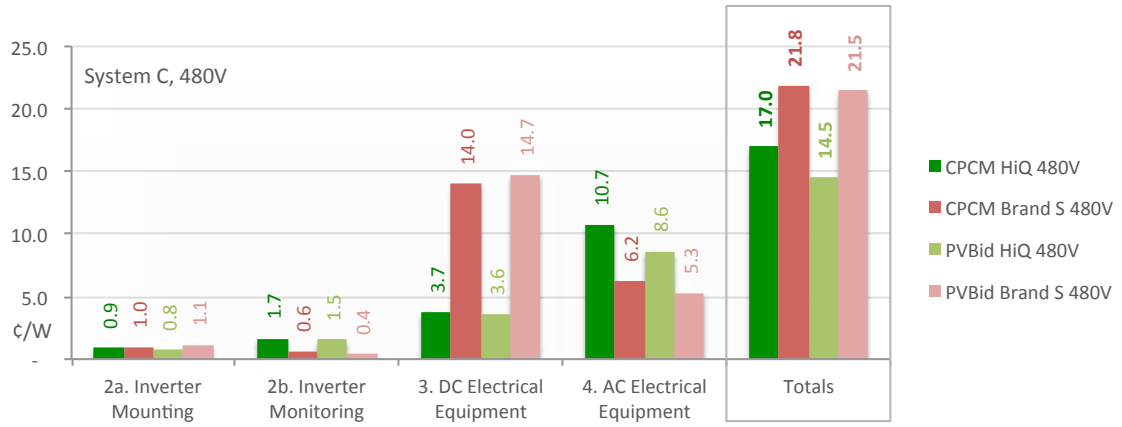


Figure 12: Graph of System C costs in ¢/W, 480V variant

The 480V version costs are shown graphically in Figure 12. Notes on the system bid are given below.

- This project used ballast mount racking, with wire trays used for DC string wiring, conduit everywhere else
- With only 2 Brand S 24 kW units, the communications costs are lower for Brand S by directly connecting Ethernet to each inverter and connecting them together using a low cost third party router, thus avoiding the cost of a Brand S communication gateway and the additional RS485 cards
- With only 2 Brand S 24 kW units mounted on the wall the cost of a gutter was avoided, with conduit being run between the two units instead
- The HiQ system avoids the cost of the DC string combiner and the DC disconnect switch. However, it does require HiQ AC whips and AC Splice boxes that the Brand S does not. On balance the difference in cost favors the HiQ approach
- **The net benefit in BOS cost of using HiQ is between 6.1 ¢/W in using HiQ in this example using the CPCM and 7 ¢/W using PVBid, excluding inverter costs. Note the good correlation between modeling tools.**

7.4. System C - 208V Variant – Cost Comparison Summary Tables

Note that this variant, along with the last one, has been modeled in the Customer Proprietary Cost Model (CPCM) and also PVBid.

System C, 56 kW, 208V

			$$$ - Total Cost	CPCM - 208V		PVBid - 208V	
				HiQ	Brand S	HiQ	Brand S
1	Modules			46,398	46,444	45,376	45,376
2a	Inverters	Mounting		**476**	**1,810**	**430**	**1,470**
2b		Monitoring		**925**	**1,150**	**795**	**893**
3	**DC Electrical Equipment**			**2,253**	**11,070**	**2,139**	**10,594**
4	**AC Electrical Equipment**			**6,264**	**3,594**	**4,847**	**3,281**
5	Interconnection			1,063	1,061	1,810	1,810
6	Racking			15,230	15,230	17,082	17,082
7	Non-Construction			18,443	18,711	18,325	18,325
Total				**$91,053**	**$99,069**	**$90,804**	**$98,830**
Hours				*478*	*513*	*488*	*505*

System C, 56 kW, 208V

			¢/W - Cost per Watt	CPCM - 208V		PVBid - 208V	
				HiQ	Brand S	HiQ	Brand S
1	Modules			82.9	82.9	81.0	81.0
2a	Inverters	Mounting		**0.9**	**3.2**	**0.8**	**2.6**
2b		Monitoring		**1.7**	**2.1**	**1.4**	**1.6**
3	**DC Electrical Equipment**			**4.0**	**19.8**	**3.8**	**18.9**
4	**AC Electrical Equipment**			**11.2**	**6.4**	**8.7**	**5.9**
5	Interconnection			1.9	1.9	3.2	3.2
6	Racking			27.2	27.2	30.5	30.5
7	Non-Construction			32.9	33.4	32.7	32.7
Total				**162.6**	**176.9**	**162.2**	**176.5**

System C, 56 kW, 208V

			¢/W Delta	CPCM HiQ vs Brand S 208V	PVBid HiQ vs Brand S 208V
1	Modules			(0.1)	-
2a	Inverters	Mounting		**(2.4)**	**(1.9)**
2b		Monitoring		**(0.4)**	**(0.2)**
3	**DC Electrical Equipment**			**(15.7)**	**(15.1)**
4	**AC Electrical Equipment**			**4.8**	**2.8**
5	Interconnection			0.0	-
6	Racking			-	-
7	Non-Construction			(0.5)	-
Total				**(14.3)**	**(14.3)**
Hours				*(35.3)*	*(17.1)*

Figure 13: System C - 208V Variant – Cost Comparison Summary Tables

7.5. System C - 208V Variant – Cost Comparison Commentary

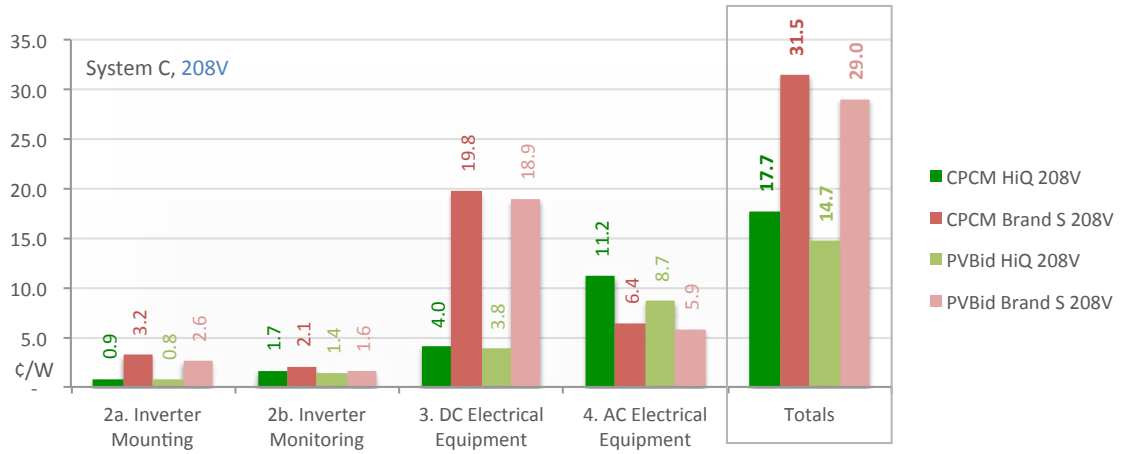


Figure 14: Graph of System C costs in ¢/W, 208V variant

Note that the site was not bid at 208V, but the installer kindly modeled it for us the way they usually approach 208V systems using Brand S inverters. However, 56 kW is at the larger end of 208V systems we have come across, and in reality would be more likely to be designed using 480V inverters and a transformer if it were bid with Brand S, rather than using single phase inverters.

Notes:

- The project used ballast mount racking, and wire trays were used for DC string wiring, with conduit everywhere else
- With a large number of both inverters, both systems use communication gateways
- With 6 wall-mounted inverters, a gutter is assumed for wiring containment between Brand S inverters
- The use of smaller single-phase inverters in the Brand S case meant direct wiring of strings to the inverter/DC disconnect, avoiding the need for Brand S string combiners but resulting in long DC runs. Part way along junction boxes were used to allow transition from #10 PV wire to #10 THHN (see Appendix 14.1 for more details)
- The HiQ system avoids the cost of the DC string combiner and the DC disconnect switch. However, it does require HiQ AC whips and AC Splice boxes that the Brand S does not. For 208V the higher AC current means that the 40A maximum current rating of the HiQ AC Splice box[2] only allows two inverters per box to be connected, increasing the AC cost. However in this example this is offset by the extra complexity of using single-phase inverters in the Brand S case
- **The net benefit is 14.3 ¢/W in using HiQ in this example, excluding inverter costs. Note the good correlation between modeling tools**

[2] As of February 2016, we are recertifying our AC Splice box product to have a 60A maximum current rating. When this is complete it will impact installation costs by allowing three TrueString 208V units per splice box instead of the two allowed now

8. Comparing Relevant Cost Categories

Rather than looking at the most relevant cost categories for each system, the following section looks at each individually and compares the cost for that particular category across all systems and variants.

8.1. Inverter Mounting Costs Compared

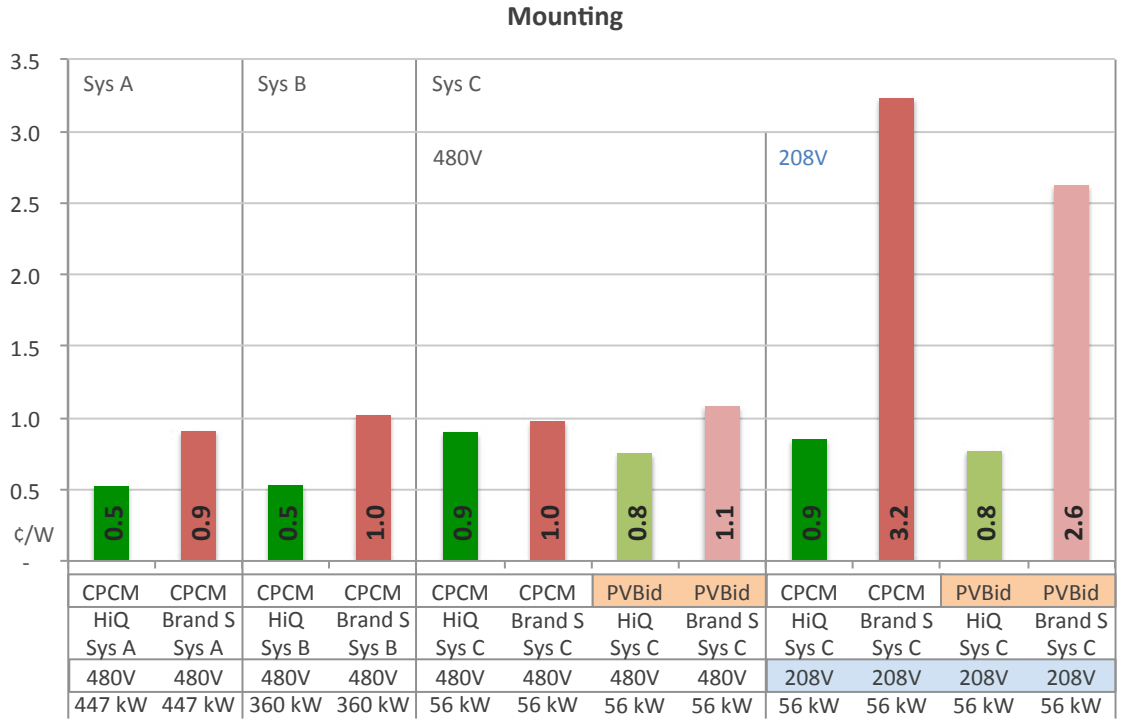


Figure 15: Comparing mounting cost/Watt between systems

The basic trade-off is that the HiQ inverters are cheaper to mount, but there are usually more of them so the net difference is not large. The exception is for the 208V case where the design uses 6 Brand S inverters vs. 8 HiQ 208V inverters.

8.2. Monitoring Costs Compared

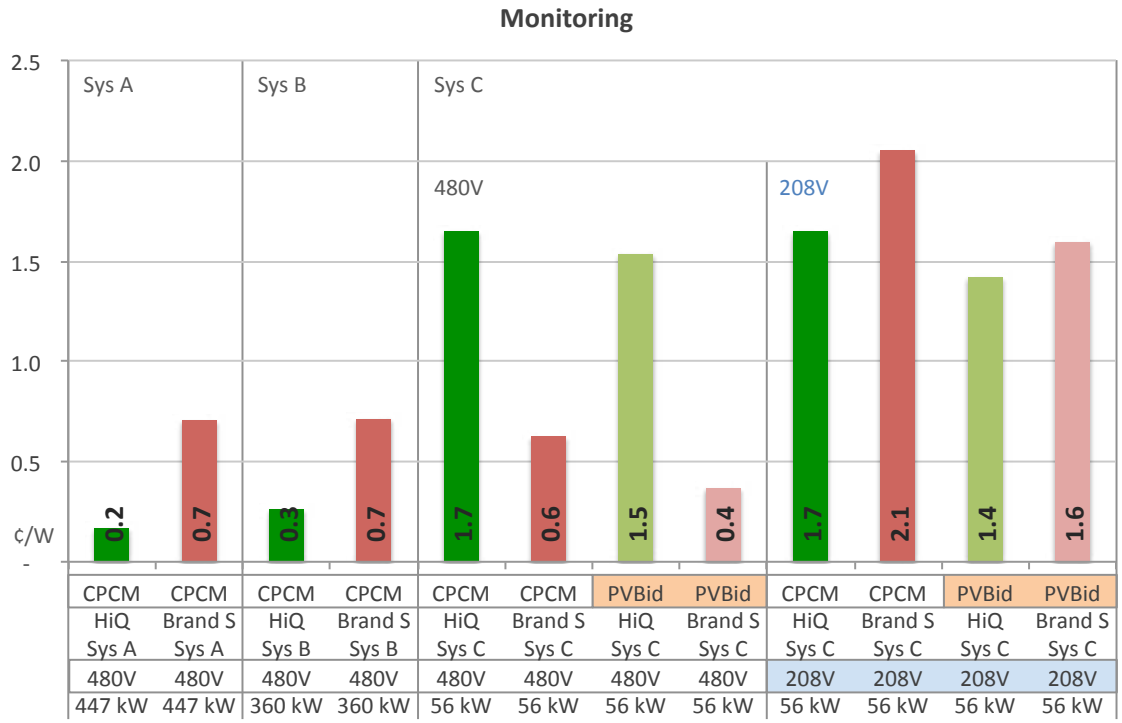


Figure 16: Comparing monitoring cost/Watt between systems

The two bigger systems (A & B) are lower cost as the gateway in each case is spread over more system Wattage. The bigger Brand S inverters need RS485 cards installed which adds a small amount of materials and labor compared to the HiQ power line-based communications.

For 480V System C, the system is small, with only 2x 24 kW inverters, so direct connection of Ethernet and the addition of a low cost router keep costs for monitoring below HiQ.

The 208V System C the situation is similar to the bigger systems in that the gateway for Brand S cannot be avoided; however, the costs are amortized over a smaller Wattage making the cost/Watt higher.

8.3. DC Electrical Equipment Costs Compared

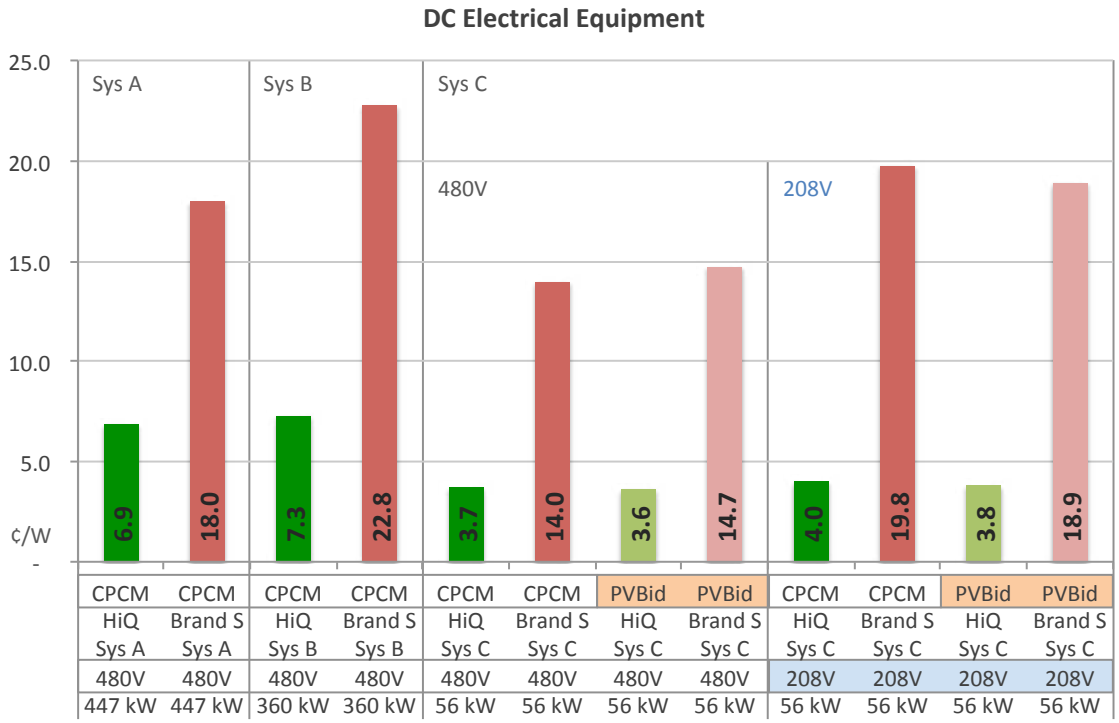


Figure 17: Comparing DC Electrical cost/Watt between systems

Siting the inverters very differently between HiQ and Brand S shows in the electrical costs:

- HiQ DC wiring is simple and short – the strings are individually routed to an inverter sited at the array. The strings can be different lengths as each has it's own individual MPPT input.

- Brand S has long DC runs. In these bids a Brand S string combiner is placed at the edge of the roof to combine strings and allow fewer runs of larger gauge wire back to the DC disconnect.

The DC disconnect, string combiner and long wiring runs all contribute to the consistently higher DC electrical cost for Brand S. Obviously the situation partially corrects itself on the DC side.

The higher costs for Systems A and B relate partially to the complexity and distances in these large installations, and also a comment from the installer that these two systems were bid conservatively.

8.4. AC Electrical Equipment Costs Compared

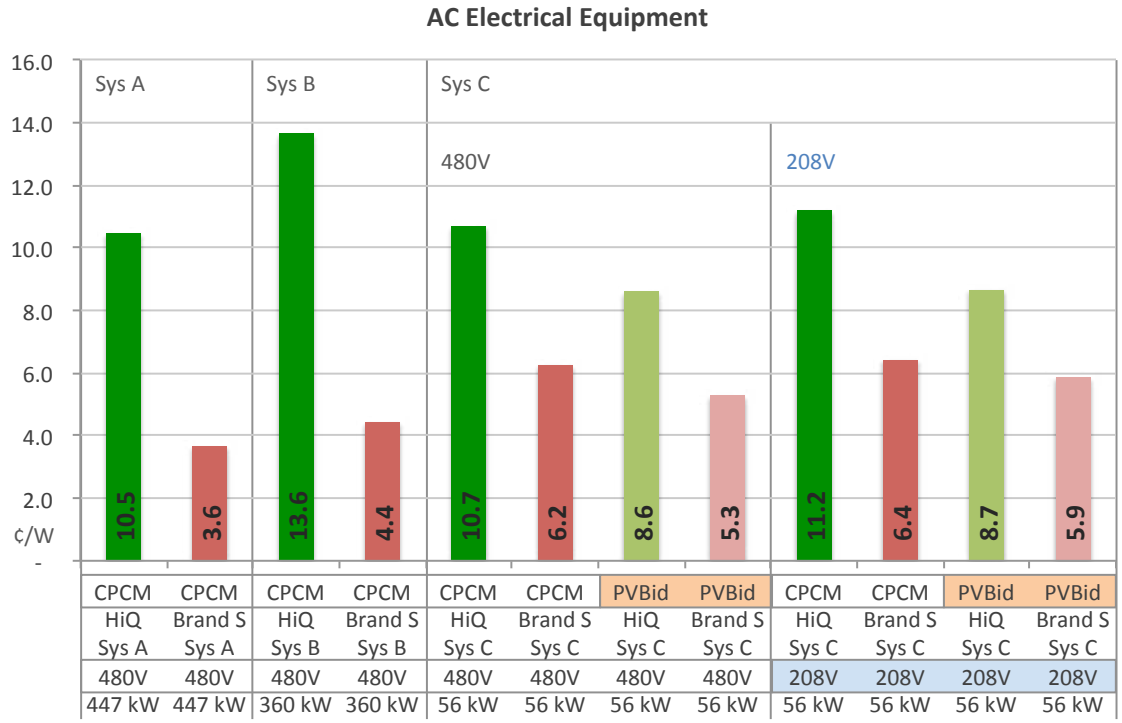


Figure 18: Comparing AC Electrical cost/Watt between systems

For the DC cost the situation flips, with HiQ being consistently higher:

- For Brand S located near the panels the AC side is simpler, with short distances to the Panel PV etc.
- With HiQ each inverter is connected with a proprietary AC whip cable. 3 (for 480V systems) or 2 (for 208V) are joined in the AC Splice box product. There is then a long distance AC run to the Panel PV.

The net result of the different AC and DC approaches is lower cost overall for HiQ.

8.5. Inverter & Electrical Category Totals Compared

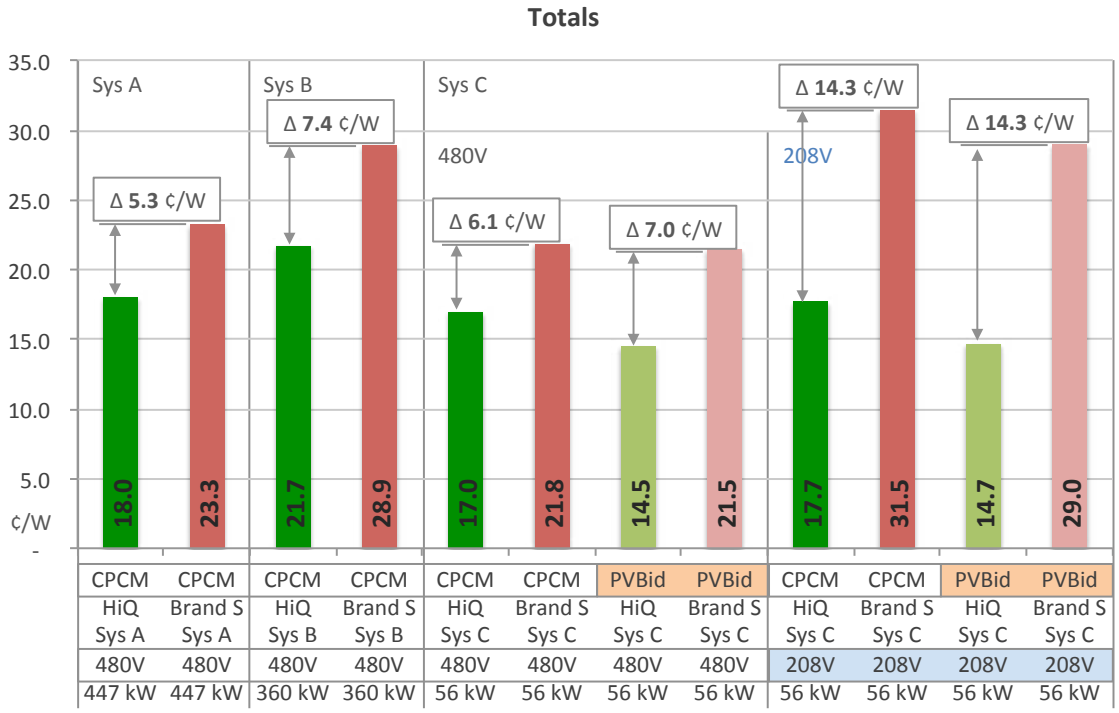


Figure 19: Graph of totals, which includes AC & DC electrical, monitoring and inverter mounting

For the categories that are affected by the inverter used, the totals for each system are shown in Figure 19. The net effect of the placement at the array of the HiQ TrueString is visible in the difference figures shown above each category.

9. Summary

The overall system differences are shown in Figure 20, and the cost/Watt results are shown graphically in Figure 21 below. These figures include categories that are not directly affected by inverter choice, including the modules, racking etc. They exclude the cost of the inverters themselves.

		CPCM $/W	HiQ Saving $/W	PV Bid $/W	HiQ Saving $/W	Voltage	Size (kW STC)	Inverters Used
System A	HiQ	$ 1.38	$ 0.05			480V	447.3 kW	46x HiQ 8k
	Brand S	$ 1.43						16x Brand S 24k
System B	HiQ	$ 1.47	$ 0.07				359.1 kW	38x HiQ 8k
	Brand S	$ 1.54						12x Brand S 24k
System C	HiQ	$ 1.63	$ 0.14	$ 1.62	$ 0.14	208V	56 kW	8x HiQ 5.75k
	Brand S	$ 1.77		$ 1.76				4x Brand S 9k, 2x Brand S 6k
	HiQ	$ 1.62	$ 0.06	$ 1.62	$ 0.07	480V		6x HiQ 8k
	Brand S	$ 1.68		$ 1.69				2x Brand S 24k

Figure 20: System comparison including $/W figure which exclude inverter cost, tax, commissions and overhead

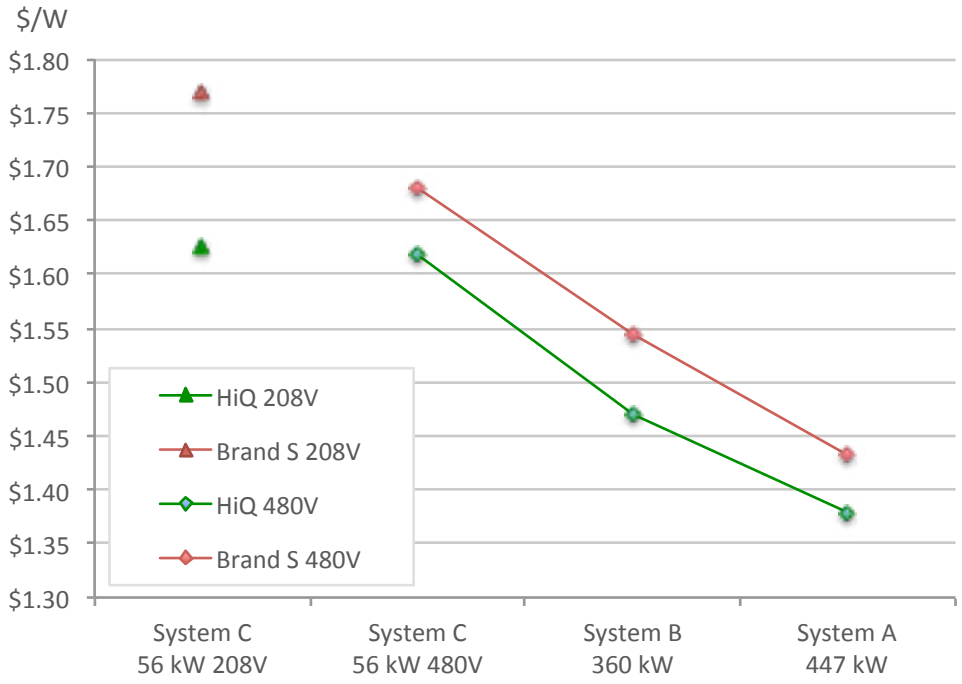


Figure 21: Comparing System Cost for Example Systems (only CPCM figures for consistency)

Note in Figure 21 that the largest system (A) used the slightly more expensive flush mount racking.

Overall costs for systems using HiQ TrueString inverters are between 5 and 7 ¢/W lower at 480V.

Points not captured in the modeling directly relate to ease of design and installation with each inverter type.

- The larger systems show significant time savings; as well as the cost saving from this that is captured in the bids, obviously a faster job with less on-site time has major benefits
- The inverters themselves differ hugely in size and weight. TrueString inverters weigh 24 lb., making them far easier to lift onto a roof and work with, without worrying about lifting equipment etc. The flip-side of this is that more inverters need to be installed compared to larger 24 kW units, but these bids show costs favoring HiQ
- The TrueString inverter's ability to have each string a different length makes layout and string sizing much simpler. Having two string inputs per inverter also makes East/West stringing very simple
- Arc detection is more reliable with an array-mounted inverter, close to the strings of panels, and with individual string inputs rather than with strings in parallel
- For installations in states that have adopted the 2014 NEC, Rapid Shutdown compliance is automatic when the inverters are mounted by the array
- Grounding of the HiQ inverter is through the AC connector, with no need to run separate equipment ground wiring
- HiQ inverters use natural convection passive cooling, meaning there are no fans, air filters or LCD displays that need replacing over time

10. Acknowledgements

Our thanks to the installer whose bids were used in this series of case studies. No inducements were given or requested for use of this information, for which we are grateful.

Considerable work was put in by Connor English of PVBid, for which we are very grateful.

Appendices follow...

11. Appendix 1 – PVBid

PVBid (www.pvbid.com) is a new web-based tool for solar estimators to quickly put together bid packages. Providing automation and feedback loops, PVBid reduces the risk and inaccuracy of bidding while increasing the speed with which accurate bidding occurs. HiQ Solar is not affiliated with the company but we were impressed with how easy it was to get a good model together and work with it.

The sales spin:

- **Bid with certainty.** See how each bid stacks up against actual project data and past proposals.
- **Automatically compile data.** Data is magically collected from all the software and distributors you use to provide a full view of each project.
- **Powerful Realtime Cost Insights.** Machine learning, distribution analysis, and special sauce provide real-time feedback on projects.

The software takes a user through basic steps to create the model, which is easy to edit later and easy to export as a CSV file when you're done if desired. An example segment of screen is shown in Figure 22.

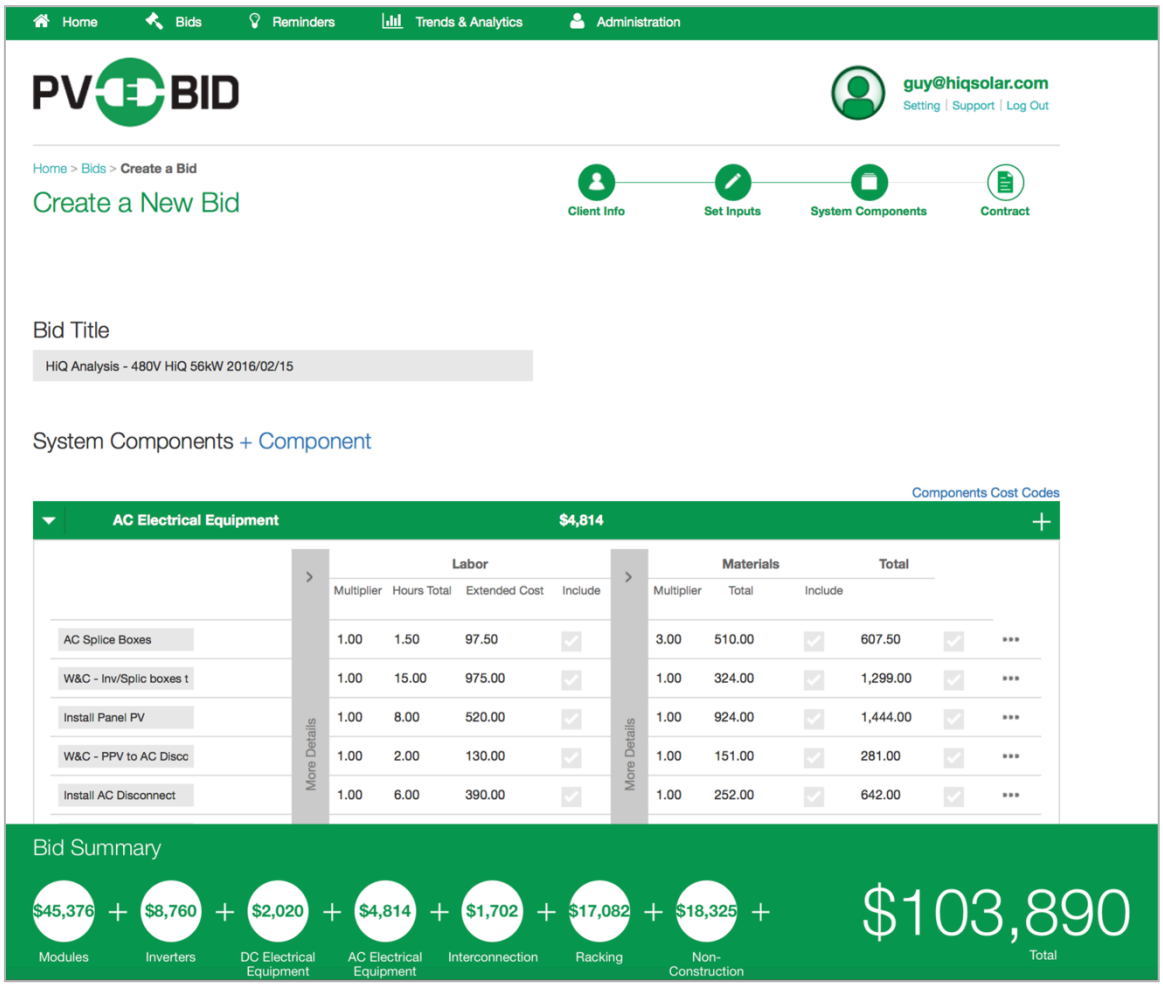


Figure 22: An example PVBid screen

12. Appendix 2 - String Length detail

The following string length calculations applied to each of the systems.

System A	HiQ String Sizing		Brand S String Sizing	
Modules	1420		1420	
Wattage	315		315	
Inverters	46		16	
AC Rating	8000		24000	
Strings	92		76	
	# Strings	Length	# Strings	Length
Length 1	40	16	11	20
Length 2	52	15	32	19
Length 3			31	18
Length 4			2	17

Figure 23: String lengths for System A

System B	HiQ String Sizing		Brand S String Sizing	
Modules	1140		1136	
Wattage	315		315	
Inverters	38		12	
AC Rating	8000		24000	
Strings	76			
	# Strings	Length	# Strings	Length
Length 1	76	15	56	19
Length 2			4	18

Figure 24: String Lengths for System B

System C, 480V	HiQ String Sizing		Brand S String Sizing	
Modules	176		176	
Wattage	320		320	
Inverters	6		2	
AC Rating	8000		24000	
Strings	12		176	
	# Strings	Length	# Strings	Length
Length 1	8	15	6	18
Length 2	4	14	4	17

Figure 25: String lengths for System C at 480V

System C, 208V	HiQ String Sizing		Brand S String Sizing A	
Modules	176		132	
Wattage	320		320	
Inverters	8		4	
AC Rating	5750		9000	
Strings	16		12	
	# Strings	Length	# Strings	Length
Length 1	16	11	12	11

	Brand S String Sizing B	
Modules	44	
Wattage	320	
Inverters	2	
AC Rating	6000	
Strings	4	
	# Strings	Length
Length 1	4	11

Figure 26: String lengths for System C at 208V

13. Appendix 3 – System Cost Details

13.1. System A – HiQ CPCM Costs

System A		480V			
CPCM	447.3 kW	HiQ			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*790.8*	$39,541	$355,291	$394,832
	Install Modules on ballasted racking	*413.1*	$20,655	$350,776	
	Mobilization	*334.0*	$16,701	$1,810	
	Safety	*43.7*	$2,185	$2,704	
2. Inverters		*45.3*	$2,242	$850	$3,092
	Install Inverter on building wall	*41.8*	$2,092	$250	
	Inverter Costs - 38x HiQ 8kW	*0.0*	$0	$0	
	Monitoring	*3.5*	$150	$600	
3. DC Electrical Equipment		*213.0*	$10,650	$20,054	$30,704
	DC String to Combiner box / inverter	*117.7*	$5,885	$3,429	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*0.0*	$0	$0	
	Install DC Disconnect	*2.7*	$133	$245	
	Grounding the Array	*92.6*	$4,632	$8,130	
	Trenching for conduit	*0.0*	$0	$8,250	
4. AC Electrical Equipment		*263.8*	$13,190	$33,647	$46,837
	AC Splice boxes	*35.7*	$1,783	$2,835	
	Wiring from Inverters to Panel PV	*147.5*	$7,377	$17,048	
	Install Panel PV	*54.7*	$2,734	$6,975	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*6.2*	$308	$3,946	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*19.7*	$987	$2,843	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*50.7*	$2,537	$1,925	$4,462
	Install Line Side Tap	*50.7*	$2,537	$1,925	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*59.3*	$2,964	$89,851	$92,815
	Panel Claw ballasted Racking	*28.1*	$1,405	$17,185	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*0.0*	$0	$0	
	Install seismic anchors	*31.2*	$1,559	$0	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$72,666	
7. Non-Construction		*696.8*	$35,097	$9,161	$44,258
	Engineering	*128.8*	$6,700	$5,020	
	Project Managment	*312.4*	$15,619	$0	
	Permitting	*51.0*	$2,552	$3,385	
	Interconnection paperwork	*71.9*	$3,596	$0	
	Crew Travel	*79.7*	$3,983	$756	
	System Commissioning	*53.0*	$2,648	$0	
Totals		***2119.8***	**$106,221**	**$510,780**	$617,001

Figure 27: System A – HiQ CPCM Costing

13.2. System A – Brand S CPCM Costs

System A			480V		
CPCM	447.3 kW		Brand S		
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*795.8*	$39,789	$355,291	$395,080
	Install Modules on ballasted racking	*413.1*	$20,655	$350,776	
	Mobilization	*339.0*	$16,949	$1,810	
	Safety	*43.7*	$2,185	$2,704	
2. Inverters		*75.0*	$3,750	$3,470	$7,220
	Install Inverter on building wall	*64.0*	$3,200	$870	
	Inverter Costs - 16x Brand S 24k	*0.0*	$0	$0	
	Monitoring	*11.0*	$550	$2,600	
3. DC Electrical Equipment		*419.4*	$20,969	$59,498	$80,468
	DC String to Combiner box / inverter	*180.1*	$9,006	$6,685	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*0.0*	$0	$0	
	Install DC Disconnect	*146.6*	$7,331	$36,433	
	Grounding the Array	*92.6*	$4,632	$8,130	
	Trenching for conduit	*0.0*	$0	$8,250	
4. AC Electrical Equipment		*117.3*	$5,871	$10,447	$16,318
	AC Splice boxes	*0.0*	$0	$0	
	Wiring from Inverters to Panel PV	*43.4*	$2,176	$2,529	
	Install Panel PV	*67.7*	$3,387	$3,972	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*6.2*	$308	$3,946	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*0.0*	$0	$0	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*50.7*	$2,537	$1,925	$4,462
	Install Line Side Tap	*50.7*	$2,537	$1,925	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*59.3*	$2,964	$89,851	$92,815
	Panel Claw ballasted Racking	*28.1*	$1,405	$17,185	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*0.0*	$0	$0	
	Install seismic anchors	*31.2*	$1,559	$0	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$72,666	
7. Non-Construction		*697.3*	$35,123	$9,179	$44,302
	Engineering	*128.8*	$6,700	$5,020	
	Project Managment	*312.4*	$15,619	$0	
	Permitting	*51.0*	$2,552	$3,385	
	Interconnection paperwork	*71.9*	$3,596	$0	
	Crew Travel	*80.2*	$4,009	$774	
	System Commissioning	*53.0*	$2,648	$0	
Totals		***2214.8***	**$111,004**	**$529,661**	$640,665

Figure 28: System A – Brand S CPCM Costing

13.3. System B – HiQ CPCM Costs

System B		480V			
CPCM	359.1 kW	HiQ			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*658.6*	$32,931	$283,486	$316,416
	Install Modules on ballasted racking	*309.4*	$15,471	$281,609	
	Mobilization	*326.7*	$16,337	$1,605	
	Safety	*22.4*	$1,122	$272	
2. Inverters		*36.3*	$1,817	$1,013	$2,830
	Install Inverter on building wall	*29.7*	$1,484	$413	
	Inverter Costs - 38x HiQ 8kW	*0.0*	$0	$0	
	Monitoring	*6.7*	$333	$600	
3. DC Electrical Equipment		*299.2*	$14,959	$11,144	$26,103
	DC String to Combiner box / inverter	*260.4*	$13,020	$7,278	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*0.0*	$0	$0	
	Install DC Disconnect	*2.5*	$127	$205	
	Grounding the Array	*36.2*	$1,812	$3,660	
	Trenching for conduit	*0.0*	$0	$0	
4. AC Electrical Equipment		*344.7*	$16,329	$32,668	$48,997
	AC Splice boxes	*30.3*	$1,517	$2,342	
	Wiring from Inverters to Panel PV	*223.7*	$11,183	$21,288	
	Install Panel PV	*55.1*	$1,849	$3,777	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*18.3*	$915	$2,913	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*17.3*	$865	$2,349	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*49.0*	$2,449	$2,220	$4,669
	Install Line Side Tap	*49.0*	$2,449	$2,220	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*77.0*	$3,852	$92,130	$95,982
	Panel Claw ballasted Racking	*14.5*	$727	$7,810	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*17.1*	$856	$69,736	
	Install seismic anchors	*45.4*	$2,269	$4,301	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$10,283	
7. Non-Construction		*573.8*	$28,993	$3,710	$32,702
	Engineering	*150.2*	$7,813	$3,020	
	Project Managment	*255.6*	$12,780	$0	
	Permitting	*30.5*	$1,523	$0	
	Interconnection paperwork	*16.0*	$800	$0	
	Crew Travel	*77.3*	$3,863	$689	
	System Commissioning	*44.3*	$2,214	$0	
Totals		***2038.7***	**$101,329**	**$426,372**	$527,701

Figure 29: System B – HiQ CPCM Costing

13.4. System B – Brand S CPCM Costs

System B			480V		
CPCM	357.8 kW		Brand S		
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*666.3*	$33,317	$282,495	$315,812
	Install Modules on ballasted racking	*308.4*	$15,421	$280,621	
	Mobilization	*335.5*	$16,776	$1,602	
	Safety	*22.4*	$1,120	$272	
2. Inverters		*66.5*	$3,450	$2,753	$6,203
	Install Inverter on building wall	*60.0*	$3,000	$653	
	Inverter Costs - 12x Brand S 24k	*0.0*	$0	$0	
	Monitoring	*6.5*	$450	$2,100	
3. DC Electrical Equipment		*596.9*	$29,846	$51,667	$81,513
	DC String to Combiner box / inverter	*437.0*	$21,850	$17,801	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*0.0*	$0	$0	
	Install DC Disconnect	*123.8*	$6,190	$30,218	
	Grounding the Array	*36.1*	$1,806	$3,648	
	Trenching for conduit	*0.0*	$0	$0	
4. AC Electrical Equipment		*123.4*	$6,144	$9,679	$15,823
	AC Splice boxes	*0.0*	$0	$0	
	Wiring from Inverters to Panel PV	*43.5*	$2,151	$2,349	
	Install Panel PV	*57.0*	$2,849	$3,777	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*18.3*	$913	$2,902	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*0.0*	$0	$0	
	Install Gutter	*4.6*	$230	$653	
5. Interconnection		*48.9*	$2,447	$2,219	$4,666
	Install Line Side Tap	*48.9*	$2,447	$2,219	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*77.0*	$3,848	$91,858	$95,707
	Panel Claw ballasted Racking	*14.5*	$725	$7,783	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*17.1*	$853	$69,491	
	Install seismic anchors	*45.4*	$2,271	$4,301	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$10,283	
7. Non-Construction		*574.5*	$29,024	$3,739	$32,763
	Engineering	*150.1*	$7,804	$3,020	
	Project Managment	*254.9*	$12,747	$0	
	Permitting	*30.4*	$1,522	$0	
	Interconnection paperwork	*16.0*	$800	$0	
	Crew Travel	*78.8*	$3,942	$719	
	System Commissioning	*44.2*	$2,208	$0	
Totals		***2153.5***	**$108,076**	**$444,410**	$552,486

Figure 30: System B – Brand S CPCM Costing

13.5. System C – HiQ CPCM 480V Costs

System C		480V			
CPCM	56 kW	HiQ			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*97.1*	$6,312	$40,095	$46,407
	Install Modules on ballasted racking	*49.3*	$3,206	$38,914	
	Mobilization	*40.7*	$2,644	$932	
	Safety	*7.1*	$461	$250	
2. Inverters		*11.8*	$769	$660	$1,429
	Install Inverter on building wall	*6.8*	$444	$60	
	Inverter Costs - 6x HiQ 8kW	*0.0*	$0	$0	
	Monitoring	*5.0*	$325	$600	
3. DC Electrical Equipment		*19.4*	$1,264	$827	$2,091
	DC String to Combiner box / inverter	*11.1*	$722	$243	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to I	*0.0*	$0	$0	
	Install DC Disconnect	*1.0*	$66	$32	
	Grounding the Array	*7.3*	$477	$552	
	Trenching for conduit				
4. AC Electrical Equipment		*44.9*	$2,920	$3,068	$5,988
	AC Splice boxes	*9.0*	$585	$340	
	Wiring from Inverters to Panel PV	*14.0*	$907	$814	
	Install Panel PV	*9.0*	$583	$1,218	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*6.0*	$390	$356	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*7.0*	$455	$341	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*9.7*	$632	$431	$1,063
	Install Line Side Tap	*9.7*	$632	$431	
	Install wire between interconnection &	*0.0*	$0	$0	
6. Racking		*21.9*	$1,421	$13,810	$15,230
	Panel Claw ballasted Racking	*10.5*	$680	$10,912	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*4.6*	$297	$880	
	Install seismic anchors	*6.8*	$444	$595	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$1,423	
7. Non-Construction		*279.3*	$18,157	$337	$18,494
	Engineering	*87.0*	$5,652	$34	
	Project Managment	*75.1*	$4,880	$0	
	Permitting	*37.7*	$2,452	$0	
	Interconnection paperwork	*23.0*	$1,498	$0	
	Crew Travel	*46.2*	$3,004	$303	
	System Commissioning	*10.3*	$672	$0	
Totals		***484.2***	**$31,473**	**$59,228**	$90,701

Figure 31: System C – HiQ CPCM 480V Costs

13.6. System C – Brand S CPCM 480V Costs

System C		480V			
CPCM	56 kW	Brand S			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*97.1*	$6,309	$40,095	$46,405
	Install Modules on ballasted racking	*49.3*	$3,206	$38,914	
	Mobilization	*40.6*	$2,642	$932	
	Safety	*7.1*	$461	$250	
2. Inverters		*11.9*	$696	$200	$896
	Install Inverter on building wall	*6.9*	$446	$100	
	Inverter Costs - 2x Brand S 24k	*0.0*	$0	$0	
	Monitoring	*5.0*	$250	$100	
3. DC Electrical Equipment		*36.2*	$2,351	$5,477	$7,828
	DC String to Combiner box / inverter	*12.8*	$834	$1,512	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to	*11.8*	$765	$2,779	
	Install DC Disconnect	*4.2*	$275	$634	
	Grounding the Array	*7.3*	$477	$552	
	Trenching for conduit				
4. AC Electrical Equipment		*22.4*	$1,456	$2,042	$3,498
	AC Splice boxes	*0.0*	$0	$0	
	Wiring from Inverters to Panel PV	*7.4*	$484	$468	
	Install Panel PV	*9.0*	$583	$1,218	
	Wiring from Panel PV to AC Disconne	*0.0*	$0	$0	
	Install AC Disconnect	*6.0*	$390	$356	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*0.0*	$0	$0	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*14.1*	$915	$862	$1,777
	Install Line Side Tap	*14.1*	$915	$862	
	Install wire between interconnection	*0.0*	$0	$0	
6. Racking		*21.9*	$1,421	$13,810	$15,230
	Panel Claw ballasted Racking	*10.5*	$680	$10,912	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*4.6*	$297	$880	
	Install seismic anchors	*6.8*	$444	$595	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$1,423	
7. Non-Construction		*279.2*	$18,146	$336	$18,482
	Engineering	*87.0*	$5,652	$34	
	Project Managment	*75.1*	$4,880	$0	
	Permitting	*37.7*	$2,452	$0	
	Interconnection paperwork	*23.0*	$1,498	$0	
	Crew Travel	*46.0*	$2,993	$302	
	System Commissioning	*10.3*	$672	$0	
Totals		***482.6***	**$31,294**	**$62,822**	$94,115

Figure 32: System C – Brand S CPCM 480V Costs

13.7. System C – HiQ PVBid 480V Costs

System C		480V			
PVBid		HiQ			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Materials Cost**	
1. Modules		*93.5*	$6,079	$39,298	$45,376
	Install Modules on ballasted racking	*47.5*	$3,089	$38,298	
	Mobilization	*6.0*	$390	$0	
	Safety	*40.0*	$2,600	$1,000	
2. Inverters		*10.0*	$650	$630	$1,280
	Install Inverter on building wall	*6.0*	$390	$30	
	HiQ 8k	*0.0*	$0	$0	
	Monitoring	*4.0*	$260	$600	
3. DC Electrical Equipment		*26.1*	$1,695	$325	$2,020
	DC String to Combiner box / inverter wi	*12.0*	$780	$202	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*0.0*	$0	$0	
	Install DC Disconnect	*0.0*	$0	$0	
	Grounding the Array	*14.1*	$915	$123	
4. AC Electrical Equipment		*36.5*	$2,370	$2,444	$4,814
	AC Splice boxes	*1.5*	$98	$510	
	Wiring from splice box to Panel PV	*15.0*	$975	$324	
	Install Panel PV	*8.0*	$520	$924	
	Wiring from Panel PV to AC Disconnect	*2.0*	$130	$151	
	Install AC Disconnect	*6.0*	$390	$252	
	Install circuit breakers	*3.0*	$195	$186	
	Inverter to AC Splice box - cables	*1.0*	$62	$97	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*15.0*	$975	$727	$1,702
	Install Line Side Tap	*12.0*	$780	$500	
	Install wire between interconnection & disco	*3.0*	$195	$227	
6. Racking		*30.1*	$1,955	$15,126	$17,082
	Panel Claw ballasted Racking	*7.0*	$458	$9,680	
	Ballast for the racking	*3.5*	$229	$1,126	
	Install Slip Sheets	*3.5*	$229	$880	
	Install seismic anchors	*10.0*	$650	$700	
	Wire trays	*6.0*	$390	$1,190	
	Roofing subcontractor	*0.0*	$0	$1,550	
7. Non-Construction		*276.0*	$17,940	$385	$18,325
	Engineering	*90.0*	$5,850	$0	
	Project Managment	*70.0*	$4,550	$0	
	Permitting	*40.0*	$2,600	$0	
	Interconnection paperwork	*20.0*	$1,300	$0	
	Crew Travel	*46.0*	$2,990	$385	
	System Commissioning	*10.0*	$650	$0	
Totals		*487.1*	$31,664	$58,935	$90,599

Figure 33: System C – HiQ PVBid 480V Costs

13.8. System C – Brand S PVBid 480V Costs

System C		480V			
PVBid		Brand S			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Materials Cost**	
1. Modules		*93.5*	$6,079	$39,298	$45,376
	Install Modules on ballasted racking	*47.5*	$3,089	$38,298	
	Mobilization	*6.0*	$390	$0	
	Safety	*40.0*	$2,600	$1,000	
2. Inverters		*9.0*	$585	$225	$810
	Install Inverter on building wall	*7.0*	$455	$150	
	Inverter Costs -Brand S 24k	*0.0*	$0		
	Monitoring	*2.0*	$130	$75	
3. DC Electrical Equipment		*42.1*	$2,735	$5,510	$8,245
	DC String to Combiner box / inverter wiring	*10.0*	$650	$280	
	Install Combiner box	*3.0*	$195	$746	
	Install wire and conduit - Combiner to Inverter	*12.0*	$780	$3,681	
	Install DC Disconnect	*3.0*	$195	$680	
	Grounding the Array	*14.1*	$915	$123	
4. AC Electrical Equipment		*21.0*	$1,365	$1,592	$2,957
	AC Splice boxes	*0.0*	$0	$0	
	Wiring from Inverters to Panel PV	*4.0*	$260	$79	
	Install Panel PV	*8.0*	$520	$924	
	Wiring from Panel PV to AC Disconnect	*2.0*	$130	$151	
	Install AC Disconnect	*6.0*	$390	$252	
	Install circuit breakers	*1.0*	$65	$186	
	Inverter to AC Splice box - cables	*0.0*	$0	$0	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*15.0*	$975	$727	$1,702
	Install Line Side Tap	*12.0*	$780	$500	
	Install wire between interconnection & disco	*3.0*	$195	$227	
6. Racking		*30.1*	$1,955	$15,126	$17,082
	Panel Claw ballasted Racking	*7.0*	$458	$9,680	
	Ballast for the racking	*3.5*	$229	$1,126	
	Install Slip Sheets	*3.5*	$229	$880	
	Install seismic anchors	*10.0*	$650	$700	
	Wire trays	*6.0*	$390	$1,190	
	Roofing subcontractor	*0.0*	$0	$1,550	
7. Non-Construction		*276.0*	$17,940	$385	$18,325
	Engineering	*90.0*	$5,850	$0	
	Project Managment	*70.0*	$4,550	$0	
	Permitting	*40.0*	$2,600	$0	
	Interconnection paperwork	*20.0*	$1,300	$0	
	Crew Travel	*46.0*	$2,990	$385	
	System Commissioning	*10.0*	$650	$0	
Totals		*486.7*	$31,634	$62,863	$94,497

Figure 34: System C – Brand S PVBid 480V Costs

13.9. System C – HiQ CPCM 208V Costs

System C		208V			
CPCM	56 kW	HiQ			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*97.0*	$6,303	$40,095	$46,398
	Install Modules on ballasted racking	*49.3*	$3,206	$38,914	
	Mobilization	*40.5*	$2,635	$932	
	Safety	*7.1*	$461	$250	
2. Inverters		*11.1*	$721	$680	$1,401
	Install Inverter on building wall	*6.1*	$396	$80	
	Inverter Costs - 8x HiQ 5.75kW	*0.0*	$0	$0	
	Monitoring	*5.0*	$325	$600	
3. DC Electrical Equipment		*18.6*	$1,209	$1,044	$2,253
	DC String to Combiner box / inverter	*10.1*	$658	$457	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*1.2*	$75	$35	
	Install DC Disconnect	*0.0*	$0	$0	
	Grounding the Array	*7.3*	$477	$552	
	Trenching for conduit				
4. AC Electrical Equipment		*40.7*	$2,643	$3,622	$6,264
	AC Splice boxes	*10.3*	$672	$453	
	Wiring from Inverters to Panel PV	*7.5*	$489	$2,056	
	Install Panel PV	*9.0*	$583	$302	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*6.2*	$401	$356	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*7.7*	$498	$455	
	Install Gutter	*0.0*	$0	$0	
5. Interconnection		*9.7*	$632	$431	$1,063
	Install Line Side Tap	*9.7*	$632	$431	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*21.9*	$1,421	$13,810	$15,230
	Panel Claw ballasted Racking	*10.5*	$680	$10,912	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*4.6*	$297	$880	
	Install seismic anchors	*6.8*	$444	$595	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$1,423	
7. Non-Construction		*278.6*	$18,112	$331	$18,443
	Engineering	*87.0*	$5,652	$34	
	Project Managment	*75.1*	$4,880	$0	
	Permitting	*37.7*	$2,452	$0	
	Interconnection paperwork	*23.0*	$1,498	$0	
	Crew Travel	*45.5*	$2,959	$298	
	System Commissioning	*10.3*	$672	$0	
Totals		***477.5***	**$31,040**	**$60,013**	$91,053

Figure 35: System C – HiQ CPCM 208V Costs

13.10. System C – Brand S CPCM 208V Costs

System C		208V			
CPCM	56 kW	Brand S			
Component	**Line Item**	*Labor Hours*	**Labor Cost**	**Material Costs**	
1. Modules		*97.7*	$6,349	$40,095	$46,444
	Install Modules on ballasted racking	*49.3*	$3,206	$38,914	
	Mobilization	*41.2*	$2,681	$932	
	Safety	*7.1*	$461	$250	
2. Inverters		*28.2*	$1,810	$1,150	$2,960
	Install Inverter on building wall	*23.2*	$1,510	$300	
	Inverter Costs - Brand S 2x 6kW & 4x 9kW	*0.0*	$0	$0	
	Monitoring	*5.0*	$300	$850	
3. DC Electrical Equipment		*49.4*	$3,210	$7,859	$11,070
	DC String to Combiner box / inverter	*29.1*	$1,894	$4,791	
	Install Combiner box	*0.0*	$0	$0	
	Install wire and conduit - Combiner to Inverter	*6.4*	$417	$1,316	
	Install DC Disconnect	*6.5*	$423	$1,200	
	Grounding the Array	*7.3*	$477	$552	
	Trenching for conduit				
4. AC Electrical Equipment		*23.7*	$1,543	$2,051	$3,594
	AC Splice boxes	*0.0*	$0	$0	
	Wiring from Inverters to Panel PV	*4.6*	$297	$1,094	
	Install Panel PV	*9.0*	$583	$302	
	Wiring from Panel PV to AC Disconnect	*0.0*	$0	$0	
	Install AC Disconnect	*6.2*	$401	$356	
	Install circuit breakers	*0.0*	$0	$0	
	Inverter to AC Splice box - cables	*0.0*	$0	$0	
	Install Gutter	*4.0*	$262	$300	
5. Interconnection		*9.7*	$630	$431	$1,061
	Install Line Side Tap	*9.7*	$630	$431	
	Install wire between interconnection & disco	*0.0*	$0	$0	
6. Racking		*21.9*	$1,421	$13,810	$15,230
	Panel Claw ballasted Racking	*10.5*	$680	$10,912	
	Ballast for the racking	*0.0*	$0	$0	
	Install Slip Sheets	*4.6*	$297	$880	
	Install seismic anchors	*6.8*	$444	$595	
	Wire trays	*0.0*	$0	$0	
	Roofing subcontractor	*0.0*	$0	$1,423	
7. Non-Construction		*282.3*	$18,349	$362	$18,711
	Engineering	*87.0*	$5,652	$34	
	Project Managment	*75.1*	$4,880	$0	
	Permitting	*37.7*	$2,452	$0	
	Interconnection paperwork	*23.0*	$1,498	$0	
	Crew Travel	*49.2*	$3,196	$328	
	System Commissioning	*10.3*	$672	$0	
Totals		***512.9***	**$33,311**	**$65,758**	$99,069

Figure 36: System C – Brand S CPCM 208V Costs

13.11. System C – HiQ PVBid 208V Costs

System C 208V
PVBid HiQ

Component	Line Item	Labor Hours	Labor Cost	Materials Cost	
1. Modules		93.5	$6,079	$39,298	$45,376
	Install Modules on ballasted racking	47.5	$3,089	$38,298	
	Mobilization	40.0	$2,600	$1,000	
	Safety	6.0	$390	$0	
2. Inverters		9.0	$585	$640	$1,225
	Install Inverter on building wall	6.0	$390	$40	
	HiQ 5.75k	0.0	$0	$0	
	Monitoring	3.0	$195	$600	
3. DC Electrical Equipment		26.9	$1,747	$392	$2,139
	DC String to Combiner box / inverter w	12.8	$832	$269	
	Install Combiner box				
	Install wire and conduit - Combiner to Inverter				
	Install DC Disconnect				
	Grounding the Array	14.1	$915	$123	
4. AC Electrical Equipment		37.3	$2,423	$2,424	$4,847
	AC Splice boxes	1.5	$98	$510	
	Wiring from Inverters to Panel PV	17.0	$1,105	$632	
	Install Panel PV	8.0	$520	$508	
	Wiring from Panel PV to AC Disconnect	2.0	$130	$223	
	Install AC Disconnect	6.0	$390	$252	
	Install circuit breakers	1.5	$98	$201	
	Inverter to AC Splice box - cables	1.3	$83	$97	
	Install Gutter	0.0	$0	$0	
5. Interconnection		15.0	$975	$835	$1,810
	Install Line Side Tap	12.0	$780	$500	
	Install wire between interconnection & disco	3.0	$195	$335	
6. Racking		30.1	$1,955	$15,126	$17,082
	Panel Claw ballasted Racking	7.0	$458	$9,680	
	Ballast for the racking	3.5	$229	$1,126	
	Install Slip Sheets	3.5	$229	$880	
	Install seismic anchors	10.0	$650	$700	
	Wire trays	6.0	$390	$1,190	
	Roofing subcontractor	0.0	$0	$1,550	
7. Non-Construction		276.0	$17,940	$385	$18,325
	Engineering	90.0	$5,850	$0	
	Project Managment	70.0	$4,550	$0	
	Permitting	40.0	$2,600	$0	
	Interconnection paperwork	20.0	$1,300	$0	
	Crew Travel	46.0	$2,990	$385	
	System Commissioning	10.0	$650	$0	
Totals		487.8	$31,704	$59,100	$90,804

Figure 37: System C – HiQ PVBid 208V Costs

13.12. System C – Brand S PVBid 208V Costs

System C 208V
PVBid Brand S

Component	Line Item	Labor Hours	Labor Cost	Materials Cost	
1. Modules		93.5	$6,079	$39,298	$45,376
	Install Modules on ballasted racking	47.5	$3,089	$38,298	
	Mobilization	6.0	$390	$0	
	Safety	40.0	$2,600	$1,000	
2. Inverters		22.5	$1,463	$900	$2,363
	Install Inverter on building wall	18.0	$1,170	$300	
	Inverter Costs - Brand S 6000US-22	0.0	$0	$0	
	Monitoring	4.5	$293	$600	
	Inverter Costs - Brand S 9000US-12	0.0	$0	$0	
3. DC Electrical Equipment		41.8	$2,716	$7,878	$10,594
	DC String to Combiner box / inverter wirir	11.2	$728	$840	
	Install Combiner box	4.5	$293	$1,194	
	Install wire and conduit - Combiner to Inverter	12.0	$780	$3,681	
	Install DC Disconnect	0.0	$0	$2,040	
	Grounding the Array	14.1	$915	$123	
4. AC Electrical Equipment		26.0	$1,690	$1,591	$3,281
	AC Splice boxes	0.0	$0	$0	
	Wiring from Inverters to Panel PV	5.0	$325	$222	
	Install Panel PV	8.0	$520	$508	
	Wiring from Panel PV to AC Disconnect	2.0	$130	$223	
	Install AC Disconnect	6.0	$390	$252	
	Install circuit breakers	3.0	$195	$246	
	Inverter to AC Splice box - cables	0.0	$0	$0	
	Install Gutter	2.0	$130	$140	
5. Interconnection		15.0	$975	$835	$1,810
	Install Line Side Tap	12.0	$780	$500	
	Install wire between interconnection & disco	3.0	$195	$335	
6. Racking		30.1	$1,955	$15,126	$17,082
	Panel Claw ballasted Racking	7.0	$458	$9,680	
	Ballast for the racking	3.5	$229	$1,126	
	Install Slip Sheets	3.5	$229	$880	
	Install seismic anchors	10.0	$650	$700	
	Wire trays	6.0	$390	$1,190	
	Roofing subcontractor	0.0	$0	$1,550	
7. Non-Construction		276.0	$17,940	$385	$18,325
	Engineering	90.0	$5,850	$0	
	Project Managment	70.0	$4,550	$0	
	Permitting	40.0	$2,600	$0	
	Interconnection paperwork	20.0	$1,300	$0	
	Crew Travel	46.0	$2,990	$385	
	System Commissioning	10.0	$650	$0	
Totals		504.9	$32,817	$66,013	$98,830

Figure 38: System C – Brand S PVBid 208V Costs

14. Appendix 4 - System C Wiring

As an example, the wiring and layout for the two System C variants are given in this section.

14.1. System C – 480V Wiring Layouts

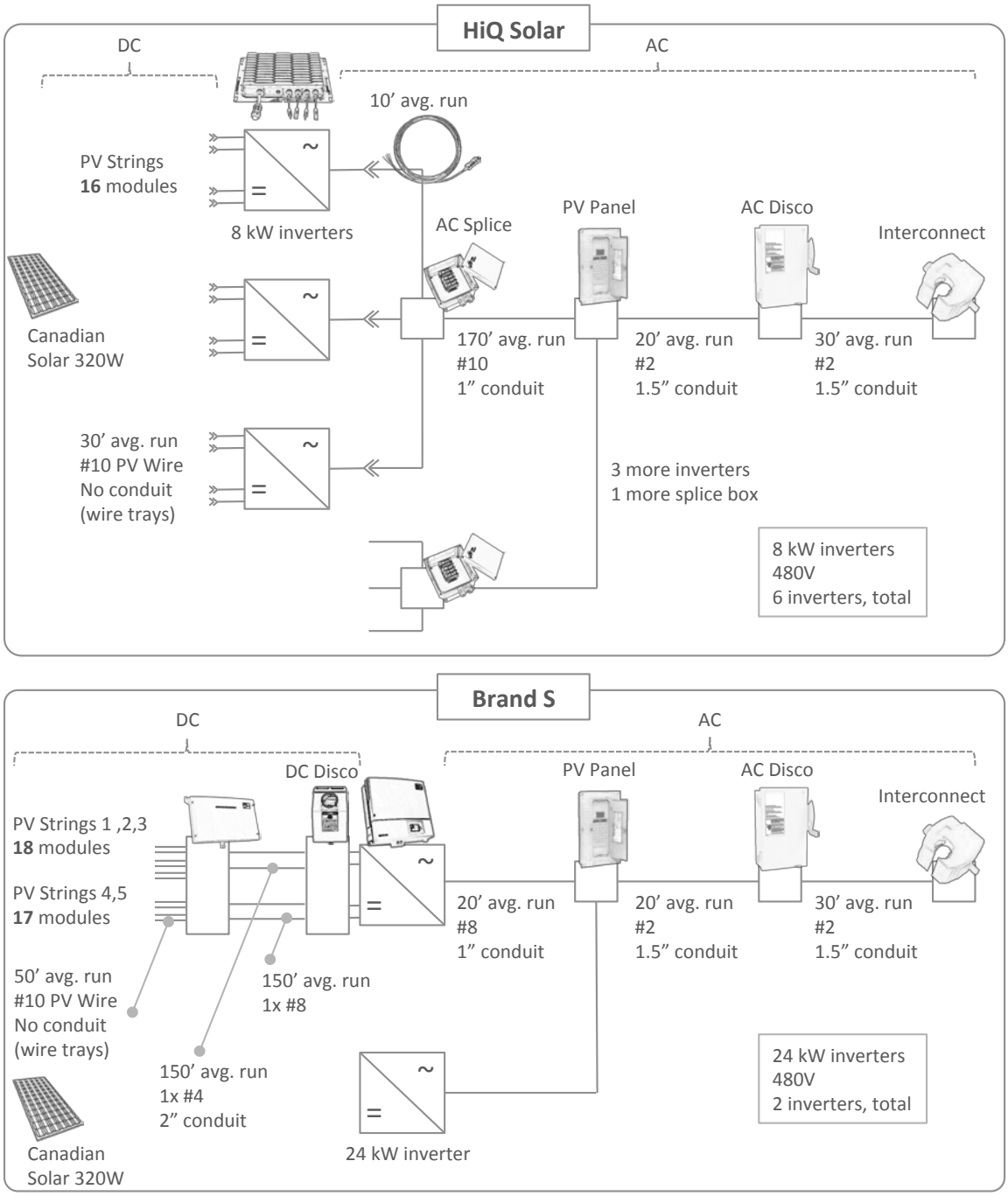


Figure 39: 480V wiring and layout details for System C

14.1. System C – 208V Wiring Layouts

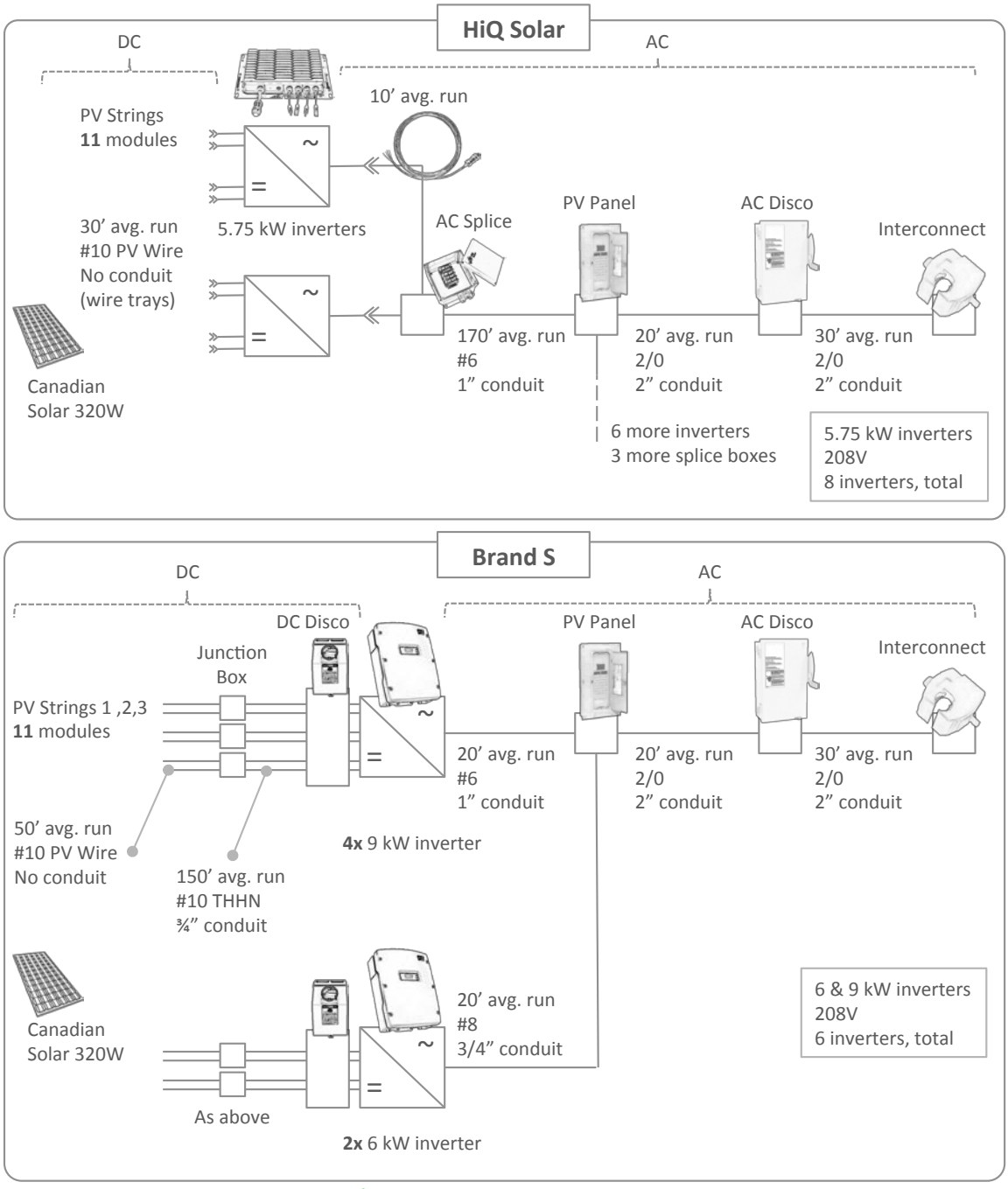


Figure 40: 208V wiring and layout details for System C

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