NORTHERN ARIZONA UNIVERSITY

College of Engineering, Informatics, and Applied Sciences

To: Dr. Carson Pete and Loran Call

From: Renewable Energy Team

Date: 4/23/2023

Re: CAD and BOM Alternate Submission

Introduction

Students are required to submit a final CAD package for their projects, this includes assemblies, components, dimensioned drawings and a final bill of materials. This deliverable was modified for the renewable energy team as their CAD deliverable was to recreate the Winiecki house and create an energy model from the design. The team has fulfilled that requirement in Autodesk's civil engineering CAD program: Revit. As this software is not readily available to the public, this memo was created to briefly demonstrate the results and effort that CAD Lead Garrett Cornelius put into designing, modeling and simulating the Winiecki Cabin. Below you will find images pulled from the program as well as preliminary results pulled from the energy model to demonstrate completeness and fulfillment of the CAD assignment.

If any additional items are required to show fulfillment of the final CAD deliverable, please reach out to the Project Manager: Michael Horn.

Part One: CAD Design

The CAD cabin needed to be modeled from the foundation up. All of the dimensions and material types were pulled directly from the house blueprints and placed as accurately as possible into the program. The accuracy of the energy model is directly correlated to the accuracy of the modeled home. Revit has a large inventory of wall, roof, siding, and structural types to ensure accurate modeling.

Figure 1 is the resultant blueprint of the first floor. This diagram will act as the deliverable for the dimensioned drawing and was used to build the house around in the software. Figures 2 and 3 are rendered images from Revit. The cabin's materials are all accurate and each specific material has pre-loaded R values from Revit's material library. Values such as insulation and flooring types were assumed to the best of our ability using the house plans provided.

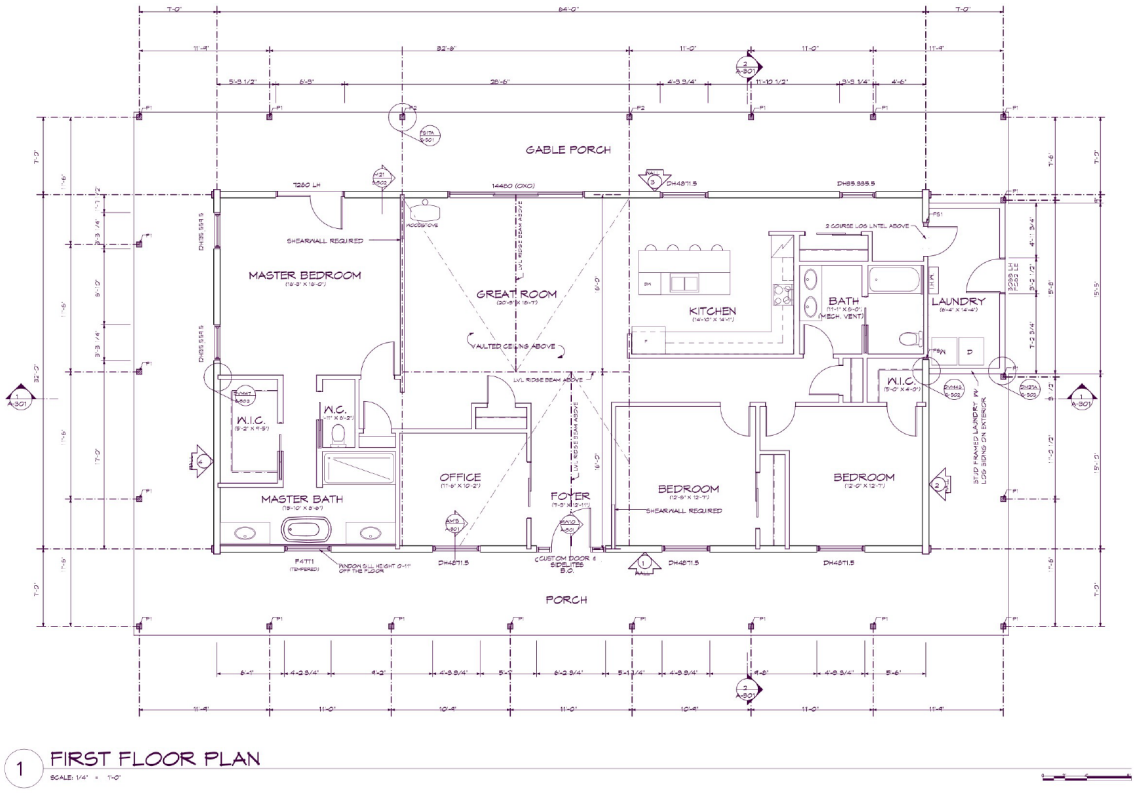

Figure 1 : Cabin Blueprints

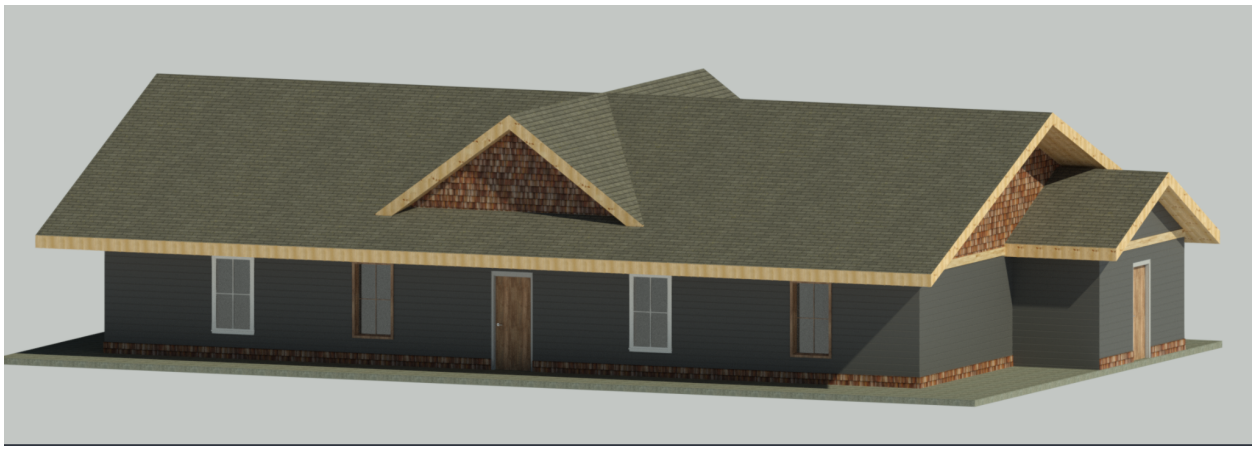

Figure 2 : Front of House Render

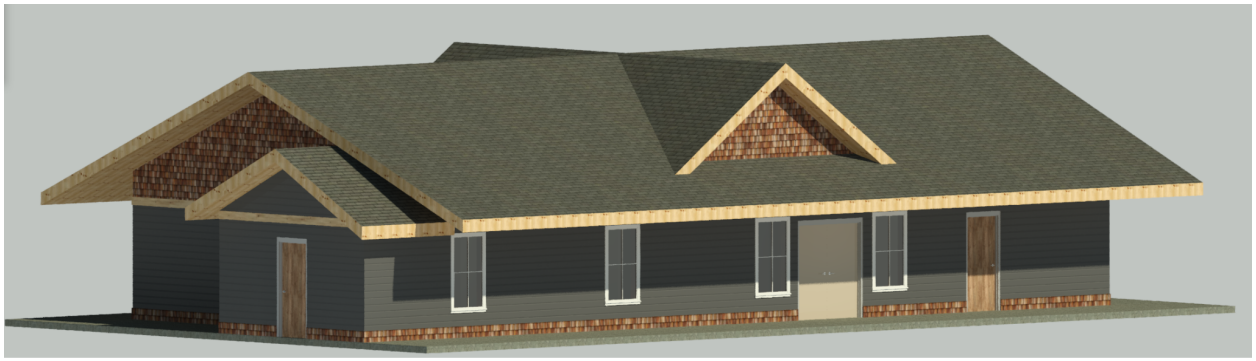

Figure 3: Back of House Render

Part Two: Energy Modeling

With the house created virtually with all of the material types and spaces designated, the team had to input the electrical loads that the house and PV system would be subjected to. Autodesk Revit allows the user to designate specific spaces with lighting, appliance and HVAC loads to each room and space in the home. Each space was designated with its specific usage type and the average occupancy load that each space would have. This allows the program to understand which spaces, like living rooms and bedrooms, will need to be cooled, and neglect closets and irrelevant unoccupied areas in the home.

Revit utilizes the USDE's Energy Plus engine to simulate the electrical, heating and cooling loads for the house. This system uses location and weather data to simulate the house and the avg monthly conditions it will be subjected to. Figure 4 shows the closest weather station that Revit has access to. It is under 5 miles from the location of the home and should provide excellent weather and condition data.

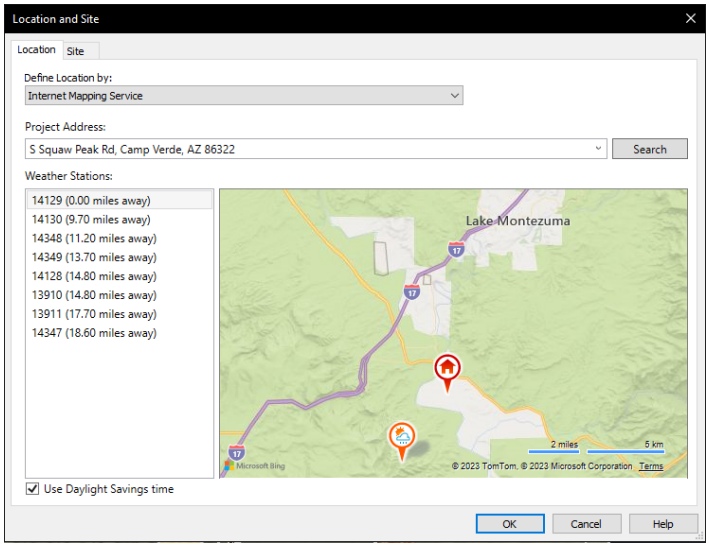

Figure 4 : Weather Station Location

Running the simulation results in a sizable abundance of data ranging from important weather impacts to obscure impacts from soil temperature 50 ft below the surface. The figures obtained in this report summarize the most important data that will directly impact the size and scale of the planned PV system.

Figure 5 shows the resultant monthly energy usage chart for the cabin. Because of technical issues, HVAC and appliances are covered under the overarching category of "interior equipment". Electrical and HVAC loads were imputed by the specs provided and assumptions of usage times and types were assumed to be in-line with a residential home. This chart shows that the PV system will need to supply at least 1400 kW of power per month to meet the simulated electrical loads. The yearly total energy draw was calculated to be 15,500 kW.

Monthly Overview

Electricity Consumption (kWh) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling													
Interior Lighting	575.61	502.2	529.88	551.14	554.35	526.67	575.61	529.88	551.14	575.61	505.42	575.61	6553.11
Exterior Lighting													
Interior Equipment	784.92	684.82	722.57	751.55	755.93	718.19	784.92	722.57	751.55	784.92	689.21	784.92	8936.06
Exterior Equipment													
Fans													
Pumps													
Heat Rejection													
Humidification													
Heat Recovery													
Water Systems													
Refrigeration													
Generators													
Total	1360.52	1187.03	1252.45	1302.69	1310.29	1244.86	1360.52	1252.45	1302.69	1360.52	1194.62	1360.52	15489.17

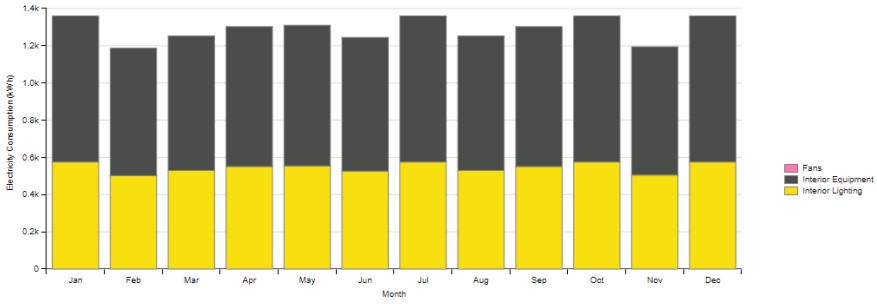

Figure 5: Monthly Electrical Loads

Heating and Cooling the home will account for the majority of the electricity consumed by the cabin. The PV system the team is designing will have to be scaled according to the efficiency of the home. The simulation also calculates the amount of heat loss from the home using the assigned material types. The simulation accounts for air exchanges, penetrations, exterior door openings, and weather data to provide an estimated heating and cooling load for the house. Revit uses a set temperature point in the home to determine how much thermal energy will need to be added or subtracted from the home to keep the temperature constant. The set temperature for this simulation is set at 70 degrees. It should be noted that energy usage can vary highly depending on the occupants preferred temperature setting. Figure 6 shows the resultant cooling load and Figure 7 shows the resultant heating load in Mega BTU's. The figures demonstrate the impact of the local weather conditions and insulation efficiencies have on the home.

District Cooling Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling	0.13	0.43	0.47	2.46	5.24	8.93	11.36	9.83	6.48	3.41	0.71	0.45	49.89
Interior Lighting													
Exterior Lighting													
Interior Equipment													
Exterior Equipment													
Fans													
Pumps													
Heat Rejection													
Humidification													
Heat Recovery													
Water Systems													
Refrigeration													
Generators													
Total	0.13	0.43	0.47	2.46	5.24	8.93	11.36	9.83	6.48	3.41	0.71	0.45	49.89

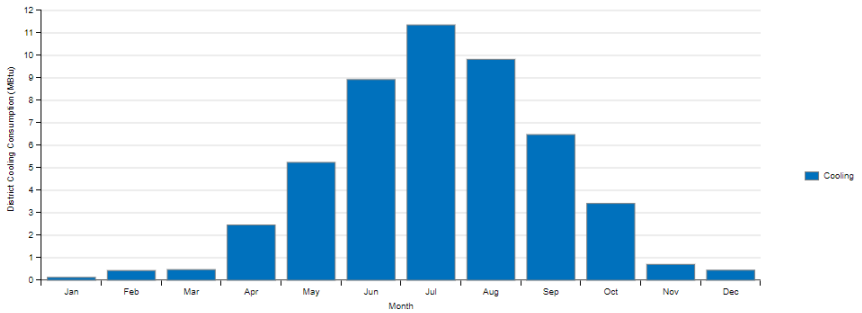

Figure 6 : Monthly Cooling Load in MBTU

District Heating Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating	12.16	6.72	6.29	2.69	1.01	0.05	0.0	0.01	0.22	1.82	6.61	10.12	47.69
Cooling													
Interior Lighting													
Exterior Lighting													
Interior Equipment													
Exterior Equipment													
Fans													
Pumps													
Heat Rejection													
Humidification													
Heat Recovery													
Water Systems													
Refrigeration													
Generators													
Total	12.16	6.72	6.29	2.69	1.01	0.05	0.0	0.01	0.22	1.82	6.61	10.12	47.69

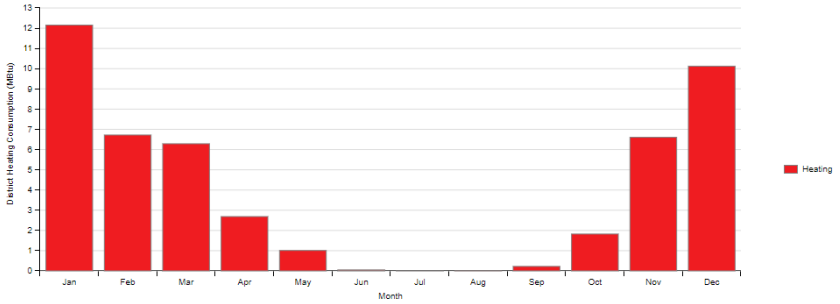

Figure 7 : Monthly Heating Loads in MBTU

Additional heating and cooling load outputs will be submitted in this package. Please see the html output and load zone summary files attached in the zipper submission. These results are the raw numbers of the report and will show the BTU effects of conduction, occupants, appliances and usage. The most important results have been shown above and this information has been used to refine our planned system to match the usage shown. A final bill of materials has been created to show the refinement of the final design.

Part Three: Updated Bill of Materials

To fulfill the requirements of the assignment as closely as possible, our team has included an updated Bill of Materials in Table 1. This list includes components, descriptions, costs, and quantities of the parts required to complete the PV system. From the results of the energy model, the quantity of the panels has been increased to 19, 480 W panels. It should be noted that the cost of the components are estimated and do not include freight charges or any dealer discounts that may be applied. A permit fee of 750 dollars was also added to cover the cost of permits should the customer choose. The system cost has dramatically decreased from over $90,000 originally quoted by Prometheus solar in Flagstaff. Most of the savings are accrued from self installation and avoiding the engineering costs related to purchasing a solar system from a private company.

This bill of materials is slated as "final" but the team will go through a series of checks through Dr. Pete and will most likely be altered over the summer months to accommodate price changes, dealer availability, and presumed design changes. All updated bills of materials will be in the renewable energy team's folder system in Microsoft Teams.

Quantity	Items	Description	Price ($)	Total Price ($)
19	Trina Tallmax 480	Trina Tall Max 480W Solar Panels	259	4921
1	Ground Mounted Solar	Ground Mounted Solar Panel Kit	5089	5089
35 Bags	Concrete	Concrete with delivery per yard	663	663
2	GS8048A-01	Outback Power Grid Interactive Inverter	4320	8640
2	GSLC	Outback Power GS Load Center	764	1528
2	FM100-300VDC	Outback Power FLEXmax 100 Solar Charge Controller	1377	2754
1	MATE3s	Outback Power Remote Display and Controller	490	490
1	HUB10.3	Outback Power Communications Manager	362	362
1	FLEXnet DC	Outback Power Battery Monitor, FN-DC	382	382
2	PNL-125-300VDC	Outback Power Mount Breaker, 125a, 300VDC	52	104
3	MNEPV20-300	Midnite Solar 20 A DIN Rail Breaker	38	114
3	MNEPC50-2P	Midnite Solar 50A/ 2P 240Vac, 200A Panel Mount Breaker	33	99
3	MNEDC-175	Midnite Solar Panel Mount 175A breaker	130	390
2	Transfer Switch	Manual Transfer Switch for Generator Bypass, 240Vac, 200A	180	360
1	Victron Lynx Power In	Victron Power Lynx Power In 1000A distribution for parallel combining up to 5 lithium batteries, with plastic cover	156	156
32	4/0 BLK Battery Cable	4/0 Black UL Listed Battery Cable - Price Per Foot	3.56	113.92
32	4/0 Red Battery Cable	4/0 Red UL Listed Battery Cable - Price Per Foot	30.65	980
20	4/0 Battery Lug	4/0 3/8 Copper UL Lug	103	2060
2	BigBattery Kong Elite	Big Battery Kong Elite Max Battery	6900	13800
1	Job Materials	Wire, conduit, breakers, j-boxes, etc	500	500
1	Permit	Building Permit, Variance, or Conditional Use Permit fees	750	750
24	Drawings/ Permits	Drawings/Paperwork for permits and/or APS Interconnect (grid-tied only), per hour	30	720
		Total		44975.92

Table 1 : Final Bill of Materials

Part Five: Moving Forward

CAD Design Lead Garrett Cornelius will continue to update and refine the model to best fit any changes in the PV system or cabin design. Moving forward with the model, Garrett will also be doing an analysis of the PV system in conjunction with the energy model to refine and simulate how the PV system will handle load changes and optimize any changes in the home design that would result in meaningful energy savings. The current state of the energy model is basic and will be refined when the home is constructed.

The rest of the team are also contributing vital engineering work that will ensure the accuracy of the model and improve the PV design. Issac Granados and Nicholis Santana will work on an analysis on battery loads and energy production of the panels to ensure that the system will meet all engineering requirements. Michael Horn will be calculating the assumed loads on the PV system structure to ensure it can meet any and all permit and coding requirements.

Over the coming months into the next semester, the team will continue to adapt, update and improve the CAD and system design. After the home is constructed in the summer of 2023, this team will be able to directly measure the usage from the grid. The measured readings will give an exact value that the PV system will expect to see and it is the team's goal that the readings match closely with the simulation values.