Silverado Senior Living

Brookfield, Wisconsin

Analysis Topics

On-site Prefabrication of Interior Wall Panels

Installation of Solar Panels

SIPS for Resident Rooms

Re-sequencing of the Project Schedule

*Courtesy of Hunzinger

Breadth Topics

Electrical

Electrical design and modifications needed for solar panel installation

Structural

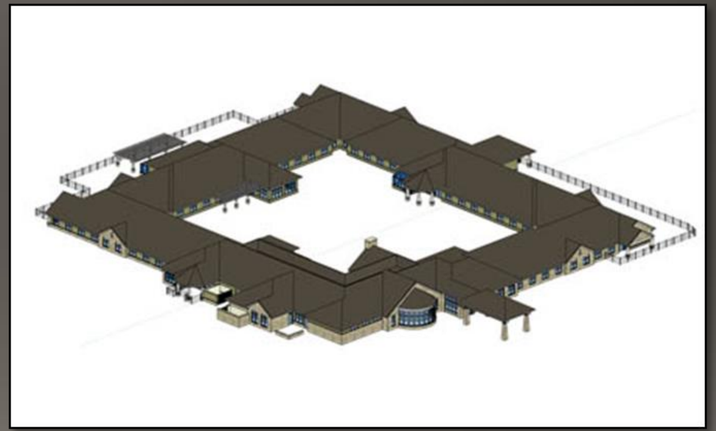
Structural design and modifications needed to support additional load from solar panels

Presented by Cameron Mikkelson April 16, 2014

Presentation Outline

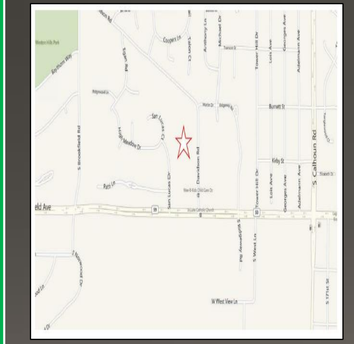
*Courtesy of Hunzinger

- Project Overview
- Analysis 1: Prefabrication
- Analysis 2: Solar Panel Installation
  - Electrical Breadth
- Analysis 3: SIPS
- Analysis 4: Re-sequencing Project Schedule
- Conclusion and Acknowledgements
- Appendix



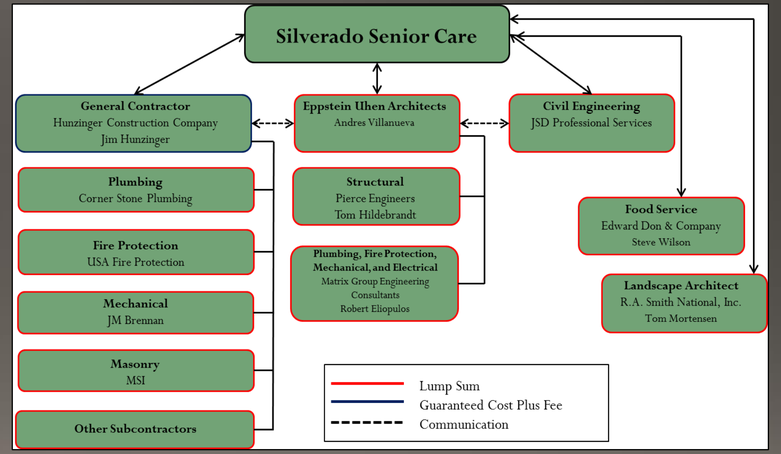
*Courtesy of Hunzinger

Project Overview



*Courtesy of Hunzinger

Building Name:	Silverado Senior Living
Location:	Brookfield, WI
Building Owner:	Silverado
Occupancy:	I-2
Delivery Method:	Design-Bid-Build
Dates of Construction:	September 2012 – September 2013
Size:	45,230 sq. ft.
Total Project Cost:	$9.2 million
Stories above Grade:	One



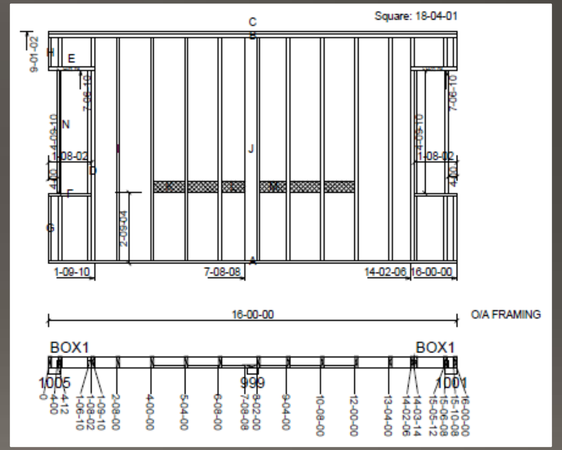
Project Overview

Design Goal

Explore alternative, cost effective methods of construction to ultimately reduce field installation time.

Prefabrication of Interior Wall Panels

*Courtesy of Hunzinger



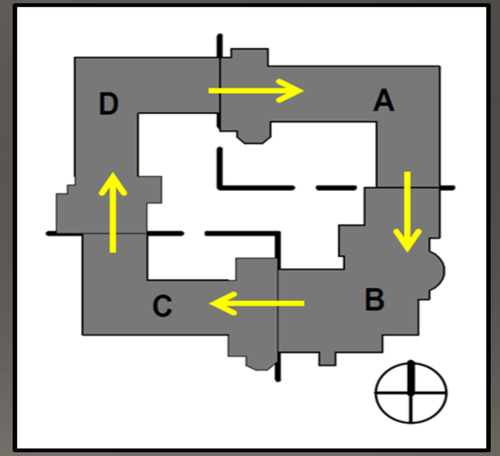
*Courtesy of Hunzinger

Prefabrication of Interior Wall Panels

Background Information

- 143 interior wall panels
- Wood stud framing
- Panel installation 34 days
- Plumbing rough-in 35 days
- 4 quadrants divided into 3 panel deliveries
- Interior courtyard

Activity	Start	Finish
Wall Panels	4-Feb	12-Mar
Plumbing Rough-In	26-Mar	19-Jul



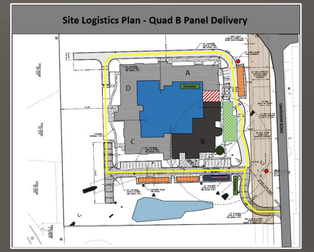
*Courtesy of Hunzinger

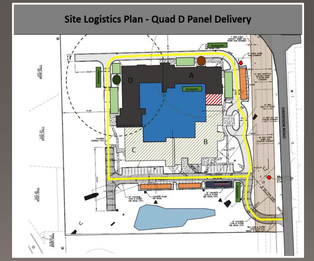
Prefabrication of Interior Wall Panels

Prefabrication Location and Temporary Enclosure

- 66’ x 82’ Mega Structure from Mahaffy
- $40,745
- Delivery, install, 3-month rent, takedown

*Courtesy of Mahaffy Fabric Structures





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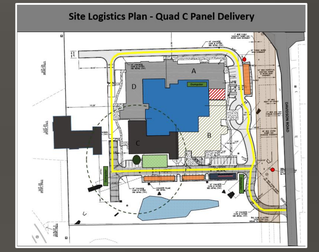
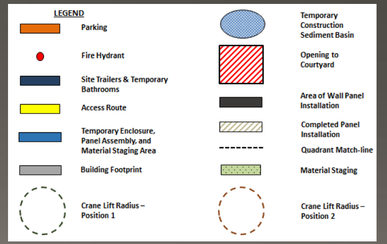




Prefabrication of Interior Wall Panels

Panel Assembly and Installation

- Reduced schedule by 13 days

Panel Quadrant Delivery	Total Labor Hours
B	151
C	230
A/D	531
	912

Panel Quadrant Delivery	No. of Panels	Delivery	Assembly	Install
B	25	17-Dec	Dec 17 - Dec 28	Jan 25 - Feb 6
C	32	28-Dec	Dec 28 - Jan 7	Feb 6 - Feb 15
A/D	86	17-Jan	Jan 17 - March 6	Feb 15 - March 8th

Constructability Concerns

- Coordination with panel supplier
- Scheduling
- Spatial considerations for temporary enclosure
- Protection of existing work
- Field Issues

Prefabrication of Interior Wall Panels

Results

- Schedule reduction: 13 days
- Additional expenses: $84, 457
- Safety
- Quality control and logistical issues

Cost Breakdown

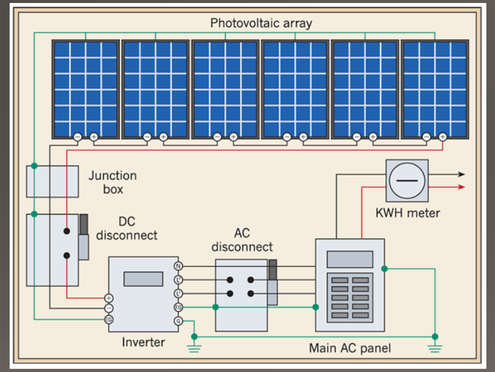
Final Cost Analysis	
Temporary Warehouse	-$40,745
Trucking Costs	-$1,670
Equpiment	-$38,580
Labor	-$32,160
General Conditions Savings	$28,698
	-$84,457

Prefabrication of Interior Wall Panels

Conclusion and Recommendation

Do not utilize prefabrication as a means of achieving a reduction in schedule.

Installation of Solar Panels



www.ecmweb.com

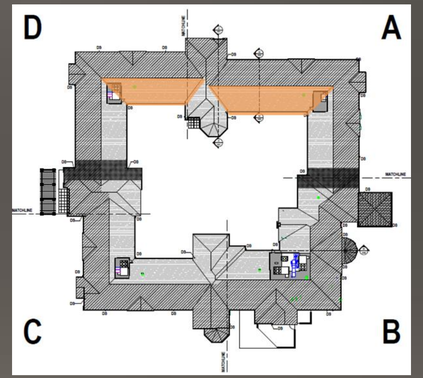
www.solren.com

www.solren.com

Installation of Solar Panels

Background Information

- Aesthetics and orientation
- 5324 SF of usable rooftop area
- Roof truss system
- EPDM roofing with composite asphalt shingles
- 3 Phase
- 208 Y/120 v



Usable rooftop area *Courtesy of Hunzinger

Installation of Solar Panels

Components

- Grid-tied system
- 5 strings of 11 modules (55 modules)
- Selectria Renewables PVI 14 TL inverter with integrated string combiner
- Quick Mount PV Classic Composition
- Rooftrac racking system
- 60 A circuit breaker

Sharp ND-250QCS

www.solren.com

Solectria Inverter

www.solren.com

Quick Mount PV Classic Composition

www.quickmountpv.com

Roof Trac™ Patent #6,360,491

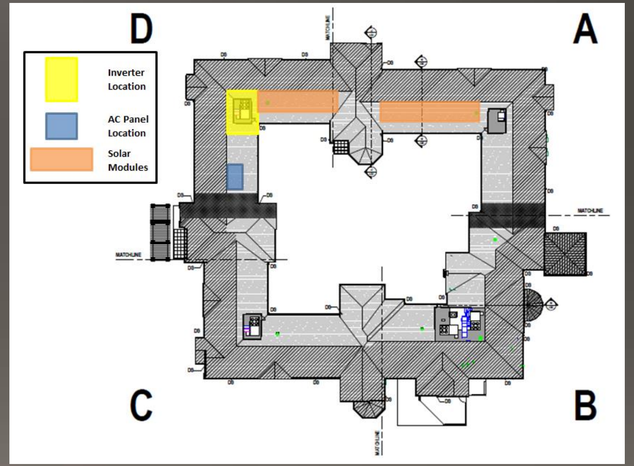
www.prosolar.com

Installation of Solar Panels

Component Placement

- Quad A: 3 strings (33 modules)
- Quad D: 2 strings (22 modules)
- Inverter located in rooftop mechanical area in Quad D
- AC panel and utility tie in located in RM D130.3

*Courtesy of Hunzinger



*Courtesy of Hunzinger

Installation of Solar Panels – Electrical Breadth

Purpose

- Additional equipment and optimal location
- Shading impact
- Electrical distribution
- Payback period
- LEED contribution

Installation of Solar Panels – Electrical Breadth

Equipment

- Module – Sharp ND-250QCS
  - Max. Power 250 W
  - Efficiency 15.3 %
  - Max. Power Voltage 29.8 V
  - Short Circuit Current 8.9 A

- Inverter – PVI 14 TL
  - Continuous Output Power 14 KW
  - Efficiency 96.7 %
  - Max. Open Circuit Voltage 600 V
  - Continuous Output Current 39 A

Distribution

Module to Inverter (DC): #12 AWG THWN-2

Voltage Drop 1.8% < 3%

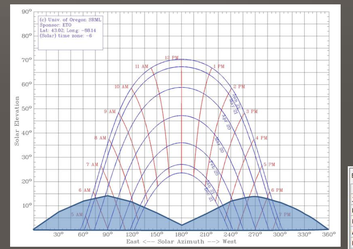
Inverter to Utility Connection (AC): #8 AWG THWN-2

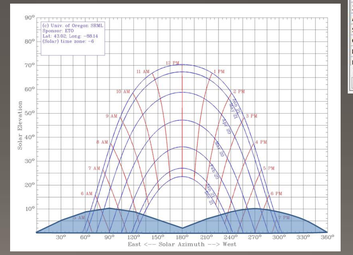
Voltage Drop 1.6% < 2%

Installation of Solar Panels – Electrical Breadth

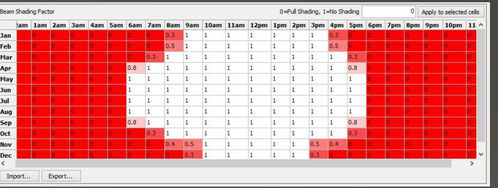
Shading and Obstructions

*Courtesy of Hunzinger





www.solardat.uoregon.edu

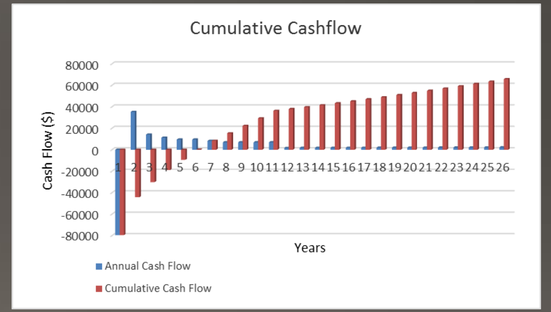


Shading Charts for Milwaukee

Installation of Solar Panels – Electrical Breadth

Payback and LEED

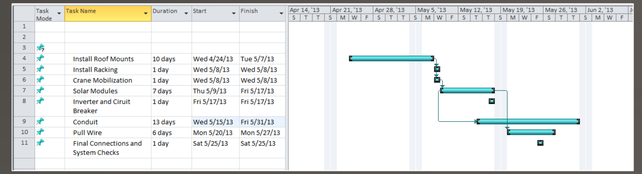
- 6.2 years
- Annual System Output: 15 (kWh)
- Annual Energy Value: $3,110.95
- 30% Federal cash incentive
- 0.5 $/kwh State incentive for Wisconsin
- 1 point LEED contribution



Installation of Solar Panels

Schedule and Cost

- 291 labor hours



Task Mode	Task Name	Duration	Start	Finish
4	Install Roof Mounts	10 days	Wed 4/24/13	Tue 5/7/13
5	Install Racking	1 day	Wed 5/8/13	Wed 5/8/13
6	Crane Mobilization	1 day	Wed 5/8/13	Wed 5/8/13
7	Solar Modules	7 days	Thu 5/9/13	Fri 5/17/13
8	Inverter and Ciruit Breaker	1 day	Fri 5/17/13	Fri 5/17/13
9	Conduit	13 days	Wed 5/15/13	Fri 5/31/13
10	Pull Wire	6 days	Mon 5/20/13	Mon 5/27/13
11	Final Connections and System Checks	1 day	Sat 5/25/13	Sat 5/25/13

Source	Item	Cost/Unit	Qty	Total Cost
Civic Solar	Solar Module (Sharp ND - 250QCS)	$268/Ea	55	$14,740.00
Civic Solar	Inverter (PVI_14TL w/ string combiner)	$5253.25/Ea	1	$5,253.25
RS MEANS	60 Amp Circuit Breaker	896/Ea	1	$896.00
Platt	Classic Composition Mount	$0.10/Watt	13750	$1,375.00
ProSolar	Racking	$234.80/Ea	6	$1,408.80
RS MEANS	#12 AWG conductor (THWN-2)	$52.55/CLF	50.24	$2,640.00
RS MEANS	#8 AWG conductor (THWN-2)	$91.50/CLF	4.15	$380.00
RS MEANS	Conduit 1/2"	$3.22/LF	1256	$4,044.30
RS MEANS	Conduit 3/4"	$4.01/LF	83	$332.80
SolarCity	Solar Panel Installation	$2.80/Watt	13750	$38,500.00
RS MEANS	Daily Crane Crew	$1275/day	3	$3,825.00
				$73,395.15

Constructability

- Contractor availability
- Equipment
- Roof penetrations and obstacles
- Warranty

Installation of Solar Panels

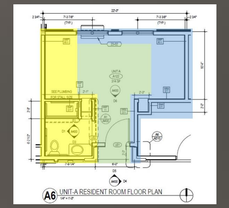
Conclusion & Recommendation

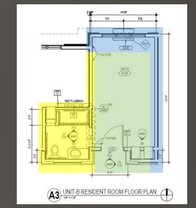
It is recommended to install rooftop solar panels for this project.

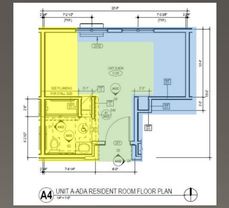
SIPS for Resident Rooms

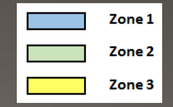
Background Information

- 50 sleeping units
- 3 layouts
- 96 days originally allotted for Mechanical, Electrical, Fire-Protection rough-in
- Work progression









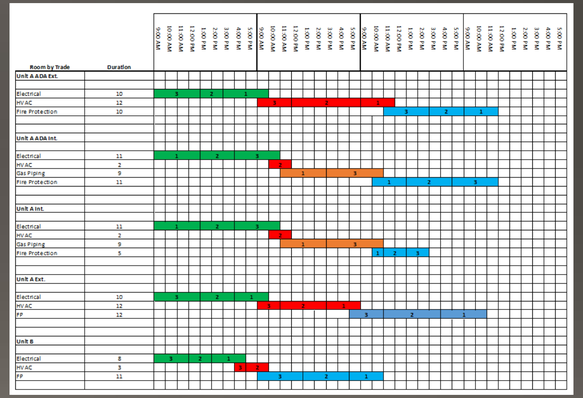
*Courtesy of Hunzinger

SIPS for Resident Rooms

Durations and Sequence

Electrical → HVAC → Gas Piping → FP

Time Saved per Room Layout					
Layout	**No. of Room**	**Original total Duration**	**SIPS Duration**	**Time Saved per Room**	**Cumulative Time Saved**
Unit A ADA Ext.	14	32	30	2	28
Unit A ADA Int.	11	33	30	3	33
Unit A Int.	7	27	24	3	21
Unit A Ext.	8	34	32	2	16
Unit B	10	22	2	2	20
		Net-total			118



SIPS for Resident Rooms

Constructability Concerns

- Early coordination
- Higher congestion
- Material and equipment staging areas
- Expected delays

Cost Savings

Schedule reduction: 14 days

$31,000 cost savings from general conditions

SIPS for Resident Rooms

Conclusion and Recommendation

It is recommended that SIPS is implemented on this project.

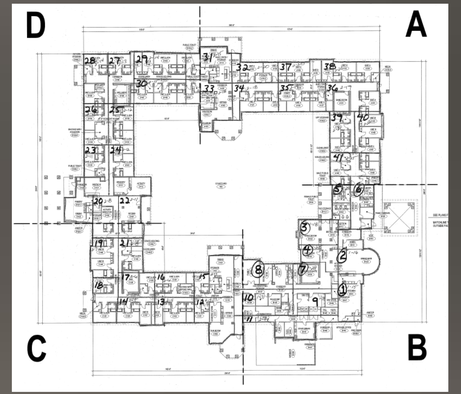
Re-sequencing of the Project Schedule

Background Information

- Slab on grade scheduled Jan 9 to March 1
- $175,000 allotted for winter conditions
- Critical path

*Courtesy of Hunzinger

*Courtesy of Hunzinger



Pour Sequence

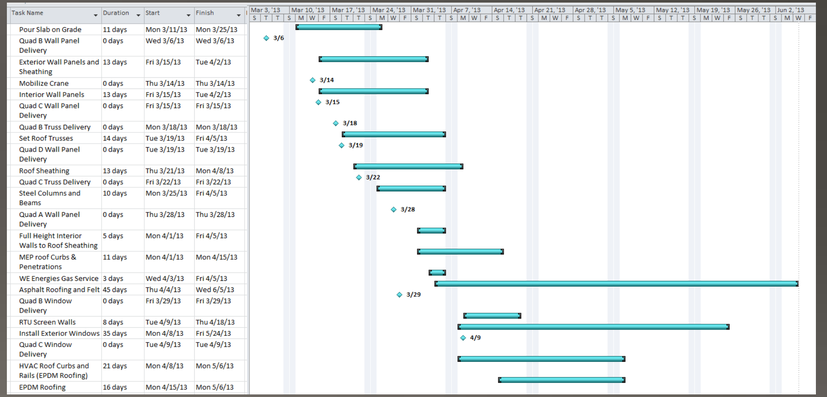
*Courtesy of Hunzinger

Re-sequencing of the Project Schedule

Schedule Modifications

- 43 Days
- Additional concrete crew
- Overtime

Activity	Original Start	Original Finish	Adjusted Start	Adjusted Finish
Pour Slab on Grade	9-Jan	1-Mar	11-Mar	25-Mar
Quad B Wall Panel Delivery	25-Jan		6-Mar	
Exterior Wall Panels and Sheathing	4-Feb	12-Mar	15-Mar	2-Apr
Mobilize Crane	4-Feb		14-Mar	
Interior Wall Panels	8-Feb	12-Mar	15-Mar	2-Apr
Quad C Wall Panel Delivery	8-Feb		15-Mar	
Quad B Truss Delivery	11-Mar		18-Mar	
Set Roof Trusses	14-Feb	2-Apr	19-Mar	5-Apr
Quad D Wall Panel Delivery	14-Feb		19-Mar	
Roof Sheathing	18-Feb	4-Apr	21-Mar	8-Apr
Quad C Truss Delivery	20-Feb		22-Mar	
Steel Columns and Beams	21-Feb	25-Feb	25-Mar	28-Mar
Quad A Wall Panel Delivery	25-Feb		28-Mar	
Full Height Interior Walls to Roof Sheathing	26-Feb	19-Mar	1-Apr	5-Apr
MEP roof Curbs & Penetrations	6-Mar	27-Mar	1-Apr	13-Apr
WE Energies Gas Service	12-Mar	14-Mar	3-Apr	5-Apr
Asphalt Roofing and Felt	14-Mar	31-May	4-Apr	31-May
Window Delivery Quad B	14-Mar		29-Mar	
RTU Screen Walls	18-Mar	22-Mar	9-Apr	18-Apr
Install Exterior Windows	26-Mar	24-May	8-Apr	24-May
Window Delivery Quad C	28-Mar		9-Apr	
HVAC Roof Curbs and Rails (EPDM Roofing)	2-Apr	9-Apr	8-Apr	6-May
EPDM Roofing	4-Apr	6-May	15-Apr	6-May



Re-sequencing of the Project Schedule

Cost Analysis

Activity	Crew	Overtime Hours	Standard Rate	Premium Rate	Total	Adjusted Total
Pour Slab on Grade (Crew 1)	C-6	72	$211.70	$317.55	$22,863.60	$16,089.20
Pour Slab on Grade (Crew 2)	C-6	72	$211.70	$317.55	$22,863.60	$16,089.20
Exterior Wall Panels and Sheathing	F-3	56	$204.85	$307.28	$17,207.40	$10,652.20
Interior Wall Panels	F-3	88	$204.85	$307.28	$27,040.20	$17,207.40
Set Roof Trusses	F-3	88	$204.85	$307.28	$27,040.20	$20,485.00
Roof Sheathing	2 Carp.	96	$90.40	$135.60	$13,017.60	$8,678.40
MEP roof Curbs & Penetrations	G-1	64	$275.60	$413.40	$26,457.60	$22,048.00
						$111,249.40

Trade/Item	Qty	Unit	Days needed	Cost/Day	Total cost
Concrete C-6					
Gas engine vibrators	2	Ea	26	$54.56	$2,837.12
MEP Roof Curbs and Penetrations G-1					
1 Application Equipment	1	Ea	2	$182.16	$364.32
1 Tar Kettle/Pot	1	Ea	2	$94.71	$189.42
Crew Truck	1	Ea	2	$176.44	$352.88
					$3,743.74

- Labor and equipment
- Quality control
- Coordination

Added Labor Expenses	Added Equipment Expenses	Potential Savings	Cost Impact
$111,249	$3,744	$105,000	-$9,993

Re-sequencing of the Project Schedule

Conclusion and Recommendation

It is not recommended to re-sequence the project schedule on this project.

Conclusion and Acknowledgements

Final Conclusion

Analysis 1: It is not recommended to utilize prefabrication as a means of achieving a reduction in schedule.

Analysis 2: It is recommended to install rooftop solar panels

Analysis 3: It is recommended that SIPS is implemented on this project.

Analysis 4: It is not recommended to re-sequence the project schedule on this project.

Conclusion and Acknowledgements

Acknowledgements

Dr. Ed Gannon

Professor Parfitt

Dr. Leicht

Penn State AE Faculty

Industry

BUILDERS Hunzinger SINCE 1907

SILVERADO AT HOME • SENIOR LIVING • HOSPICE

eua eppstein uhen : architects

Special Thanks

James R. Hunzinger –*Executive Vice President*

Jon Sheahan –*Senior Project Manager*

Tim Verheyen –*VDCC Coordinator, Senior Estimator*

Jim Callen –*Field Superintendent*

PACE Industry Members

Family and Friends

Conclusion and Acknowledgements

Questions?

*Courtesy of Hunzinger

Appendix

Quad B Wall Panel Plumbing Take-offs

Panel	Component	Quantiy	Units	Labor Hours	Total Hours
7	1 1/2" Diameter, PVC Schedule 40 Cleanout Tee	1.0	Ea.	0.533	0.5
	1 1/2" Diameter PVC, Schedule 40 Piping	10.5	LF	0.222	2.3
	1 1/4" Diameter PVC, Schedule 40 Piping	10.5	LF	0.19	2.0
	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	3" Diameter PVC, Schedule 40 Piping	1.3	LF	0.302	0.4
	1 1/2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.602	0.6
	1 1/4" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	1 1/2" Diameter, PVC, Schedule 40 Cleanout Plug	1.0	Ea.	0.25	0.3
	2" Diameter PVC, Reducing Insert	1.0	Ea.	0.4	0.4
	3" Diameter PVC, Reducing Insert	1.0	Ea.	0.8	0.8
10	1 1/2" Diameter PVC, Schedule 40 Piping	12.7	LF	0.222	2.8
11	2" Diameter PVC, Schedule 40 Piping	12.7	LF	0.271	3.4
13	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	2" Diameter PVC, Reducing Insert	1.0	Ea.	0.4	0.4
14	1 1/4" Diameter PVC, Schedule 40 Piping	7.1	LF	0.19	1.4
	2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.271	2.4
	3" Diameter PVC, Schedule 40 Piping	1.3	LF	0.302	0.4
	3" Diameter PVC, Schedule 40 Tee	1.0	Ea.	1.053	1.1
	3" Diameter PVC, Reducing Insert	1.0	Ea.	0.8	0.8
43	1 1/2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.222	1.9
40	1 1/4" Diameter PVC, Schedule 40 Piping	5.9	LF	0.19	1.1
	3" Diameter, PVC Schedule 40 Cleanout Tee	1.0	Ea.	0.762	0.8
	3" Diameter, PVC, Schedule 40 Cleanout Plug	1.0	Ea.	0.444	0.4
	3" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	3" Diameter PVC, Schedule 40 Piping	1.8	LF	0.302	0.5
	3" Diameter PVC, Reducing Insert	1.0	Ea.	0.8	0.8
46	1 1/2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.222	1.9
47	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	3" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	3" Diameter PVC, Schedule 40 Piping	1.3	LF	0.302	0.4
	3" Diameter PVC, Reducing Insert	1.0	Ea.	0.8	0.8
51	1 1/4" Diameter PVC, Schedule 40 Piping	7.3	LF	0.19	1.4
55	1 1/2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.222	1.9
60	2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.271	2.4
70	1 1/2" Diameter, PVC Schedule 40 Cleanout Tee	1.0	Ea.	0.533	0.5
	1 1/2" Diameter PVC, Schedule 40 Piping	15.8	LF	0.222	3.5
	1 1/2" Diameter, PVC, Schedule 40 Cleanout Plug	1.0	Ea.	0.25	0.3
	1 1/4" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	1 1/4" Diameter PVC, Schedule 40 Piping	8.3	LF	0.19	1.6
	2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.271	2.4
91	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	1 1/2" Diameter PVC, Schedule 40 Piping	10.1	LF	0.222	2.2
	1 1/2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.602	0.6
	1 1/2 Diameter PVC, Reducing Insert	1.0	Ea.	0.364	0.4
154	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	1 1/2" Diameter PVC, Schedule 40 Piping	9.3	LF	0.222	2.1
	1 1/2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.602	0.6
	1 1/2 Diameter PVC, Reducing Insert	1.0	Ea.	0.364	0.4
232	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	2" Diameter PVC, Reducing Insert	1.0	Ea.	0.4	0.4
238	1 1/2" Diameter PVC, Schedule 40 Piping	26.0	LF	0.222	5.8
	3" Diameter PVC, Schedule 40 Piping	8.7	LF	0.302	2.6
234	1 1/4" Diameter PVC, Schedule 40 Piping	13.6	LF	0.19	2.6
	1 1/2" Diameter PVC, Schedule 40 Piping	8.7	LF	0.222	1.9
	2" Diameter PVC, Schedule 40 Piping	2.6	LF	0.271	0.7
	2" Diameter PVC, Reducing Insert	2.0	Ea.	0.4	0.8
	2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
248	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	1 1/2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.222	0.3
	1 1/2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.602	0.6
	1 1/2 Diameter PVC, Reducing Insert	1.0	Ea.	0.364	0.4
243	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.271	0.4
	2" Diameter PVC, Reducing Insert	2.0	Ea.	0.4	0.8
	2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.541	0.5
246	1 1/4" Diameter PVC, Schedule 40 Piping	6.8	LF	0.19	1.3
	1 1/2" Diameter PVC, Schedule 40 Piping	1.3	LF	0.222	0.3
	1 1/2" Diameter PVC, Schedule 40 Tee	1.0	Ea.	0.602	0.6
	1 1/2 Diameter PVC, Reducing Insert	1.0	Ea.	0.364	0.4
					81.6

Appendix

Quad B Wall Panel Plumbing Take-offs

Panel	Component	Quantity	Units	Labor Hours	Total Hours
91	3/4" CPVC Piping, socket joint, incl. clamps and supports	8.4	LF	0.157	1.3188
	3/4" CPVC 90 Deg. Elbow	1	Ea.	0.308	0.308
	1/2" CPVC Piping, socket joint, incl. clamps and supports	8.4	LF	0.148	1.2432
	1/2" CPVC 90 Deg. Elbow	3	Ea.	0.25	0.75
40	3/4" CPVC Piping, socket joint, incl. clamps and supports	8.4	LF	0.157	1.3188
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
	1/2" CPVC Piping, socket joint, incl. clamps and supports	16.8	LF	0.148	2.4864
	1/2" CPVC 90 Deg. Elbow	4	Ea.	0.25	1
7	3/4" CPVC Piping, socket joint, incl. clamps and supports	8.4	LF	0.157	1.3188
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
	1/2" CPVC Piping, socket joint, incl. clamps and supports	25.2	LF	0.148	3.7296
	1/2" CPVC 90 Deg. Elbow	6	Ea.	0.25	1.5
	1-1/2" CPVC Piping, socket joint, incl. clamps and supports	8.4	LF	0.222	1.8648
	1-1/2" CPVC 90 Deg. Elbow	2	Ea.	0.661	1.322
47	3/4" CPVC Piping, socket joint, incl. clamps and supports	3	LF	0.157	0.471
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
70	1/2" CPVC Piping, socket joint, incl. clamps and supports	33.6	LF	0.148	4.9728
	1/2" CPVC 90 Deg. Elbow	8	Ea.	0.25	2
71	1/2" CPVC Piping, socket joint, incl. clamps and supports	18	LF	0.148	2.664
	1/2" CPVC 90 Deg. Elbow	2	Ea.	0.25	0.5
63	3/4" CPVC Piping, socket joint, incl. clamps and supports	18	LF	0.157	2.826
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
	1/2" CPVC Piping, socket joint, incl. clamps and supports	12	LF	0.148	1.776
	1/2" CPVC 90 Deg. Elbow	4	Ea.	0.25	1
11	3/4" CPVC Piping, socket joint, incl. clamps and supports	18	LF	0.157	2.826
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
	1/2" CPVC Piping, socket joint, incl. clamps and supports	12	LF	0.148	1.776
	1/2" CPVC 90 Deg. Elbow	4	Ea.	0.25	1
13	3/4" CPVC Piping, socket joint, incl. clamps and supports	12.4	LF	0.157	1.9468
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
14	1/2" CPVC Piping, socket joint, incl. clamps and supports	36	LF	0.148	5.328
	1/2" CPVC 90 Deg. Elbow	8	Ea.	0.25	2
12	1/2" CPVC Piping, socket joint, incl. clamps and supports	16.8	LF	0.148	2.4864
	1/2" CPVC 90 Deg. Elbow	4	Ea.	0.25	1
154	3/4" CPVC Piping, socket joint, incl. clamps and supports	3	LF	0.157	0.471
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
232	3/4" CPVC Piping, socket joint, incl. clamps and supports	3	LF	0.157	0.471
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
234	3/4" CPVC Piping, socket joint, incl. clamps and supports	3	LF	0.157	0.471
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
252	3/4" CPVC Piping, socket joint, incl. clamps and supports	5.6	LF	0.157	0.8792
	3/4" CPVC 90 Deg. Elbow	2	Ea.	0.308	0.616
240	1/2" CPVC Piping, socket joint, incl. clamps and supports	13.3	LF	0.148	1.9684
	1/2" CPVC 90 Deg. Elbow	2	Ea.	0.25	0.5
	1/2" Tee, CPVC, Sched. 80, Socket	2	Ea.	0.396	0.792
246	1/2" CPVC Piping, socket joint, incl. clamps and supports	13.3	LF	0.148	1.9684
	1/2" CPVC 90 Deg. Elbow	2	Ea.	0.25	0.5
	1/2" Tee, CPVC, Sched. 80, Socket	2	Ea.	0.396	0.792
					67.7064

Conductor Sizing Take-offs

DC Circuit Conductors

Isc = Rated short circuit current = 8.9 A @ 90°C

Required Ampacity for solar circuit = 1.25 x 1.25 x 8.9 = 13.9 Amps → #12 AWG ✓

Adjustment for Conduit Fill

- 5 conductors = .80 derating factor → #12 AWG
- 13.9 Amps/.80 = 17.375 A → #12 AWG ✓

Adjustment for Ambient Temperature (90°F for Milwaukee)

- Factor = .96
- Adjusted Ampacity = 17.375 Amp x .96 = 16.69 Amps
- Adjustment for height above roof
- ½" to 3.5" → 40°F rise in ambient temperature
- 134° → Factor = .71
- Needed Ampacity = .71 x .80 x 30 A = 17.04 Amp

#12 AWG THWN-2 rating 30 Amp @ 90°C > 17.04 Amp → #12 AWG ✓

Appendix

Conductor Sizing Take-offs

AC (Inverter to Utility) Circuit Conductors

Min Ampacity = 39 A x 1.25 = 48.75 Amps A → #8 AWG ✓
Conduit Fill → 5 Conductors = .80 derating factor
Ambient Temperature→ .96
Height above roof (1/2" – 3.5") " → 40°F rise in ambient temperature →
New Factor = .71
Needed Ampacity = 55 Amps x .80 x .71 = 31.24 Amps
#8 AWG THWN-2 rating → 55 Amp @ 90°C > 31.24 Amp → #8 AWG ✓

Conductor Sizing Take-offs

Voltage Drop DC

VD = 1.732 x L x R x I / 1000
Vpm = 29.8 V x 11 modules in series = 327.8 Volts
Imp = 8.4 A, R (#12 AWG)=5.320 ohm/km, L = 80' max length
VD = {2 x 80' max length x 5.230 ohm/km x 8.4 A} / 1000 = 6.19 Volts
6.19 V/327.8 V = 1.8% Voltage drop < 3% ✓

Voltage Drop AC

VD = 1.732 x L x R x I / 1000
Vpm = 29.8 V x 11 modules in series = 208 Volts
I = 39 A, R (#8 AWG) = 0.6401 ohm/km, L = 75' max length
VD = {1.732 x 75' max length x 0.6401 ohm/km x 39 A} / 1000 = 3.24 Volts
3.24 V/208 V = 1.6% Voltage drop < 2% ✓

Appendix

Electrical Design Tables

Conductor Size (AWG)	60°C (140°F)	75°C (167°F)	90°C (194°F)
	Types UF	Types RHW, THHW, THWN, XHHW, USE	Types RHW-2, THHN, THHW, THWN-2, USE-2, XHHW, XHHW-2
14*	20	20	25
12*	25	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
2	95	115	130
1	110	130	150
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260

*Limits to fuse size for 14, 12, 10 AWG wire [240.4 (D)]: 14 AWG, use max 15 A fuse; 12 AWG, use max 20 A fuse; 10 AWG, use max 30 A fuse.

Ambient Temperature		60°C (140°F)	75°C (167°F)	90°C (194°F)
(C)	(F)	Types UF	Types RHW, THHW, THWN, XHHW, USE	Types RHW-2, THHN, THHW, THWN-2, USE-2, XHHW, XHHW-2
31-35	87-95	0.91	0.94	0.96
36-40	96-104	0.82	0.88	0.91
41-45	105-113	0.71	0.82	0.87
46-50	114-122	0.58	0.75	0.82
51-55	123-131	0.41	0.67	0.76
56-60	132-140	-	0.58	0.71
61-70	141-158	-	0.33	0.58
71-80	159-176	-		0.41

Electrical Design Tables

Number of Current Carrying Conductors	Conductor Fill Derating Factor
4-6	0.80
7-9	0.70
10-20	0.50

Size		Diameter		Resistance @ 77°F	
AWG	Metric mm²	inch	mm	ohm/1000'	ohm/km
24	0.205	0.0232	0.590	26.1823	85.900
22	0.326	0.0293	0.744	16.4592	54.000
20	0.518	0.0369	0.938	10.3632	34.000
18	0.823	0.0465	1.182	6.5227	21.400
16	1.309	0.0587	1.491	4.0843	13.400
14	2.081	0.0740	1.880	2.5756	8.450
12	3.309	0.0933	2.371	1.6215	5.320
10	5.261	0.1177	2.989	1.0180	3.340
8	8.366	0.1484	3.770	0.6401	2.100
6	13.302	0.1871	4.753	0.4023	1.320
4	21.151	0.2360	5.994	0.2533	0.831
2	33.631	0.2976	7.558	0.1594	0.523
1	42.408	0.3341	8.487	0.1265	0.415
1/0	53.475	0.3752	9.530	0.1003	0.329
2/0	67.431	0.4213	10.702	0.0796	0.261
3/0	85.029	0.4732	12.018	0.0631	0.207
4/0	107.219	0.5313	13.495	0.0500	0.164

Appendix

Labor Durations for Solar Panels

Item	Crew	Qty	Unit	Labor Hours/unit	Total Duration
Classic Composition Mount	Roofer	55	Per Panel	1.455	80.0
Rooftrac Racking	Roofer	7	Per 8 Panels	0.78	5.5
Sharp Solar Module	Electrician	55	Per Panel	1	55.0
Inverter	Electrician	1	Ea.	4	4.0
60 Amp Circuit Breaker	Electrician	1	Ea.	1.702	1.7
#12 AWG conductor	Electrician	50.24	CLF	0.727	36.5
#8 AWG conductor	Electrician	4.15	CLF	1	4.2
Conduit 3/4"	Electrician	1256	LF	0.055	69.1
Conduit 1/2"	Electrician	83	LF	0.42	34.9
					290.8

SIPS Labor Durations by Room

Fire Protection Duration by Room		
Room	**Qty**	**Duration (hrs)**
Unit A ADA Ext.	14	10.0
Unit A ADA Int.	11	11.0
Unit A Int.	7	4.8
Unit A Ext	8	11.4
Unit B	10	10.5

HVAC Gas Piping		
Room	**Qty**	**Duration (hrs)**
Unit A	7	8.6
Unit A ADA	11	8.2

HVAC		
Room	**Qty**	**Duration (hrs)**
Unit A ADA Ext.	14	11.8
Unit A ADA Int.	11	8.6
Unit A Int.	7	0.7
Unit A Ext	8	8.4
Unit B	10	2.2

Electrical			
Room	**Qty**	**Duration (hrs)**	**Adjusted Duration**
Unit A/A ADA Exterior	22	27.95	9.3
Unit A/A ADA Interior	18	30.52	10.2
Unit B	10	22.54	7.5