

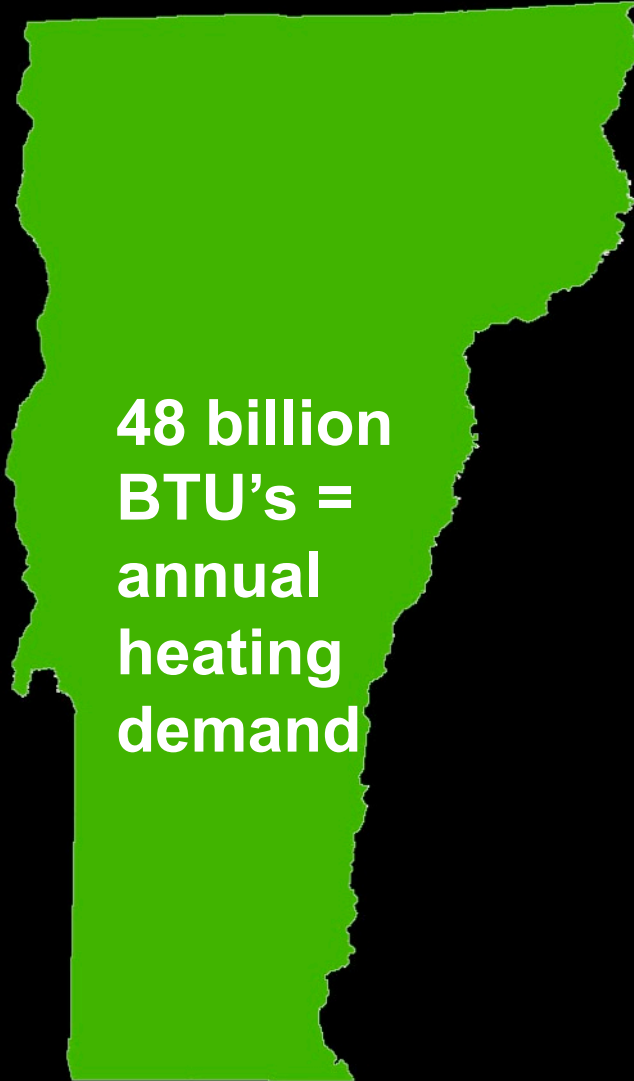
# A Year in the Delta-T-90: Post Occupancy Data from the Westcott Center for Architecture and Design

Norwich University  $\Delta$ T90 Solar Decathlon Team

*c/o* Matt Lutz

Northfield, Vermont

(802)-793-6363



48 billion  
BTU's =  
annual  
heating  
demand

6<sup>th</sup>



heat demand  
satisfied by  
petroleum-  
based  
products

80%



63%



82%

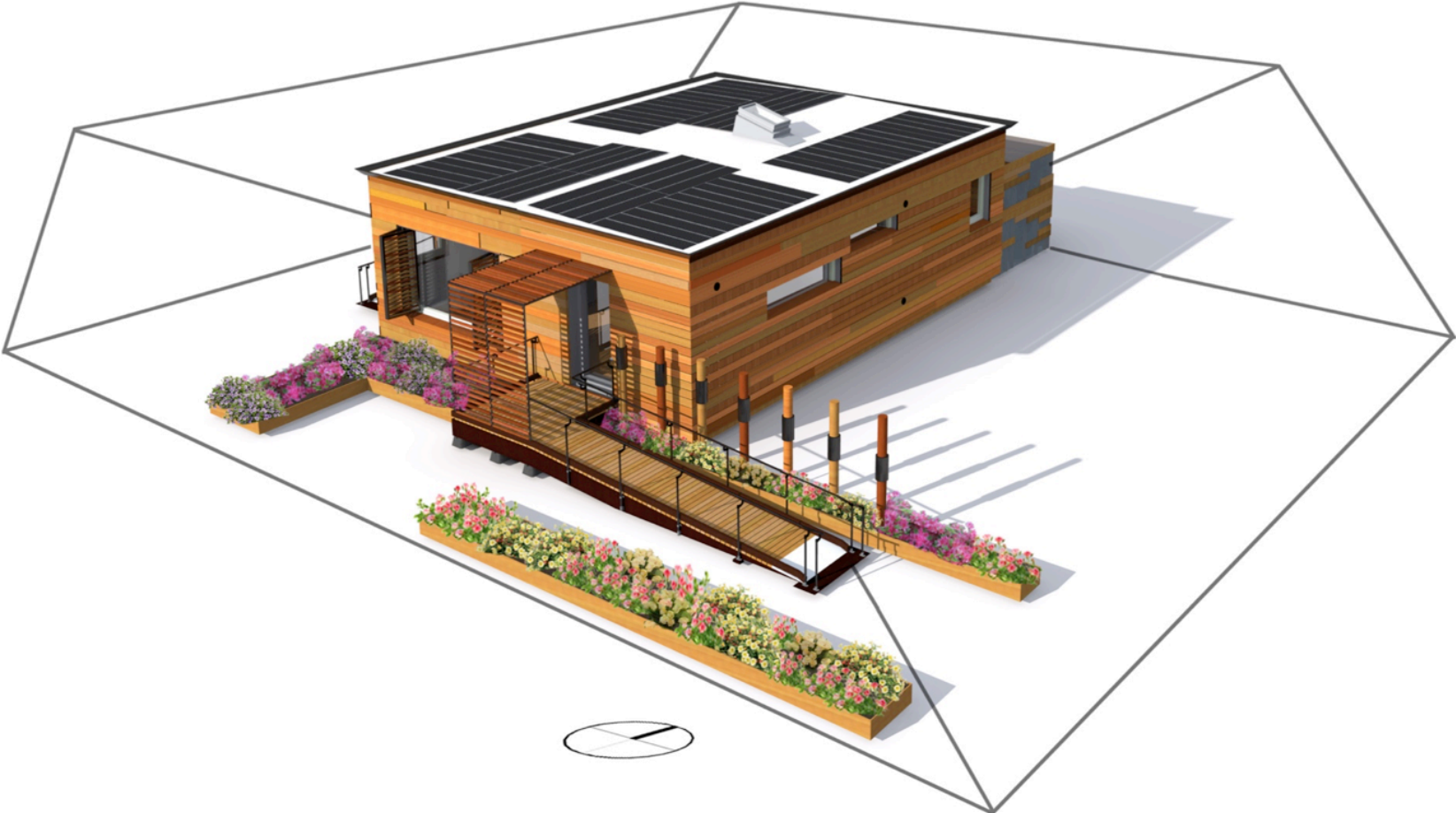


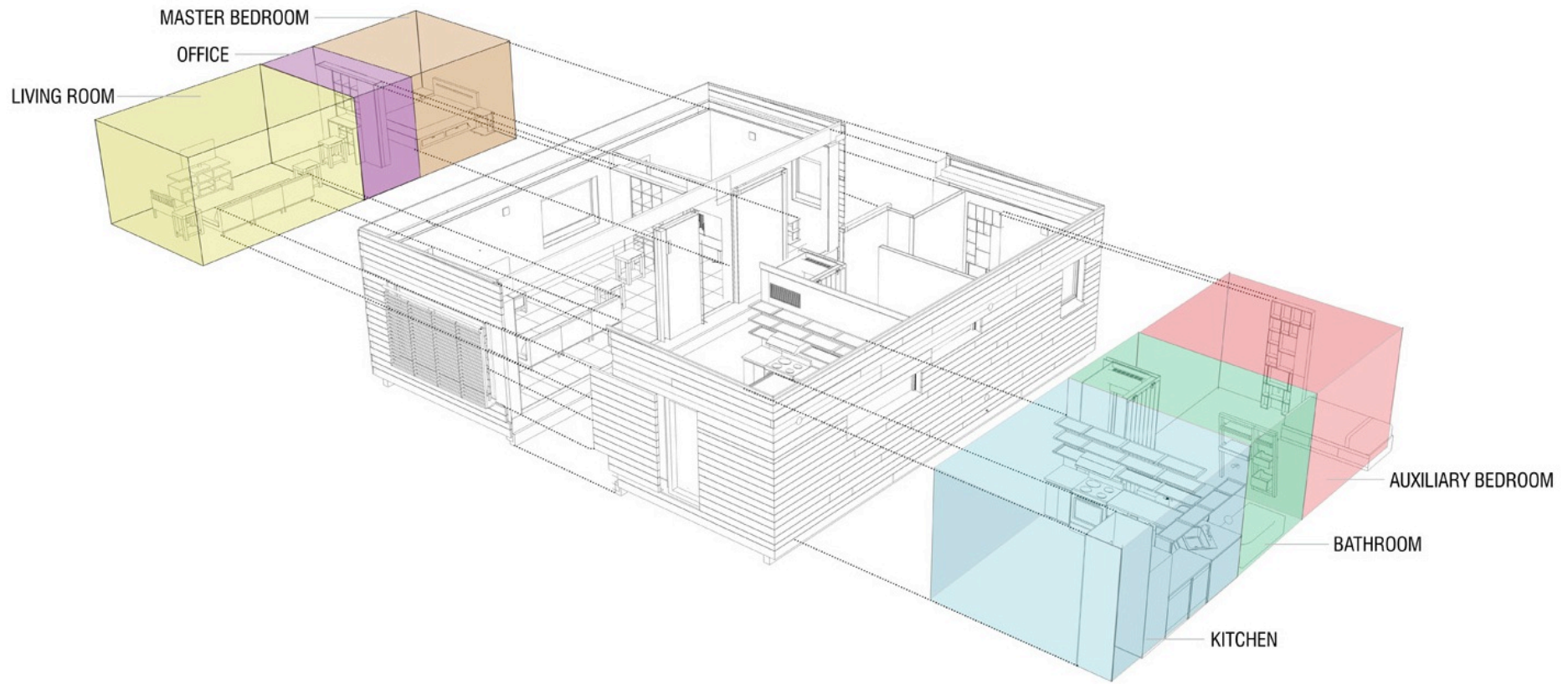
18%

minimum wage x (2) = 1000 sq.ft. of high performance architecture + 5.8 kw PV array

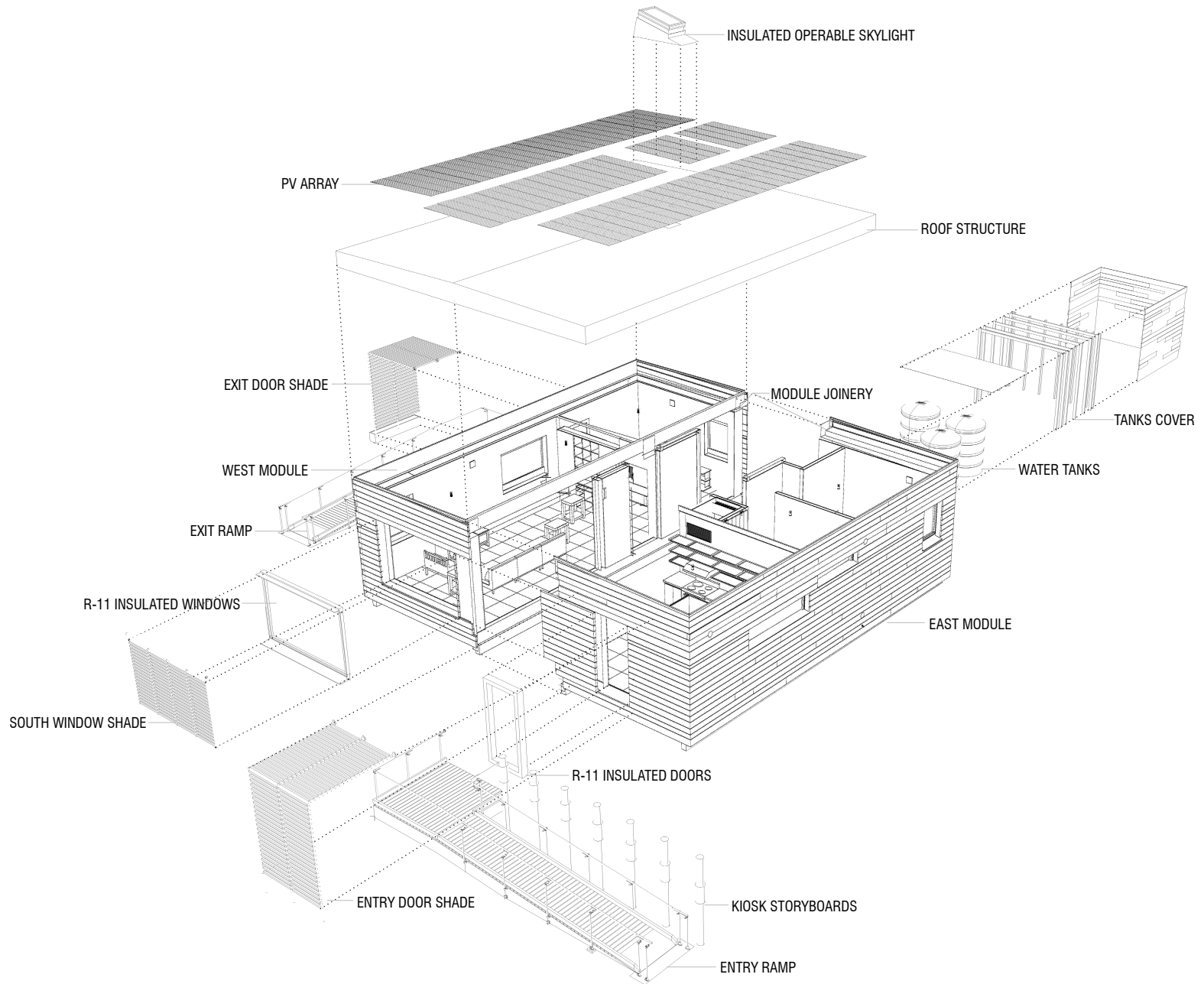


minimum wage x (2) = 1000 sq.ft. of high performance architecture + 5.8 kw PV array





# villa économie







# architecture as sport

**Solar Decathlon 2009**

**Most Expensive House = \$849,000**  
(estimated)

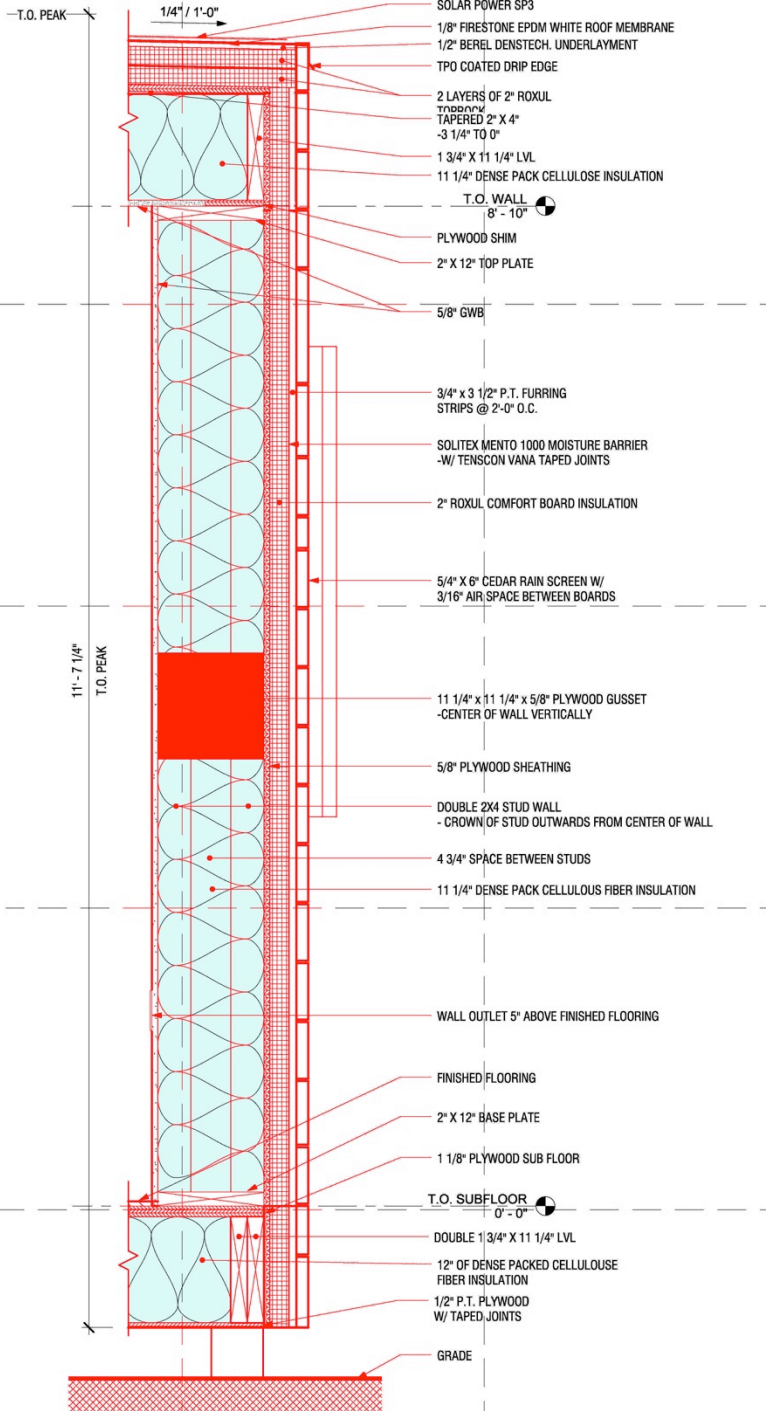
**Solar Decathlon 2011**

**Least Expensive House = \$249,000**  
(estimated)

**Solar Decathlon 2013**

**Vermont's  $\Delta T90$  = \$168,385**  
(estimated)





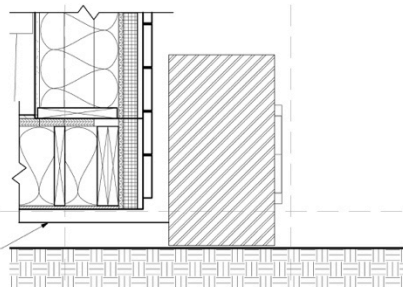
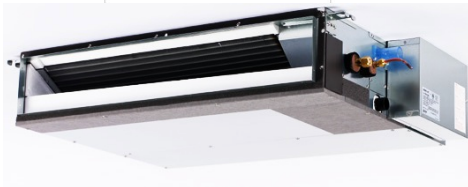
Assembly		Building Assembly Description				
1		Floor				
		Surface Film Resistance, R	Interior: 0.97 (hr.ft <sup>2</sup> .F/BTU)			
			Exterior: 0.23			
Primary Material (Enter from interior to exterior)	Resistivity R per inch	Secondary Material (optional)	Resistivity R per inch	Tertiary Material (optional)	Resistivity R per inch	Thickness [in]
1. Wood Laminate	1.280					0.500
2. Plywood Sheathing	1.390					1.125
3. Cellulose	3.800	Stud 2x12	1.280			11.250
4. Plywood S	1.390					0.500
5. Moisture barrier						
6.						
7.						
8.						
		Percentage of Mat'l 2	12.5%	Percentage of Mat'l 3		Total Width
						13.4 in
		R-Value:	38.9 (hr.ft <sup>2</sup> .F/BTU)			
		U-Value:	0.0257 (BTU/hr.ft <sup>2</sup> .F)			

Assembly		Building Assembly Description				
2		Wall				
		Surface Film Resistance, R	Interior: 0.74 (hr.ft <sup>2</sup> .F/BTU)			
			Exterior: 0.45			
Primary Material (Enter from interior to exterior)	Resistivity R per inch	Secondary Material (optional)	Resistivity R per inch	Tertiary Material (optional)	Resistivity R per inch	Thickness [in]
1. Drywall	0.910					0.625
2. Cellulose	3.800	Stud 2x4	1.280			11.250
3. OSB	1.390					0.500
4. Mineral Wool	4.230					2.000
5. moisture barrier						
6.						
7.						
8.						
		Percentage of Mat'l 2	12.5%	Percentage of Mat'l 3	1.0%	Total Width
						14.4 in
		R-Value:	46.2 (hr.ft <sup>2</sup> .F/BTU)			
		U-Value:	0.0217 (BTU/hr.ft <sup>2</sup> .F)			

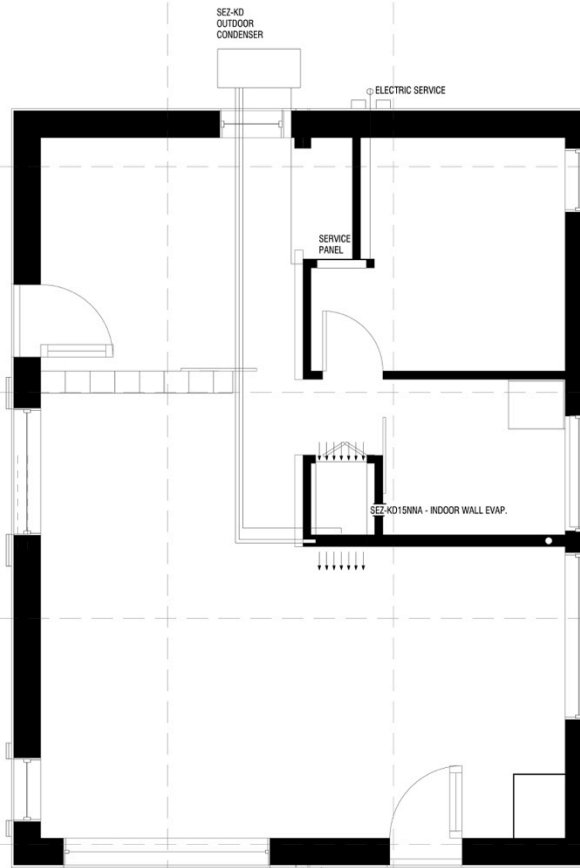
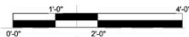
Assembly		Building Assembly Description				
3		Roof				
		Surface Film Resistance, R	Interior: 0.57 (hr.ft <sup>2</sup> .F/BTU)			
			Exterior: 0.45			
Primary Material (Enter from interior to exterior)	Resistivity R per inch	Secondary Material (optional)	Resistivity R per inch	Tertiary Material (optional)	Resistivity R per inch	Thickness [in]
1. Drywall	0.910					0.500
2. Cellulose	3.800	studs	1.280			14.000
3. Plywood	1.470					0.750
4. roxul	4.230					4.000
5.						
6. EPDM	0.850					0.125
7.						
8.						
		Percentage of Mat'l 2	12.5%	Percentage of Mat'l 3		Total Width
						19.4 in
		R-Value:	63.7 (hr.ft <sup>2</sup> .F/BTU)			
		U-Value:	0.0157 (BTU/hr.ft <sup>2</sup> .F)			

# 15,000 BTU ductless, clg mounted unit.

MECHANICAL EQUIPMENT SCHEDULE			
DESCRIPTION	MANUFACTURER	MODEL	LOCATION
LUNOS	LUNOS	E2	MASTER BEDROOM
LUNOS	LUNOS	E2	LIVING ROOM
LUNOS	LUNOS	E2	AUXILIARY BEDROOM
LUNOS	LUNOS	E2	BATHROOM
LUNOS	LUNOS	E2	BATHROOM
HEAT PUMP	MITSUBISHI	SEZ-KD 1 SUZKA15NA	KITCHEN/DINING
HEAT PUMP	MITSUBISHI	SEZ-KD 1 SUZKA15NA	LAUNDRY ROOM HALL
LUNOS	LUNOS	E2	KITCHEN/DINING



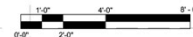
**A1** HEAT PUMP TRANSVERSE SECTION  
1 1/2" = 1'-0"



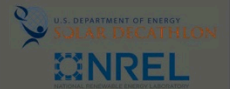
**A3** HEAT PUMP EQUIPMENT PLAN  
3/8" = 1'-0"

**GENERAL SHEET NOTES**  
SEE M-103 FOR HEAT RECOVERY VENTILATION PLAN

**REFERENCE KEYNOTES**  
DIVISION 23: HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC)



NORWICH UNIVERSITY  
158 HARMON DR.  
NORTHFIELD  
VERMONT 05663



WWW.SOLARDECATHLON.GOV

CONSULTANT: MATTHEW LUTZ  
CONSULTANT: EDWIN SCHMECKPEPER

REVISIONS

No.	Description	Date
1	LABELING ADJUSTMENTS	4/1/13

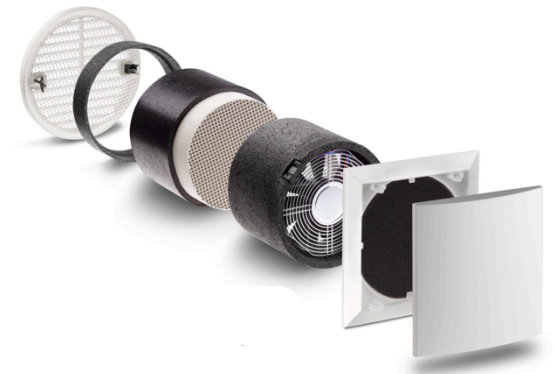
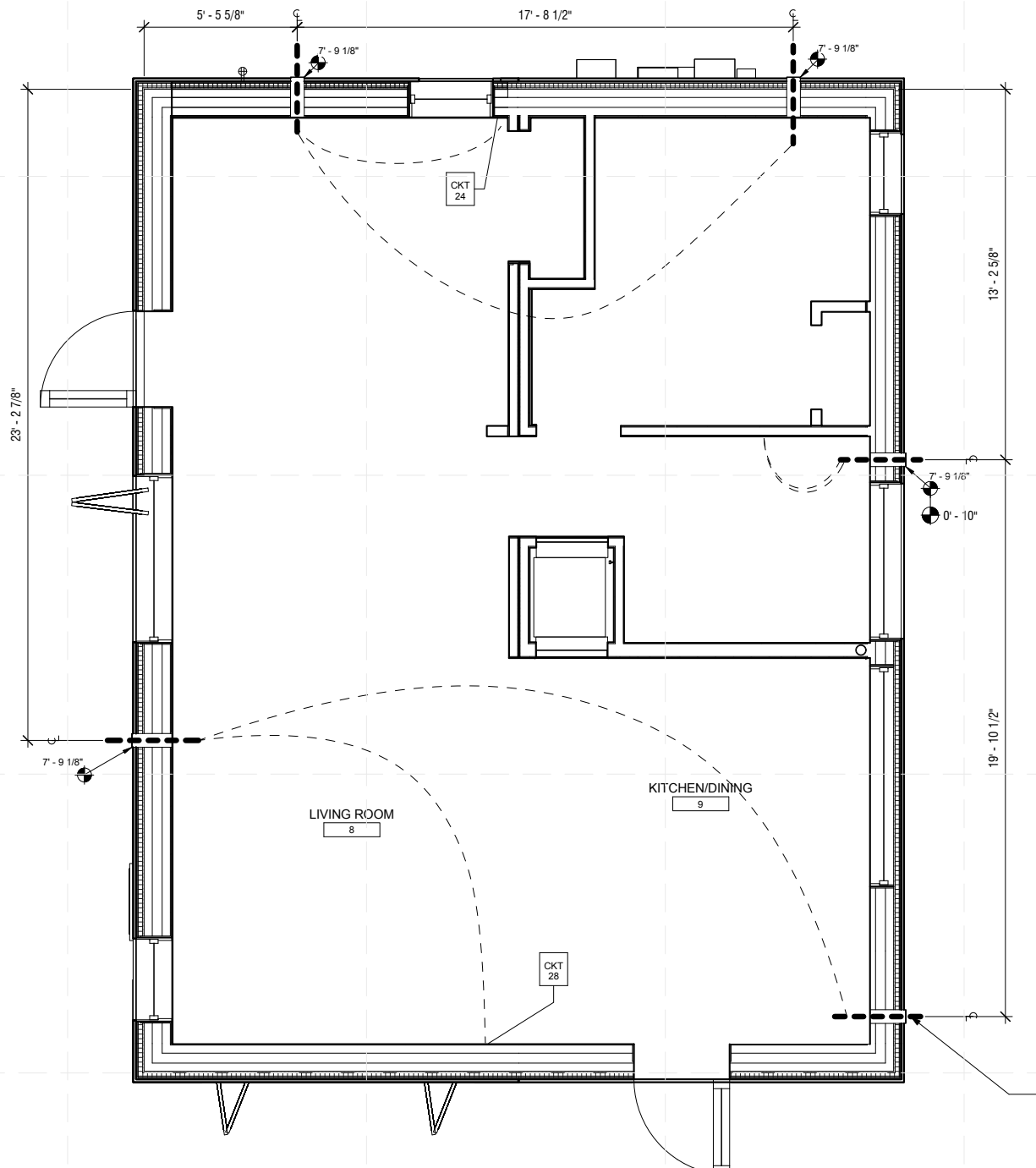
AS BUILT

DELTA T90

HEAT PUMP EQUIPMENT PLAN

Date 2012/8/1  
Drawn by Author

M-101



<http://www.foursevenfive.com/spec/Lunos%20brochure%20e2%20475.pdf> page 2

3 pairs - Lunos e2 system

Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
Applied:	Monthly Method		PH Certificate:	Fulfilled?	
Specific Space Heat Demand:	9.12	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	0.30	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	Yes

VERMONT

Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
Applied:	Monthly Method		PH Certificate:	Fulfilled?	
Specific Space Heat Demand:	4.99	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	0.30	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	Yes

OHIO

Climate:						Heating Degree Days:	
PHIUS Burlington Data						7237	
Window Area Orientation	Global Radiation (Cardinal Points)	Shading	Dirt	Non-Perpendicular Incident Radiation		Transmission Losses	Heat Gains Solar Radiation
maximum:	kBTU/ft <sup>2</sup> yr	0.75	0.95	0.85		kBTU/yr	kBTU/yr
North	41	0.76	0.95	0.85		350	66
East	99	0.72	0.95	0.85		1182	482
South	180	0.96	0.95	0.85		2546	6088
West	98	0.82	0.95	0.85		1380	1024
Horizontal	154	0.59	0.95	0.85		344	183
Total or Average Value for All Windows.						5802	7843

optimized/?



buy it now = 12 day construction time











Everyone stays happy  
(inside)







A  
SERIES  
SERIES  
← →

A  
SERIES  
SERIES  
← →

A  
SERIES  
SERIES  
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SERIES  
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← →



WOOD  
ONLY

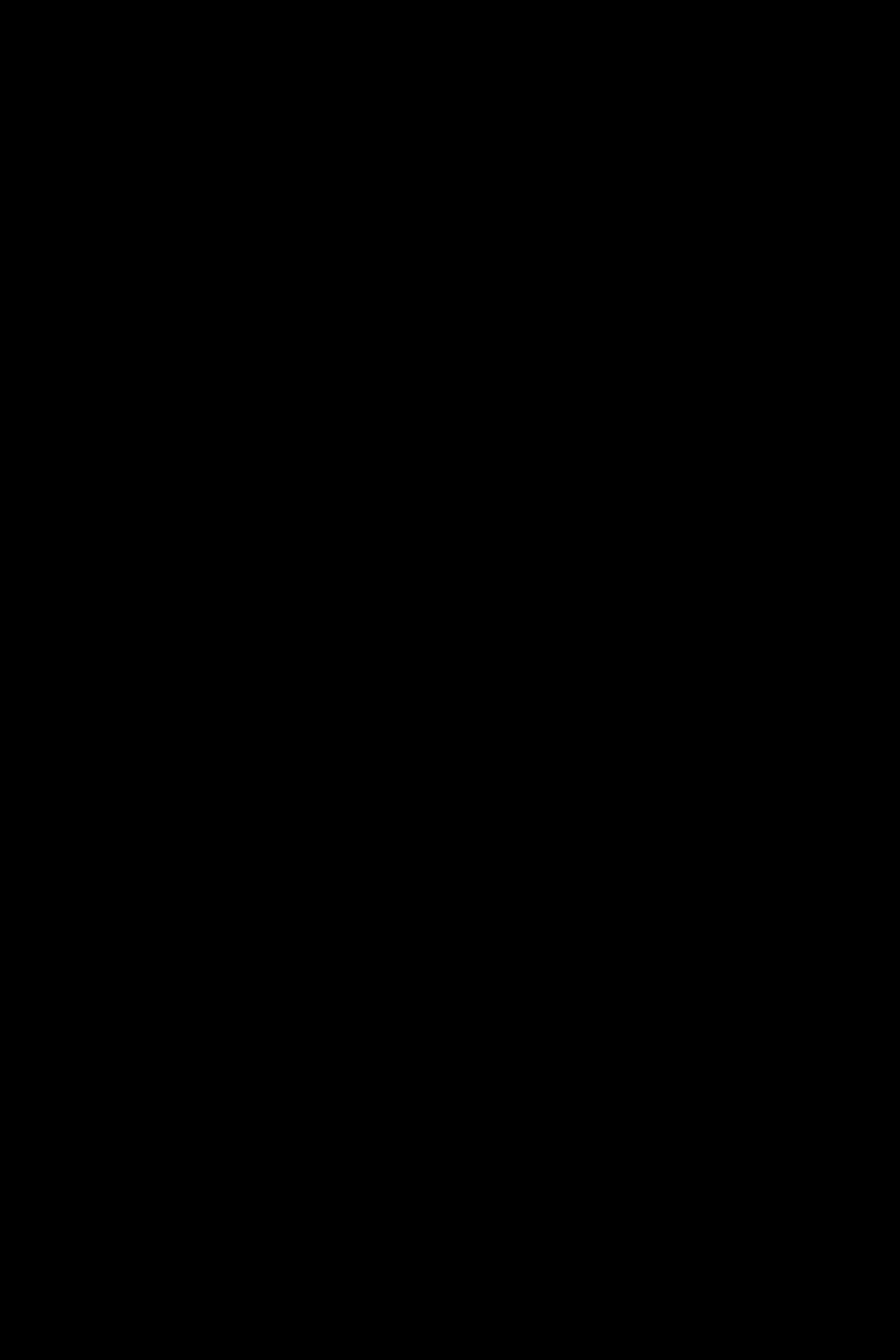
15/32 APLY TOP





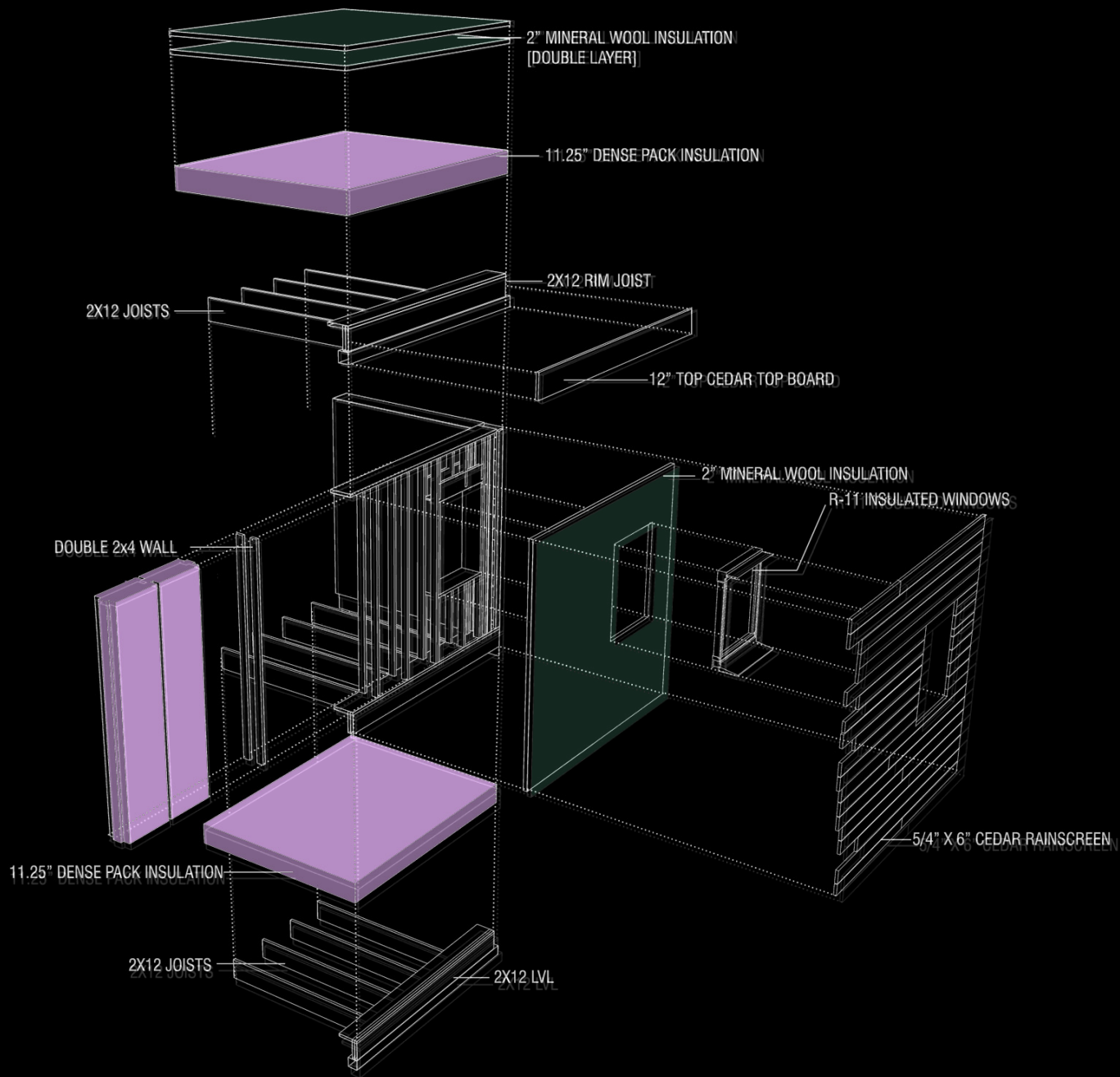


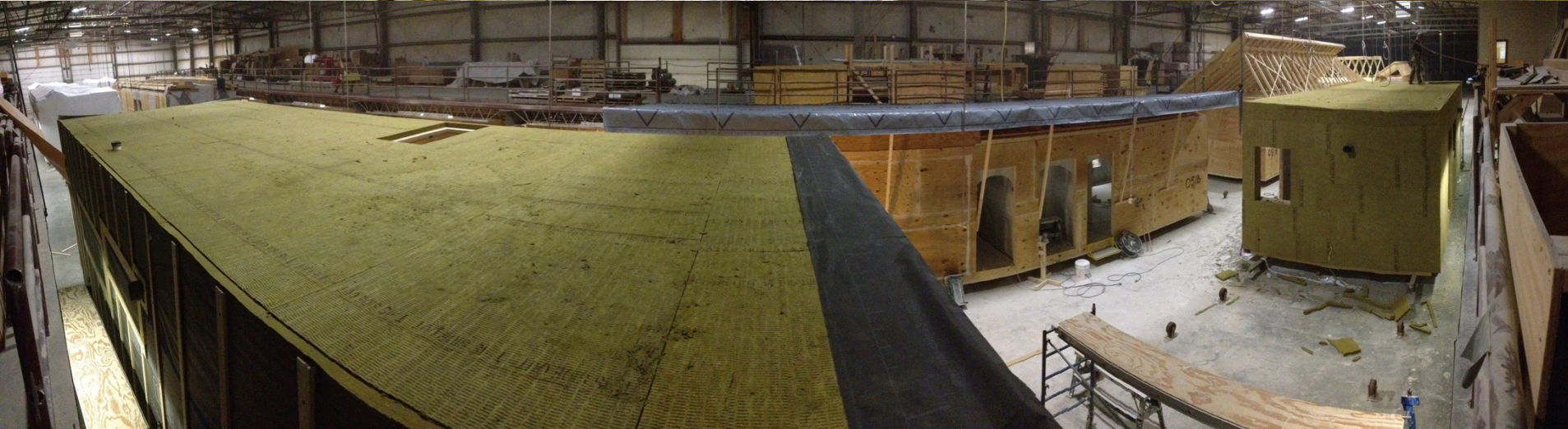














pro clima SOLITEX

MENTO

1000

MENTO

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MENTO

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510







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clima.com

MENTO

www.

MENTO  
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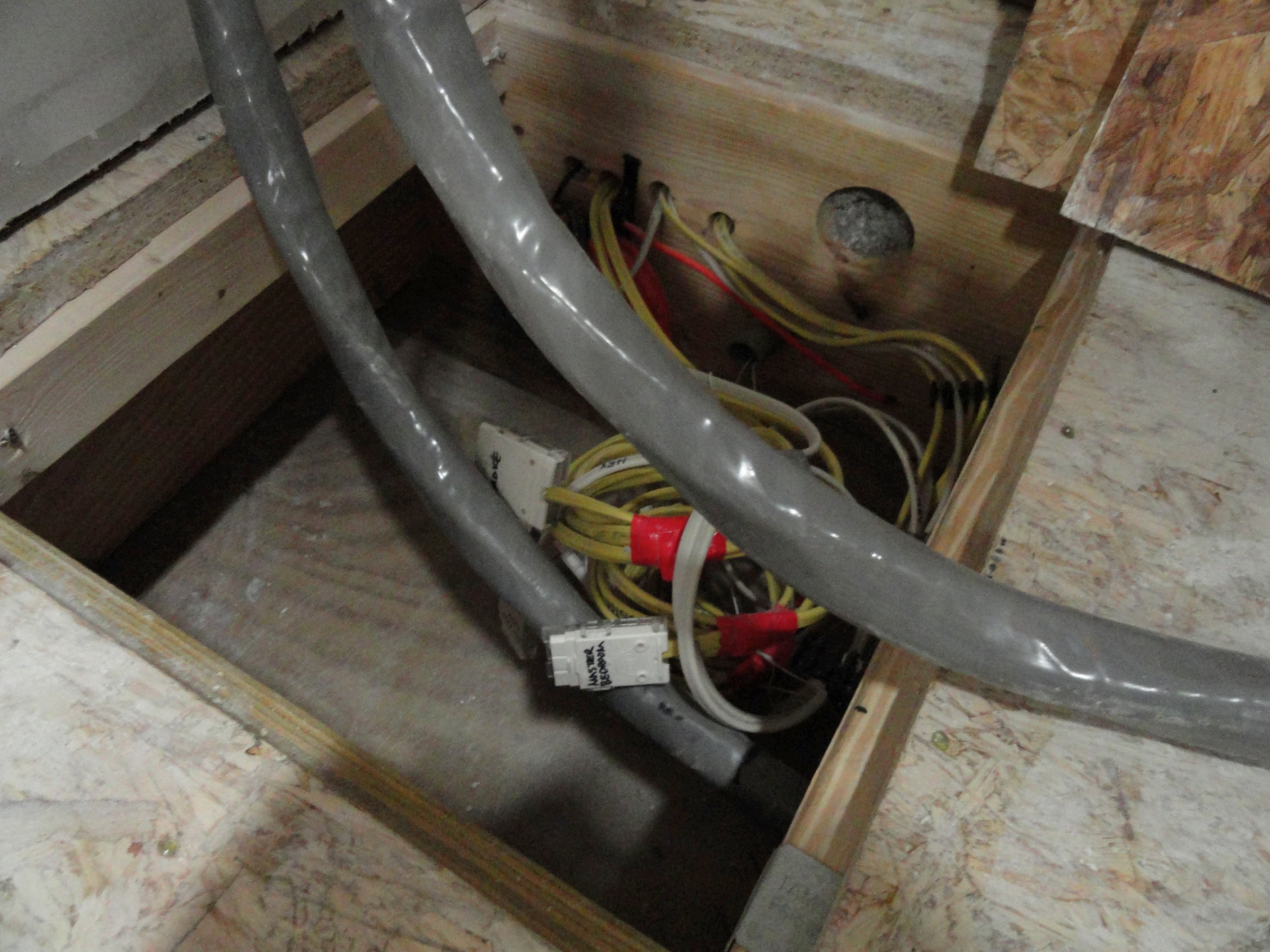
ME  
1000

1000

M

ALL SETTING





MASTER ROOM



































How did the  $\Delta T90$  perform?



Winner, Solar Decathlon 2013, Team Austria



(1) of these = (1) ΔT90 House + \$100,000



# U.S. Department of Energy Solar Decathlon 2013

Lot Number	Team	PV Produced (kWh)	PV System Size (kW)	Net house production (kWh)	House consumption (kWh)
105	Norwich	94.68	5.97	15.01	79.67
109	Team Austria	311.45	8.62	217.94	93.51
114	Las Vegas	228.88	6.75	94.40	134.48
103	Czech Republic	205.02	6.11	59.21	145.81
102	Stevens	160.18	6.34	5.53	154.66
104	Stanford	166.95	6.48	11.25	155.70
101	SCI-Arc/Caltech	178.63	6.10	14.17	164.46
118	Santa Clara	193.20	7.14	24.08	169.12
117	AZ State/New Mexico	305.72	8.82	121.46	184.25
107	Missouri S&T	361.80	11.56	176.99	184.81
115	Team Capitol DC	283.00	7.84	95.91	187.09
112	North Carolina	279.08	9.18	85.89	193.19
116	Team Alberta	323.13	10.00	119.55	203.58
110	Middlebury College	245.88	6.20	38.90	206.98
111	U of So Cal	247.25	8.16	20.93	226.32
120	Team Ontario	270.30	7.80	38.01	232.29
113	Kentucky/Indiana	287.10	7.40	39.93	247.17
106	Team Texas	285.12	8.30	20.83	264.28
119	West Virginia	341.30	8.50	36.45	304.85

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SOLAR  
DECATHLON

U.S. DEPT  
OF ENER  
SOLAR  
DECATHLON

U.S. DEPARTMENT  
OF ENERGY  
SOLAR  
DECATHLON

U.S. DEPARTMENT  
OF ENERGY  
SOLAR  
DECATHLON

Affordability  
FIRST PLACE

U.S. DEPARTMENT  
OF ENERGY  
SOLAR  
DECATHLON

U.S. Department of Energy  
Solar Decathlon 2013 and XPO





[Solar Decathlon Home](#)  
[Blog Home](#)

## Norwich University Receives Byron Stafford Award of Distinction

Monday, October 28, 2013

*By Solar Decathlon*

The Norwich University Solar Decathlon 2013 team received the Byron Stafford Award of Distinction at the U.S. Department of Energy Solar Decathlon 2013 Victory Reception on Oct. 12. Presented by Solar Decathlon Director Richard King's wife, Melissa, the award is a tribute to Byron Stafford, who served as the event's site operations manager from the first Solar Decathlon in 2002 until his death in May. A National Renewable Energy Laboratory senior scientist, Stafford was instrumental in formulating the competition rules and was dedicated to ensuring a safe competition and public exhibit. In 2009, his team installed the first Solar Decathlon village microgrid to distribute energy safely and reliably among the competition houses and to the utility grid.



### Archives

- » [March 2014](#)
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- » [November 2013](#)
- » [October 2013](#)
- » [September 2013](#)
- » [August 2013](#)
- » [July 2013](#)
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- » [January 2012](#)
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- » [June 2011](#)
- » [May 2011](#)
- » [April 2011](#)
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- » [October 2010](#)
- » [August 2010](#)
- » [June 2010](#)
- » [May 2010](#)
- » [April 2010](#)
- » [February 2010](#)
- » [January 2010](#)

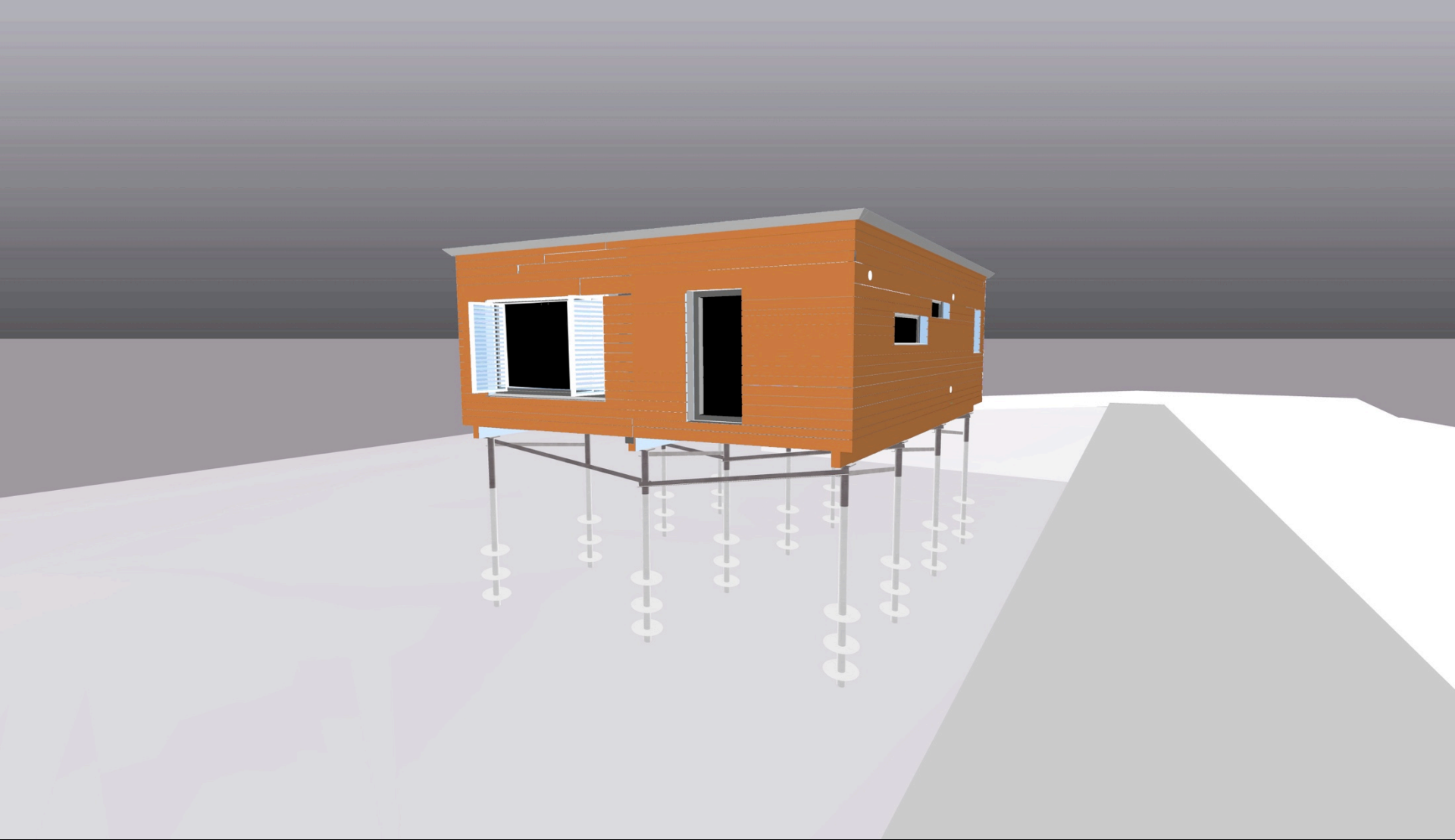


Conceptual Plan - C

Westcott House Master Plan  
Springfield, Ohio

CYLA Design Associates, Inc.  
October 2, 2013









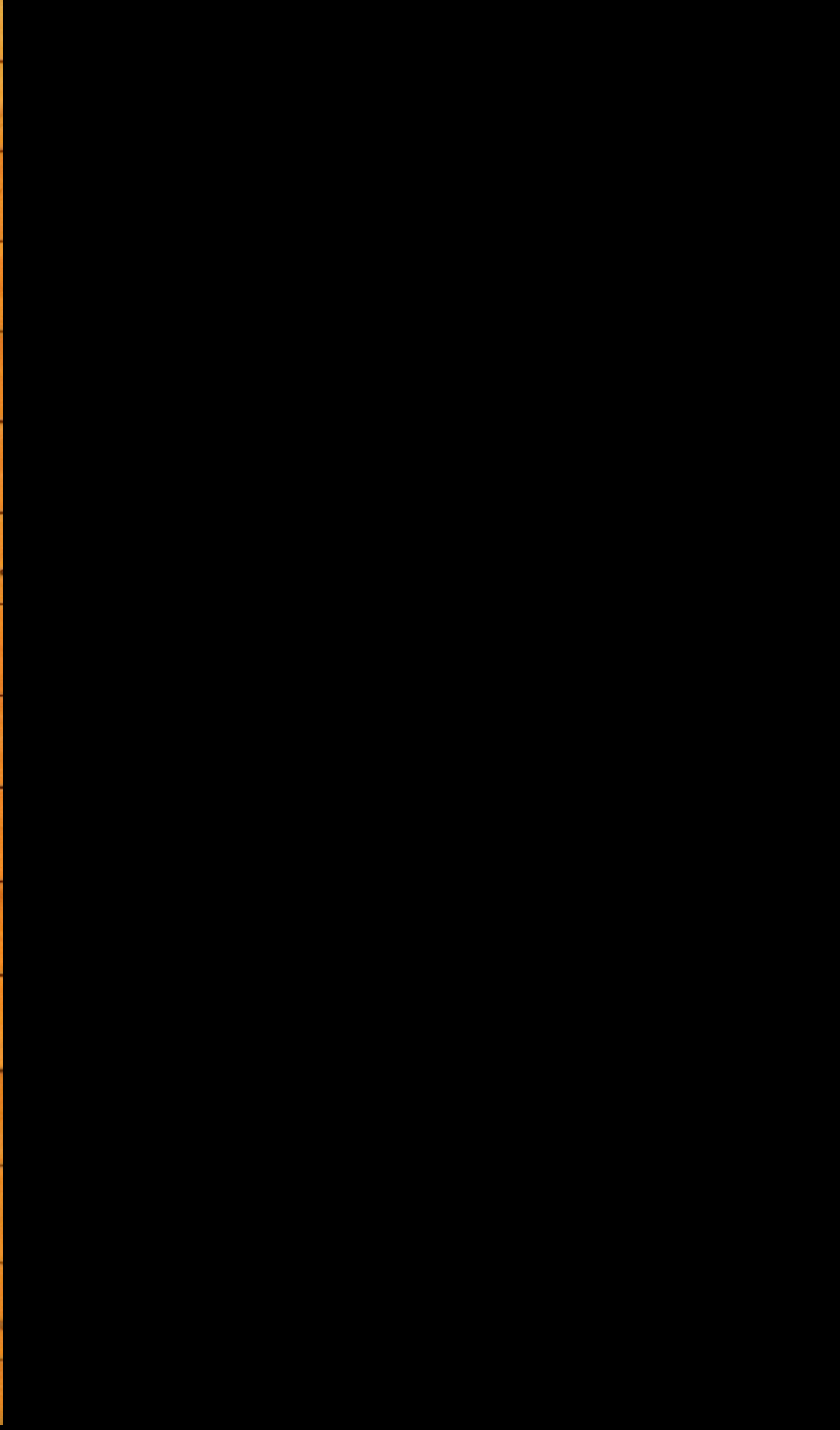


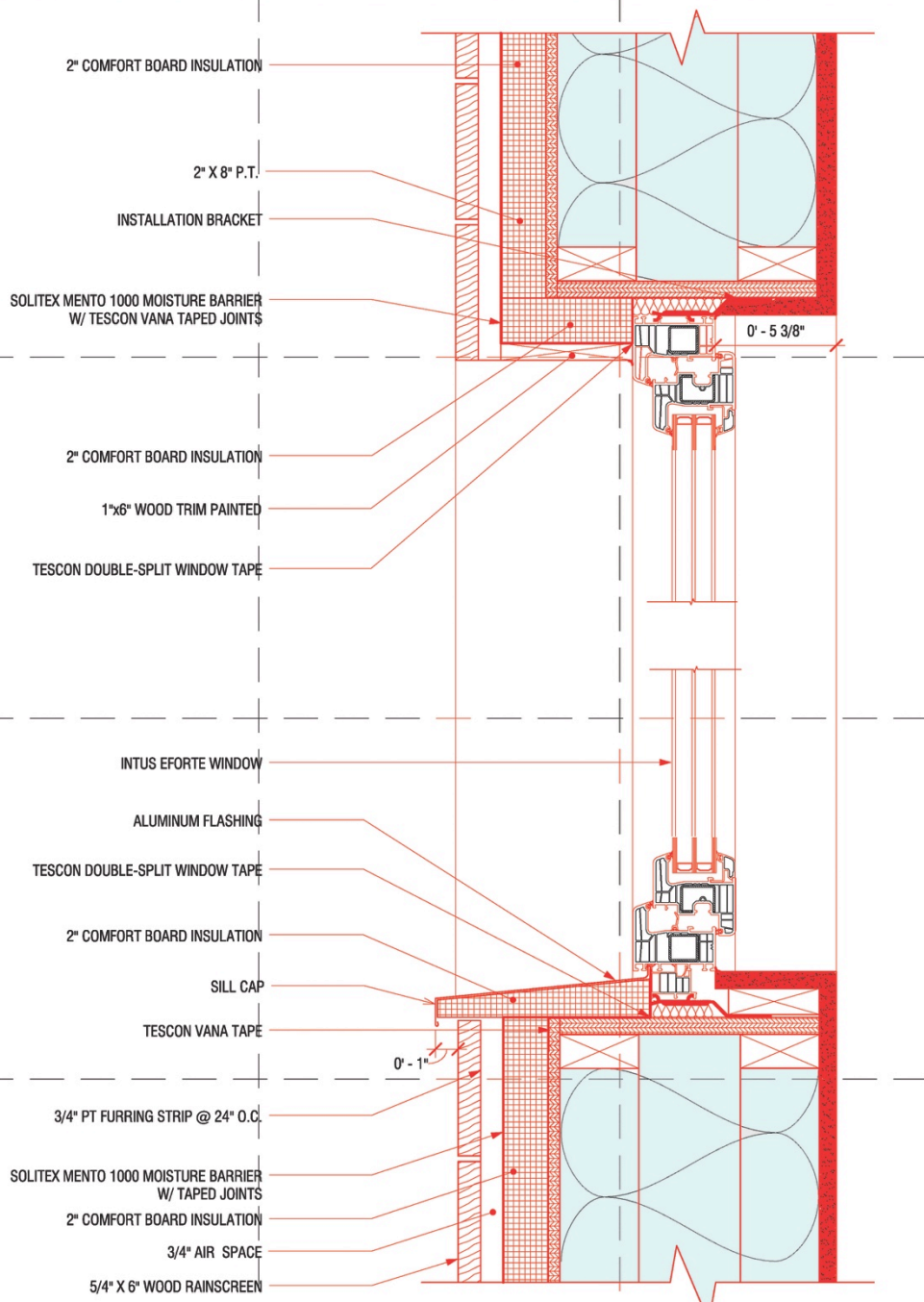














CONSUMPTION	ACTUAL kWh
Apr-14	34
May-14	184
Jun-14	223
Jul-14	203
Aug-14	68
Sep-14	191
Oct-14	144
Nov-14	350
Dec-14	384
Jan-15	402
Feb-15	459
Mar-15	343
Apr-15	175

Very little hot water demand, primarily space heating / cooling

**3126**

PV_PRODUCTION	ACTUAL kWh		ESTIMATED kWh
Apr-14	280	beginning ap.15	400
May-14	548		548
Jun-14	455		455
Jul-14	486		486
Aug-14	215	missing data Aug 12 - aug 26	430
Sep-14	354		354
Oct-14	205		205
Nov-14	118		118
Dec-14	81		81
Jan-15	111		111
Feb-15	111		111
Mar-15	329		329
Apr-15	416		416

NREL's PV Watts Calculator ←

**3709**

**4044**

Month / Year	AVG.Int. RH.	AVG. Int. Temp.	AVG. Ext. Temp.
<b>Nov-14</b>	31%	72.26°F	33.76°F
<b>Dec-14</b>	28.51%	71.54°F	35.5°F
<b>Jan-15</b>	24.05%	66.83°F	26.4°F
<b>Feb-15</b>	19%	65.64°F	20°F
<b>Mar-15</b>	25.72%	66.95°F	38.4°F
<b>Apr-15</b>	40.52%	68.87°F	56.05°F

Avg. int. temp.  
69°F



Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
	Applied:	Monthly Method		PH Certificate:	Fulfilled?
Specific Space Heat Demand:	10.55	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	3.82	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	No

first blower door test (data)  
- int. temp data collected during heating season

Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
	Applied:	Monthly Method		PH Certificate:	Fulfilled?
Specific Space Heat Demand:	5.94	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	1.00	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	No

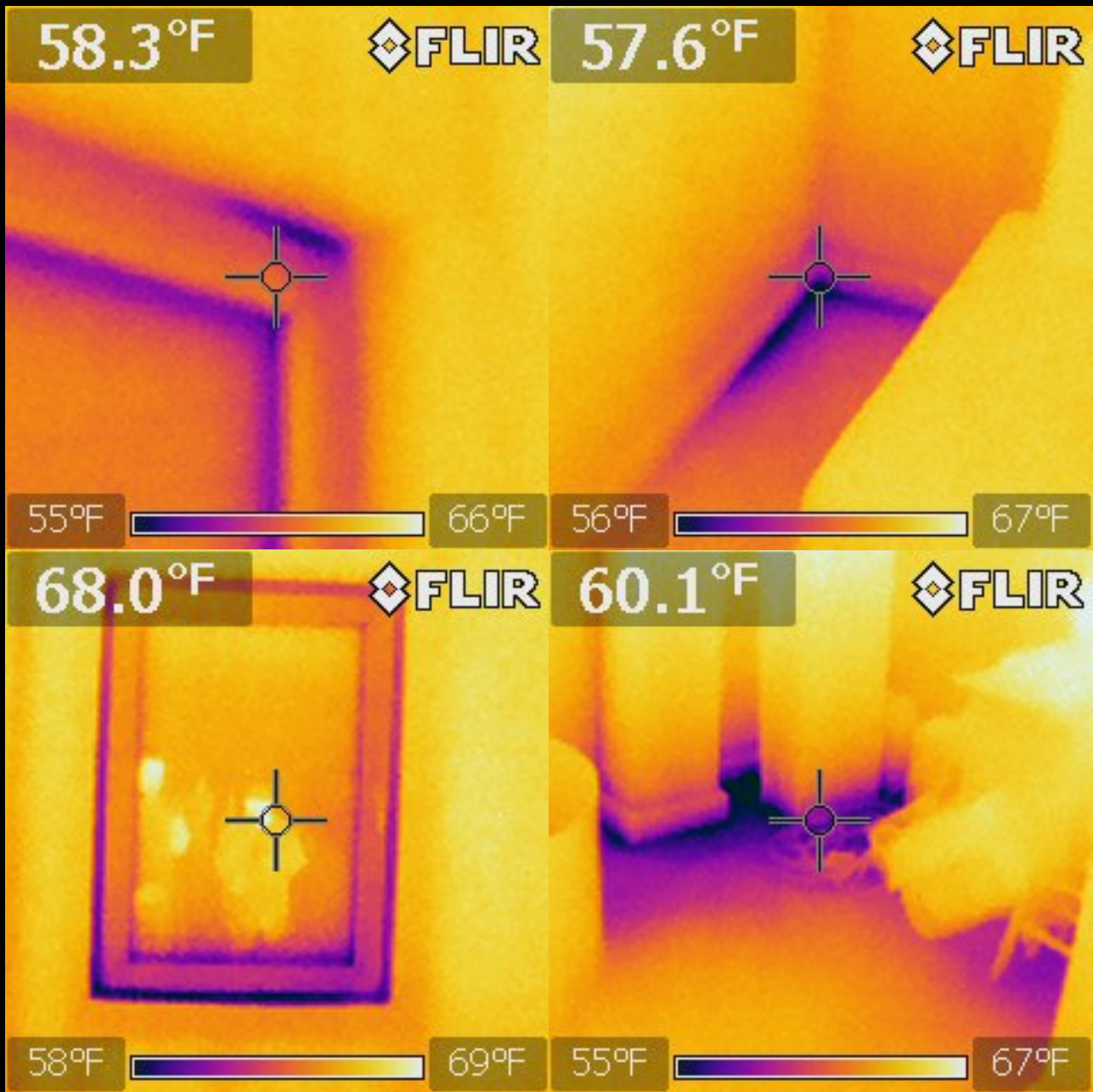
second blower door test – after corrective air sealing  
- projected performance 2016 heating season

Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
	Applied:	Monthly Method		PH Certificate:	Fulfilled?
Specific Space Heat Demand:	5.77	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	0.60	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	Yes

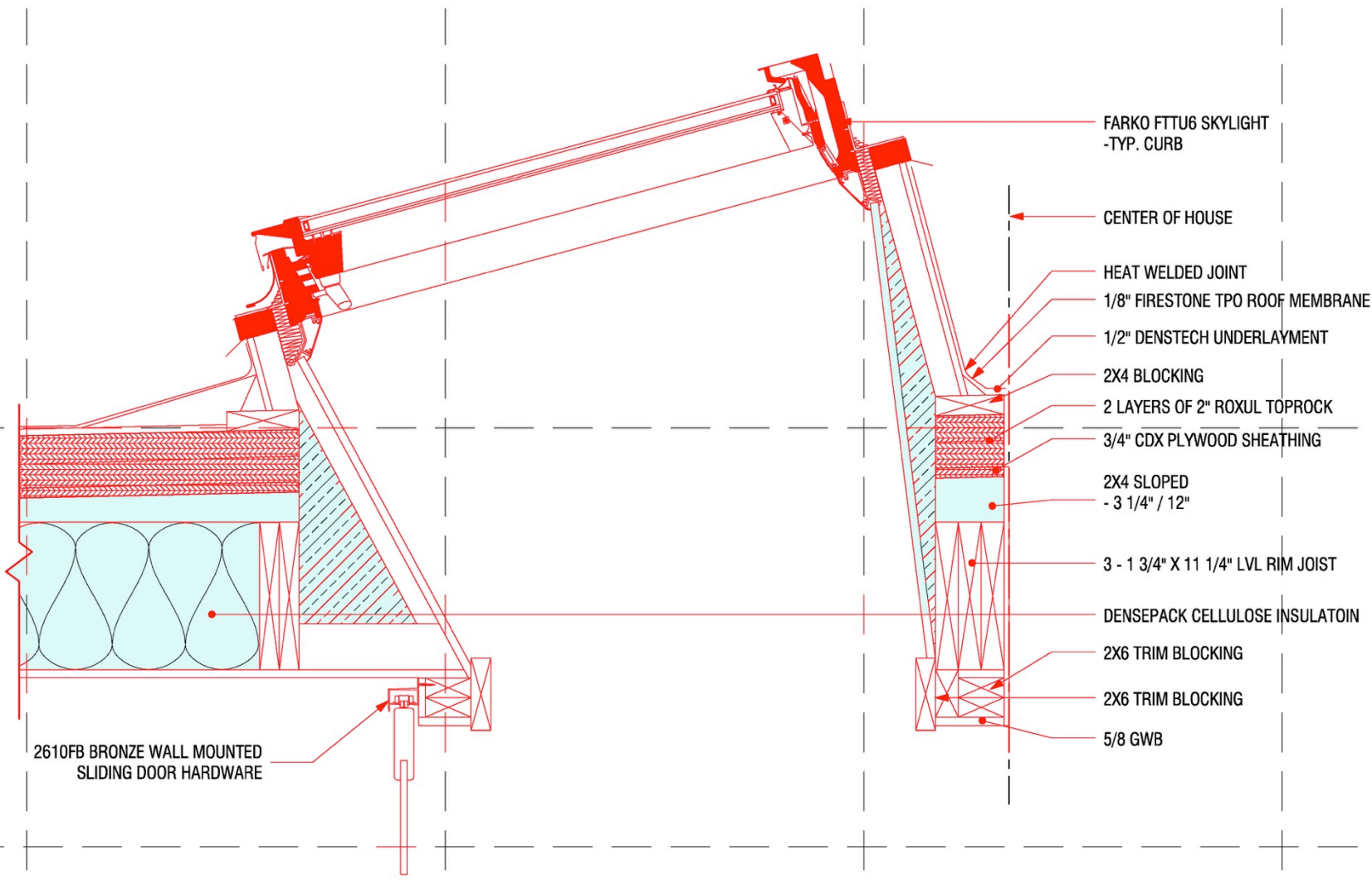
PH standard

Energy Demands with Reference to the Treated Floor Area					
Treated Floor Area:	790	ft <sup>2</sup>			
	Applied:	Monthly Method		PH Certificate:	Fulfilled?
Specific Space Heat Demand:	4.99	kBTU/(ft <sup>2</sup> yr)	4.75	kBTU/(ft <sup>2</sup> yr)	No
Pressurization Test Result:	0.30	ACH <sub>50</sub>	0.6	ACH <sub>50</sub>	Yes

And..... what we thought the ΔT90 would test when we were building it.....







FARKO FTTU6 SKYLIGHT  
-TYP. CURB

CENTER OF HOUSE

HEAT WELDED JOINT

1/8" FIRESTONE TPO ROOF MEMBRANE

1/2" DENSTECH UNDERLAYMENT

2X4 BLOCKING

2 LAYERS OF 2" ROXUL TOPROCK

3/4" CDX PLYWOOD SHEATHING

2X4 SLOPED

- 3 1/4" / 12"

3 - 1 3/4" X 11 1/4" LVL RIM JOIST

DENSEPACK CELLULOSE INSULATOIN

2X6 TRIM BLOCKING

2X6 TRIM BLOCKING

5/8 GWB

2610FB BRONZE WALL MOUNTED  
SLIDING DOOR HARDWARE



2015/07/21

ATTENTION: VERIFIER  
L'ALIMENTATION A  
ADVERTENCIA: AP  
ANTES DE LEVANTAR

HOT WATER  
CIRCUIT BREAKER

2015/07/21

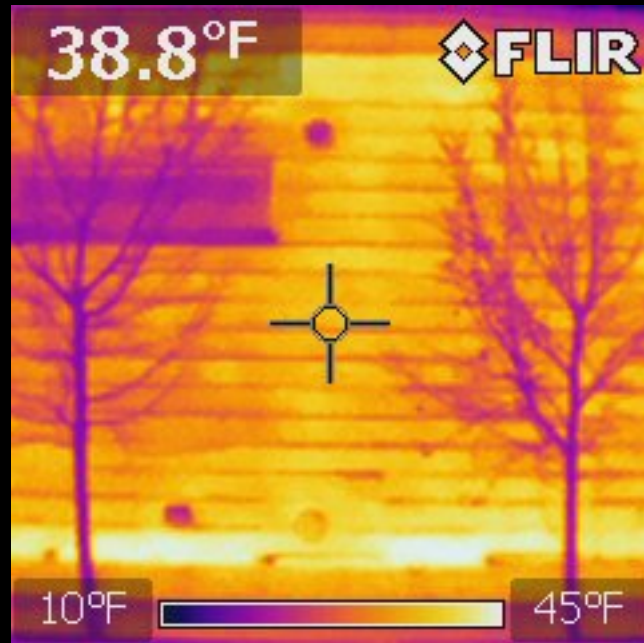
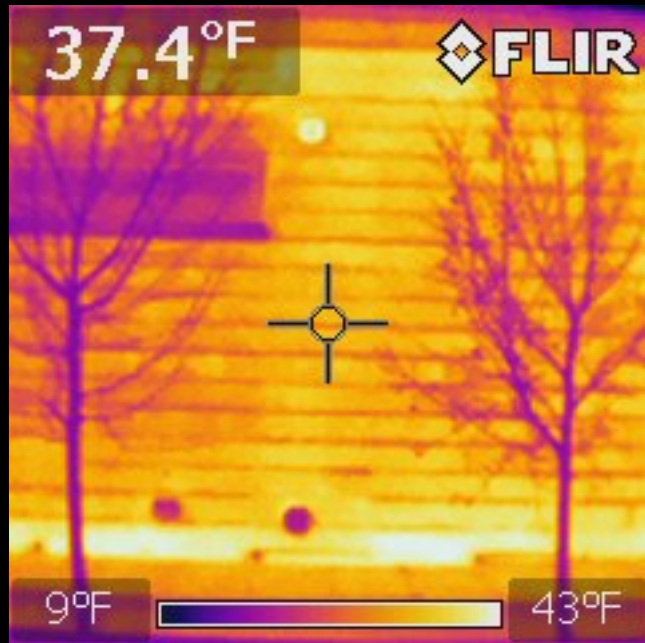


2015/07/21

2015/06/01



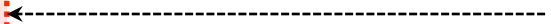




Month / Year	AVG.Int. RH.	AVG. Int. Temp.	AVG. Ext. Temp.
<b>Nov-14</b>	31%	72.26°F	33.76°F
<b>Dec-14</b>	28.51%	71.54°F	35.5°F
<b>Jan-15</b>	24.05%	66.83°F	26.4°F
<b>Feb-15</b>	19%	65.64°F	20°F
<b>Mar-15</b>	25.72%	66.95°F	38.4°F
<b>Apr-15</b>	40.52%	68.87°F	56.05°F

Avg. int. temp.  
69°F

with 3.82ACH50



CONSUMPTION	ACTUAL kWh
Apr-14	34
May-14	184
Jun-14	223
Jul-14	203
Aug-14	68
Sep-14	191
Oct-14	144
Nov-14	350
Dec-14	384
Jan-15	402
Feb-15	459
Mar-15	343
Apr-15	175

**3126**

Energy consumption while maintaining avg. interior temperature of 69°F with 3.82ACH50

PV_PRODUCTION	ACTUAL kWh
Apr-14	280
May-14	548
Jun-14	455
Jul-14	486
Aug-14	215
Sep-14	354
Oct-14	205
Nov-14	118
Dec-14	81
Jan-15	111
Feb-15	111
Mar-15	329
Apr-15	416

**3709**

Average Interior Temperature : **69°F**

Average Exterior Temperature: **33°F**

Percent time interior temperature is above 72°F: **12.62%**

Percent time interior temperature is below 68°F: **50.6%**

Percent time interior temperature is between 68°F and 72°F: **36.78%**

Percent time interior temperature is above 75°F: **.7%**

Percent time interior temperature is below 64°F: **7.48%**

Percent time interior temperature is between 64°F and 75°F: **98.6%**

Average interior RH: **27.2%**

Percent time interior RH is above 50%: **5.46%**

Percent time interior RH is below 40%: **93.44%**

Percent time interior RH is between 50% and 40%: **1.1%**

Average Interior Temperature : **69°F**

Average Exterior Temperature: **33°F**

Percent time interior temperature is above 72°F: **12.62%**

Percent time interior temperature is below 68°F: **50.6%**

Percent time interior temperature is between 68°F and 72°F: **36.78%**

Percent time interior temperature is above 75°F: **.7%**

Percent time interior temperature is below 64°F: **7.48%**

**Percent time interior temperature is between 64°F and 75°F: 98.6%**

Average interior RH: **27.2%**

Percent time interior RH is above 60%: **5.46%**

Percent time interior RH is below 40%: **93.44%**

Percent time interior RH is between 60% and 40%: **1.1%**





A Year in the Delta-T-90:  
Post Occupancy Data from the Westcott  
Center for Architecture and Design

Questions?

Norwich University  $\Delta T90$  Solar Decathlon Team

*c/o* Matt Lutz

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