Spring 2021

Camper Conversion

Owen Christian Hafler
och7@zips.uakron.edu

Zebediah Paul Benedict Zehentbauer
zpz1@uakron.edu

Madilyn Beatrice Willis
mbw42@uakron.edu

Zachary Eli Owen
zeo2@uakron.edu

Justin Robert Nicholas
jrn51@uakron.edu

WERETOGO BUS CONVERSION

Spring 2021 | University of Akron M.E. Senior Design Project

Team: Owen Hafler | Justin Nicholas | Zachary Owen | Madilyn Willis | Zebediah Zehentbauer

Readers: Michael McGroarty | Elizabeth Clifford

ID #: 47_self_Deckler_Bus Conversion

Abstract | Executive Summary

The term "off-grid living" is defined as sustainable survival while not plugged into any major public amenities such as electricity or sewage disposal. The term "getting back to our nomadic roots" also applies in this context. Due to the low-monthly cost, the added benefits of self-sustainability, and the lack of need for support from public entities, off-grid living is a viable option for those who wish for a different way of life.

The COVID-19 pandemic of 2020-2021 has seen hundreds of thousands sequestered in quarantine for long periods of time. When quarantined in an urban setting, many cannot leave their respective apartment buildings which only adds to the strain of isolation. In the context of isolation, the design team of Hafler, Nicholas, Owen, Willis, and Zehentbauer personally sought to incorporate their individual enthusiasm for nature with the benefits of living off-grid. After initial research and deliberation, the team discovered the "Skoolie" community and the plans for a mobile tiny home began production.

The team outlined the design project as the full design, purchase, and construction of a 54-passenger bus transformed into a mobile tiny home. In addition, the team will seek to inspire others to live sustainably by releasing all designs and information on how to complete a similar school bus conversion on their Social Media Pages. The team highlights the terms "sustainable" and "off-grid" in the problem statement, this was done intentionally to ensure that all decisions made in the project were centralized back to these two main themes. By completing this project, the team will make a point to include all living amenities of an average student's apartment such as hot water shower, fridge storage, living and recreation area, sleeping area for 4-5 adults.

Bus conversion organization was consolidated in a time oriented Ghannt Chart. This Chart split the project into 4 major components: Conceptualization, Living Space, Plumbing, and Electrical Systems, respectively. The project was completed for $13,500 which fell under the $15,000 budget. Main costs for the project included Bus Purchase, Solar System and Kitchen Construction. The project was completed in 5 months by the team while utilizing professional supervision at all points necessary. At the end of the project, the team logged over 3100 hours and spent 15 consecutives 3-day weekends of both manual and technical design labor.

Contents

***This report utilizes Microsoft Word's Built-in heading navigation system. When viewed in Microsoft Word, please utilize the links to the report sub-sections located in the Table of Contents. In addition, all heading sections can be tabbed open and tabbed closed for a more consolidated and efficient reading experience.*

Introduction

Team Weretogo was formed officially in the fall of 2020 by the research and design team of Hafler, Nicholas, Owen, Willis and Zehentbauer. This project team sought to provide a sustainable, off-grid living option to escape the confines of urban quarantine due to the COVID-19 Pandemic of 2020-2021. After initial deliberation with team members the project goal was refined to fully design, purchase, and construct a mobile tiny home in a decommissioned school bus. All references such as "the team", "the research group" etc. in the following report denote the aforementioned team members.

Problem Statement:

> *"The COVID-19 pandemic has brought light the long-term effects of isolation. This project seeks to create a sustainable, off-grid, living solution that will be used as an opportunity to escape the confines of urban quarantine by living big in a tiny home."*

This report contains the Design Procedure and Details, Overall Budget, and all Verification necessary according to standards set by the University of Akron Senior Project advisory council ** Please see References | Appendix Sections for all links, research material, and other necessary information.

- Zehentbauer: Project Manager | zpz1@uakron.edu
- Hafler: Construction & Layout Lead | och7@uakron.edu
- Nicholas: Plumbing Lead | jrn51@uakron.edu
- Owen: Electrical Lead | zeo2@uakron.edu
- Willis: Installation Specialist | mbw42@uakron.edu

The project was notated complete as of the third of May 2021. @we_choose_wheretogo

**Point of Contact: Dr Gopal Nadkarni ______

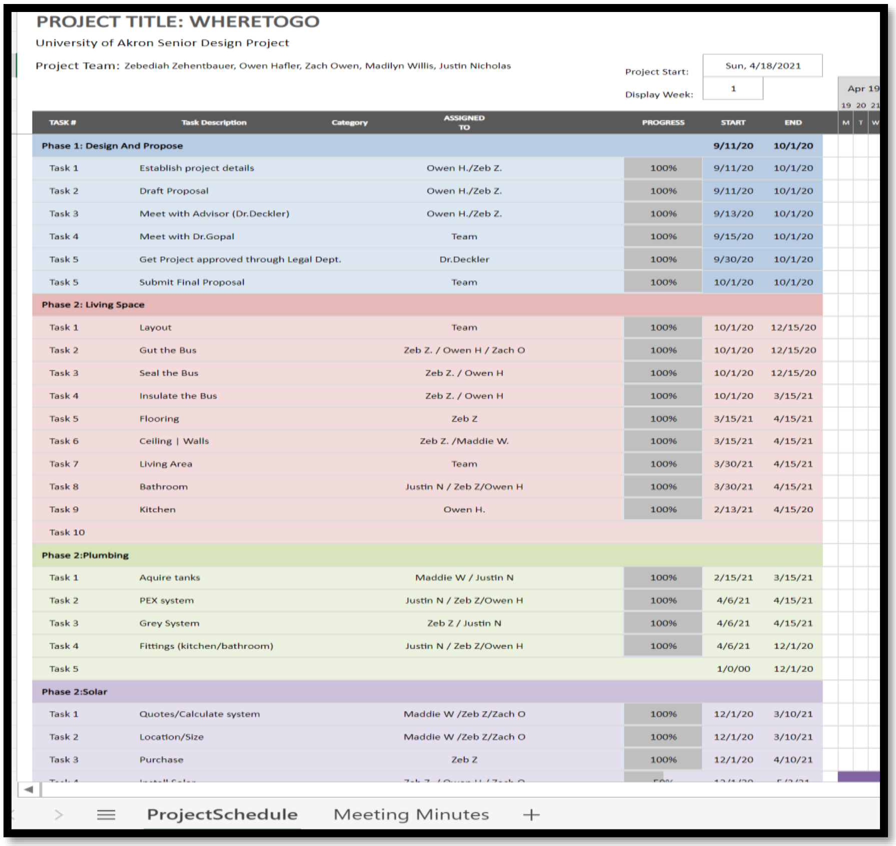
Phase 1: Workflow & Conceptualization

In the beginning stages, the team observed the best way to complete such a large project undertaking in the allotted time was to maintain a strict organization & timeline. The overall project was dissected into 2 main phases: 1. Workflow & Conceptualization and 2. Construction. **Please observe the report is organized as such.

Workflow

The main components of the build all required a team member to be the section lead. This group organization tactic allowed for all team members to engage in a leadership role in the project, which gave great real-world experience of workplace leadership, in addition to aiding in a more free-thinking space for problem solving. All team members were responsible for each section based on previous experience in the given field. For a complete list of team roles, please see the above ‘Introduction’ section of this report.

A deadline-based Gantt chart was used to track all major deadlines of the project. A Gantt chart is a horizontal bar chart that aid in large project organization by providing a visual observation of scheduled tasks over time. The vertical axis on the graph denotes the phases of the project and noteworthy subcategories. The horizontal axis represents the timeframe to complete the stated subcategories based on the given timeframe (“Gantt Chart – Long Form Info Page”).



PROJECT TITLE: WHERETOGO

University of Akron Senior Design Project

Project Team: Zebediah Zehentbauer, Owen Hafler, Zach Owen, Madilyn Willis, Justin Nicholas

Project Start: Sun, 4/18/2021

Display Week: 1

TASK #	Task Description	Category	ASSIGNED TO	PROGRESS	START	END
Phase 1: Design And Propose					**9/11/20**	**10/1/20**
Task 1	Establish project details		Owen H./Zeb Z.	100%	9/11/20	10/1/20
Task 2	Draft Proposal		Owen H./Zeb Z.	100%	9/11/20	10/1/20
Task 3	Meet with Advisor (Dr.Deckler)		Owen H./Zeb Z.	100%	9/13/20	10/1/20
Task 4	Meet with Dr.Gopal		Team	100%	9/15/20	10/1/20
Task 5	Get Project approved through Legal Dept.		Dr.Deckler	100%	9/30/20	10/1/20
Task 5	Submit Final Proposal		Team	100%	10/1/20	10/1/20
Phase 2: Living Space						
Task 1	Layout		Team	100%	10/1/20	12/15/20
Task 2	Gut the Bus		Zeb Z. / Owen H / Zach O	100%	10/1/20	12/15/20
Task 3	Seal the Bus		Zeb Z. / Owen H	100%	10/1/20	12/15/20
Task 4	Insulate the Bus		Zeb Z. / Owen H	100%	10/1/20	3/15/21
Task 5	Flooring		Zeb Z	100%	3/15/21	4/15/21
Task 6	Ceiling | Walls		Zeb Z. /Maddie W.	100%	3/15/21	4/15/21
Task 7	Living Area		Team	100%	3/30/21	4/15/21
Task 8	Bathroom		Justin N / Zeb Z/Owen H	100%	3/30/21	4/15/21
Task 9	Kitchen		Owen H.	100%	2/13/21	4/15/20
Task 10						
Phase 2:Plumbing						
Task 1	Aquire tanks		Maddie W / Justin N	100%	2/15/21	3/15/21
Task 2	PEX system		Justin N / Zeb Z/Owen H	100%	4/6/21	4/15/21
Task 3	Grey System		Zeb Z / Justin N	100%	4/6/21	4/15/21
Task 4	Fittings (kitchen/bathroom)		Justin N / Zeb Z/Owen H	100%	4/6/21	12/1/20
Task 5					1/0/00	12/1/20
Phase 2:Solar						
Task 1	Quotes/Calculate system		Maddie W /Zeb Z/Zach O	100%	12/1/20	3/10/21
Task 2	Location/Size		Maddie W /Zeb Z/Zach O	100%	12/1/20	3/10/21
Task 3	Purchase		Zeb Z	100%	12/1/20	4/10/21

ProjectSchedule | Meeting Minutes

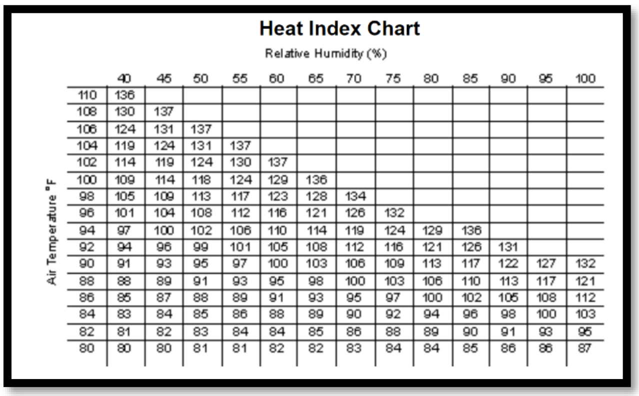
Figure 1: Team Weretogo Gantt Chart for Project Organization. c2021

The team scheduled meetings on weekly intervals to follow up on tasks, adjust timeframes, and to look to future duties to be completed before the next meeting. The above Gannt chart was simplified from the original task list into more digestible and understandable subsections. Due to an overwhelming number of tasks listed to complete, the team found it most advantageous to discuss and conclude on main subcategory points rather that to overpopulate the Gannt chart and confuse overall flow.

Conceptualization

Construction of a tiny living space brings a set of new challenges that the team quantified and tackled in a systematic nature. The team went through many iterations of designs for the flow layout, citing inspiration from popular skoolie builds such as “@just_another_skoolie” “@pacific.pioneer” “@roamerbus” and “@bussymcbusface” (all @ reference Instagram accounts please see References section for complete compilation). Continually through the iterative brainstorming process, the team determined aspects of the build that were necessary to design a comprehensive floorplan that fit the needs of the project via living big in a tiny space. The team utilized these aspects to confirm that the living space of the bus was a proper living space, thus they needed to be discussed and decide upon by the team before main construction of the bus commenced.

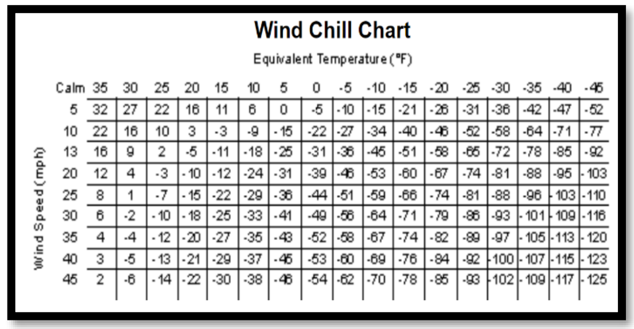
Heating and Cooling systems



Heat Index Chart

Relative Humidity (%)

Air Temperature °F	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	131	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	128	134						
96	101	104	108	112	116	121	126	132					
94	97	100	102	106	110	114	119	124	129	136			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87



Wind Chill Chart

Equivalent Temperature (°F)

Wind Speed (mph) \ Calm	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	32	27	22	16	11	6	0	-5	-10	-15	-21	-26	-31	-36	-42	-47	-52
10	22	16	10	3	-3	-9	-15	-22	-27	-34	-40	-46	-52	-58	-64	-71	-77
13	16	9	2	-5	-11	-18	-25	-31	-36	-45	-51	-58	-65	-72	-78	-85	-92
20	12	4	-3	-10	-12	-24	-31	-39	-46	-53	-60	-67	-74	-81	-88	-95	-103
25	8	1	-7	-15	-22	-29	-36	-44	-51	-59	-66	-74	-81	-88	-96	-103	-110
30	6	-2	-10	-18	-25	-33	-41	-49	-56	-64	-71	-79	-86	-93	-101	-109	-116
35	4	-4	-12	-20	-27	-35	-43	-52	-58	-67	-74	-82	-89	-97	-105	-113	-120
40	3	-5	-13	-21	-29	-37	-45	-53	-60	-69	-76	-84	-92	-100	-107	-115	-123
45	2	-6	-14	-22	-30	-38	-46	-54	-62	-70	-78	-85	-93	-102	-109	-117	-125

Figures 2 & 3 respectively. Heat and Wind Chill Charts via NHTSA.gov

In the construction of a home that will need to be livable in many different climates, the major concern for the research team was establishing the proper insulation to be able to keep the bus warm in the winter and cool in the summer months. The above graphs show the relative heat index a wind chill values for different temperatures and relative humidity. Information relating to this was essential to the team's process of insulation. To maintain the ability to live and thrive in and climate in the mainland USA, the bus will need to withstand temperatures from approx. -10 °F (-23.3 °C) to upwards of 100 °F (37.8 °C).

Figure 4: Climate Map of Mainland USA Max Temperatures via @printablemaps

(Please see Engineering Standards section for full list of proper standards used in the construction of this project, the following information will relate to the team's research on specific aspects of the heating and cooling systems)

The metal nature of the bus contains a high thermal mass and will thus retain considerably more heat than for example a conventional house. According to the NHTSA (The US National Highway Traffic Safety Administration) in an addendum regarding extreme temperature procedures for school bus drivers, "Extreme heat causes a problem when the temperature and the humidity combine – within a bus – to create high indices. This makes hot weather seem warmer." ("NHTSA"). Therefore, the team would be utilizing a Fan-Tastic Fan TM to circulate the air and keep the bus cool in the summer months. This system of fan would be placed in the ceiling of the bus to pull the rising hot air out of the bus, thus would most benefit from an open-air layout to allow for optimal free flowing efficient air-escape from the system. Especially the metal nature of the bus contains a high thermal mass and will thus retain considerably more heat during the heat of the summer than for example a conventional house. To maintain the off-grid nature of the bus, the team determined that an air-conditioning system was not an efficient use of the electricity that the system would house on board (See Electrical section for more information on this subject).

The NHTSA goes on to discuss how Extreme Cold is also quite dangerous in a bus due to the low insulation value already present and the conductivity of the cold. Which is simply combatted by insulating the walls to an effective measure to prevent the loss of maintained heat inside of the bus and implementation of a diesel heating system. However, the team is confident in a second more unexpected heating source during the winter: the sun. This is possible via a small-scale Greenhouse Effect. Greenhouse effect is the natural process that warms the earth's surface where the solar radiation from the sun is absorbed by the oceans and land and then slowly released back towards space. Some of this released heat is stopped from escaping to space by the atmosphere of earth and reflected back down, thus raising the temperature of planet earth.

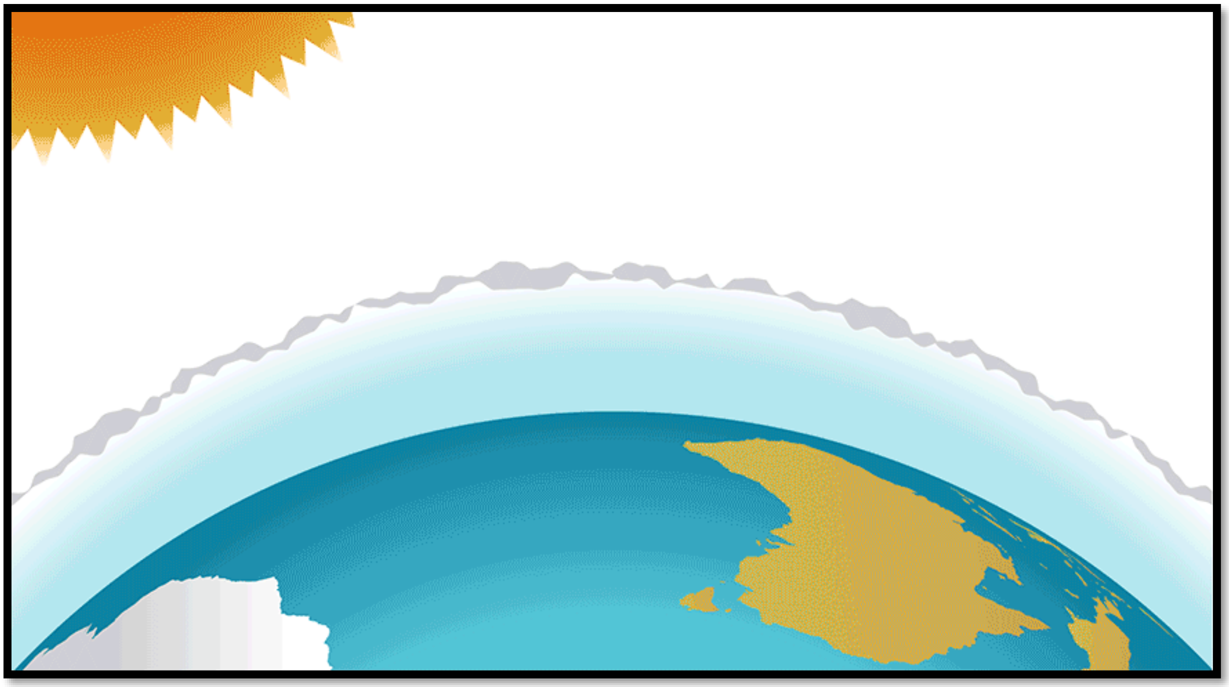


Figure 5: Greenhouse Effect on Planet Earth via environment.gov.au

In the context of the bus project, this same greenhouse effect should be in operation just on a smaller scale.

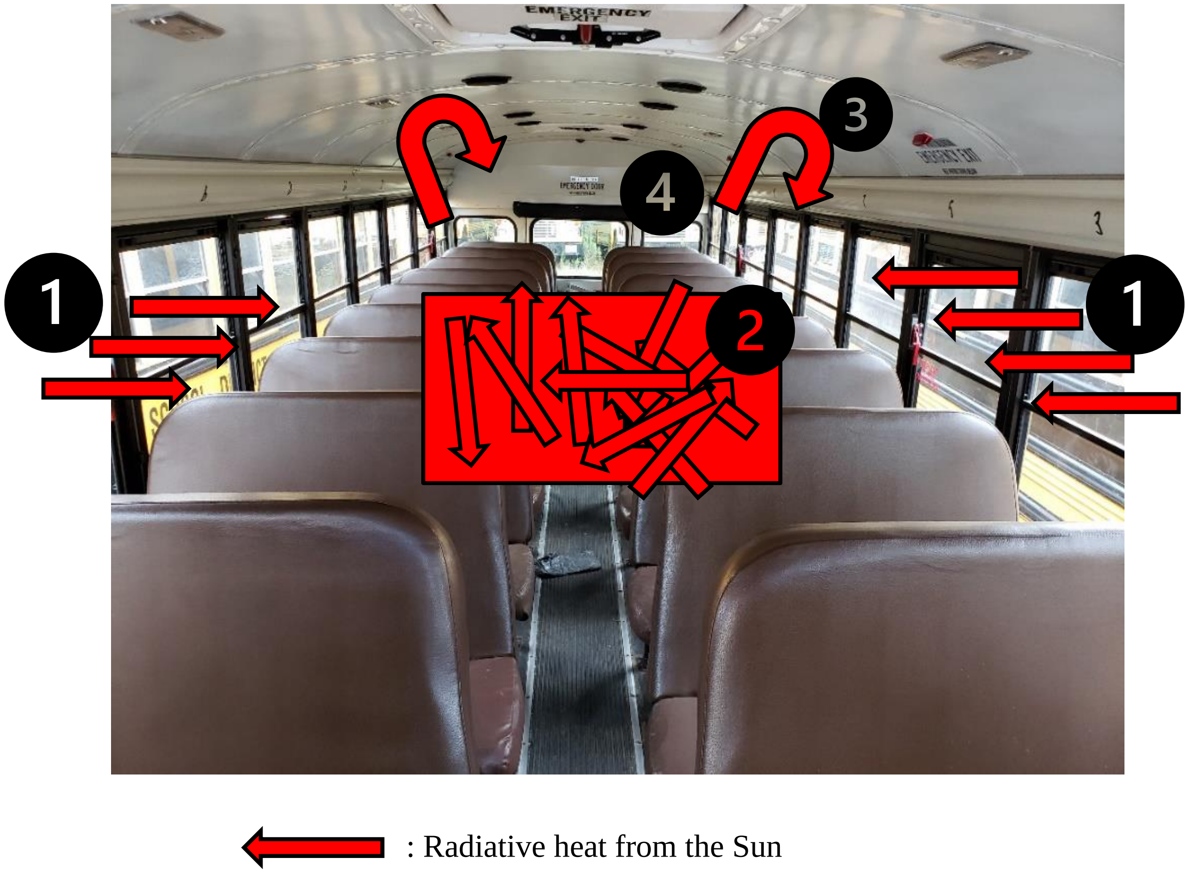


Figure 6: Example of Bus Greenhouse Effect image via Zehentbauer

The sun's radiation ❶ should initially pass through the bus windows/skylights (these simulate earth's atmosphere) and get absorbed by the objects in the space such as dark colored cabinets, metal interior trim and walls etc. ❷ (earth's land and oceans). When heat is radiated out of these objects with the addition of human occupancy, this heat will try to escape out the bus anyway it can and will be held inside by the added insulation/windowpanes ❸ (reflective atmosphere) thus raising the overall temperature of the interior of the bus when sufficient sunlight is present ❹.

In theory, this will help maintain the warmth of the bus during the hours when sunlight is present and allow for less reliance on the diesel heaters during the day. The added benefit of this secondary aspect of heating, lead the team to not block out all windows of the bus as originally planned. Utilizing two separate heating sources gives better peace of mind that the winter months will not be too hard to weather and is a great selling point of the project.

Wastewater

One of the main components of the off-grid nature of the project relies upon the freedom from sewage systems, thus the bathroom and wastewater removal system needed to be allocated in a different way. Black water is defined as and water from toilets or urinals. Greywater is wastewater that has been used for washing, laundering, bathing, or showering. In the interest of this project, the team consolidated to only include a greywater system and to mitigate the blackwater by installing a composting toilet. The blackwater system includes many aspects such as line flushing and regular chemical treatment that the team felt was in the long run-not very sustainable to remain in line with the project directives. The team decided on the implementation of a Natures Head Composting Toilet ® to serve as a replacement to the blackwater system. The composting toilet utilizes a separation of liquid and solids waste and a built-in fan system to mitigate odors. The US based company is extremely reputable in the Tiny-House community as being a sustainable option to mitigate blackwater systems. The solids/liquids reservoirs are both vented and allow for easy removal and cleaning. Please see below.

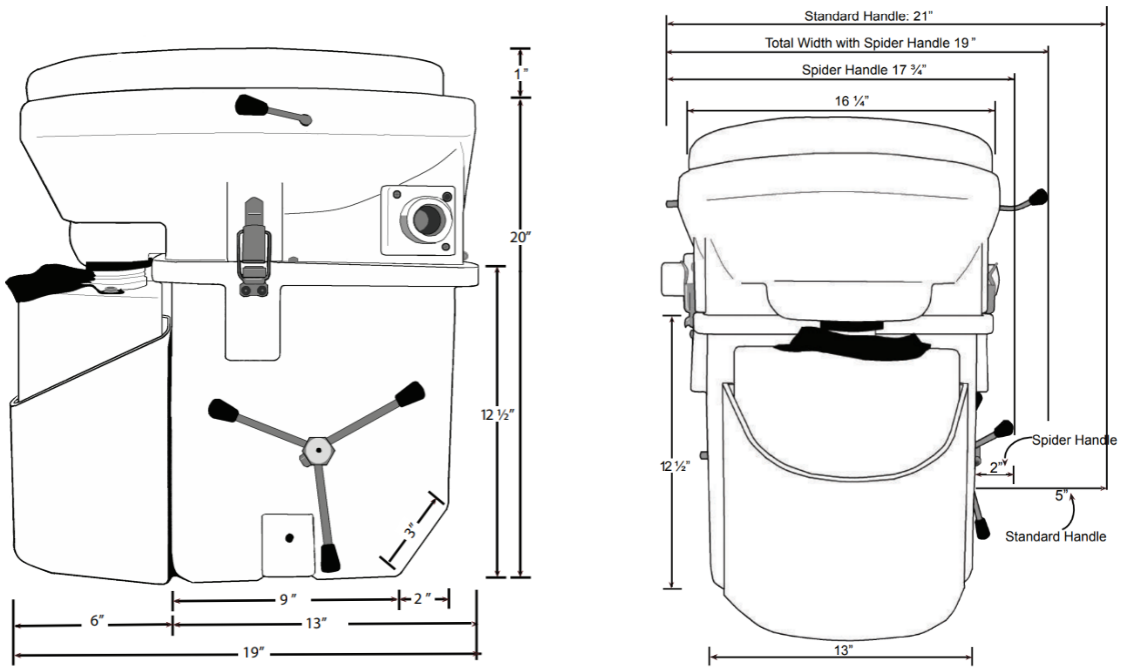


Figure 7: Nature's head Composting toilet diagram via Nature's Head

In terms of greywater, the team noted that the kitchen sink and the shower will need to be drained into a grey water tank that is undermounted on the bus. According to mandate bay the National Parks Service, "It is illegal to dump greywater, drain gray tanks, on the ground. Via CFR title 26" Please see Plumbing section for more information.

Phase 2: Construction

Living Space

When designing any living space, be it a 10,000 sq ft. mansion or a 168 sq ft. school bus turned off-grid camper, a functionally comfortable atmosphere is of utmost importance. The inhabitant should be able to walk in through the front door, be greeted with a clear and distinct path, and be able to navigate to the destination of their choosing (Living Room, Kitchen, Bathroom, Bedroom, etc.). This decision should not be a confusing one, conflated by disorganization or obtuse barriers, but rather one of fluid transitions, moving from space to space gracefully and sensibly. Design elements from space to space are free to change, but a memory of the space prior or the space to come can very well bring each space together in harmony. Each of these design elements and more were considered when designing the layout and eventually decorating, painting, and trimming each of the elements within. To maximize the feeling of size and space within the bus, the color scheme traversed from dark colors down low, to the lightest colors up high, drawing the eye along the lengthy ceiling lines rather than focusing on the close and sometimes confined lower areas. Choosing a dark brown flooring color, black countertops, light tan countertops with a red hue, red bathroom walls, white wall paneling, and a white ceiling, the team was able to make large feeling living, dining, bathing, and sleeping areas from a entire space that is objectively “Tiny”.

With a space as small as some living rooms, the task of utilizing the space in a manner that looked inviting and comfortable, but more importantly functioned as a true tiny home was a great challenge. The following elements were a must for the team and owner of the bus Mr. Zehentbauer:

- Living/Dining Space
    - Pull-out couch to sleep two occupants
    - Dinette for use as a workspace and eating surface

- Kitchen
    - Sink
    - Fridge/Freezer combo
    - Storage
    - Durable countertops
- Bathroom
    - Composting toilet
    - Shower with indoor and outdoor capabilities
    - A location to house an in-line hot water heater
- Bedroom
    - Queen sized mattress
    - Dedicated wardrobe location
- Underbed storage/Garage
    - 75 gallon fresh water tank
    - Room enough for snow skis and heater

Each of these with the addition of outlets and overhead lighting would eventually turn into the design shown below. A layout that met the goal of fluidity while still utilizing the small space to the maximum.

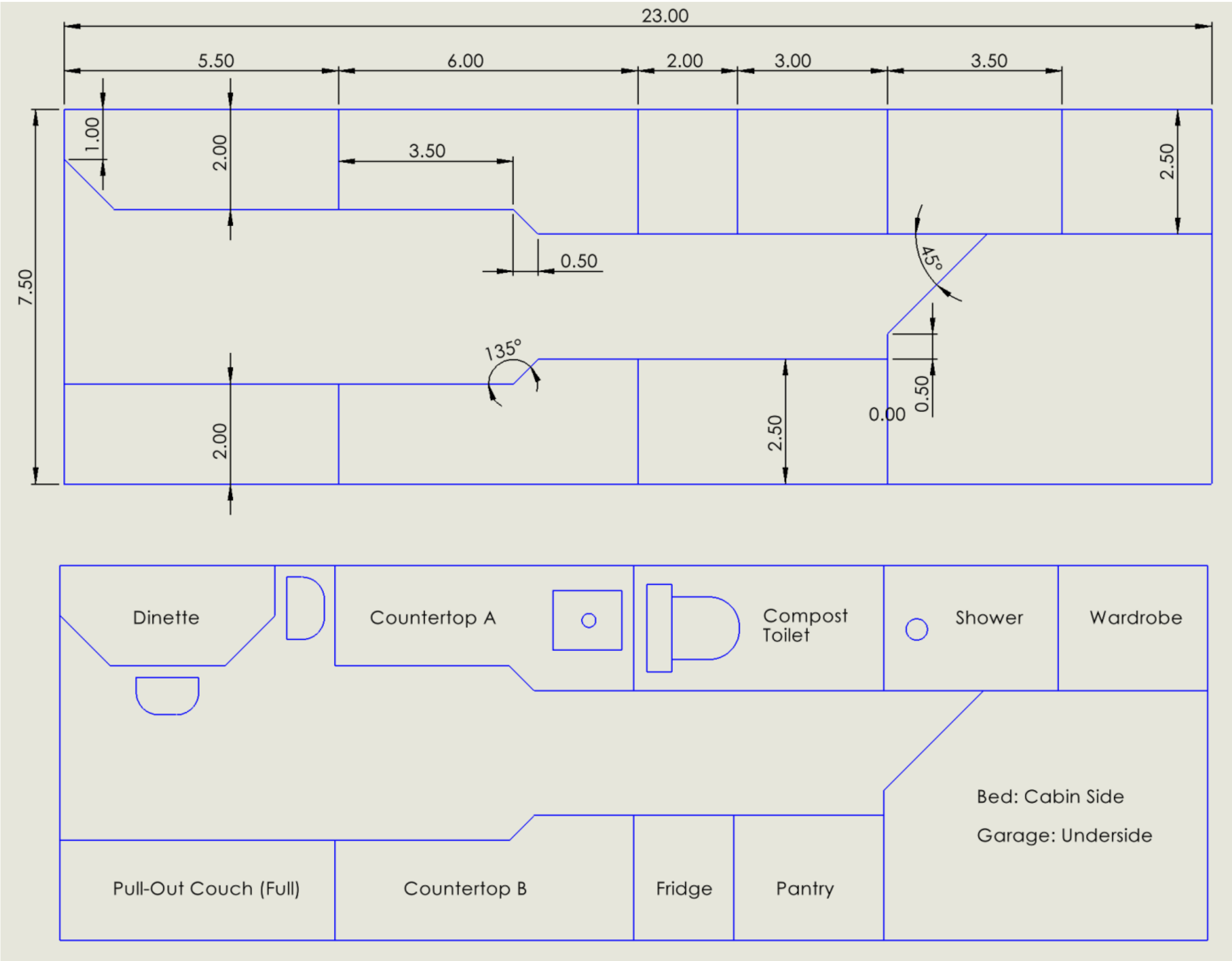


Figure 8: Solidworks Dimensional (top) and Annotated (bottom) layouts

As the viewer can see, each of the needed elements have been implemented into this design in a manner that allows for ample movement and comfortability throughout the bus.

With a layout chosen, designs could be rendered, and construction rather than destruction could begin. This was a big turning point for the team, as no longer were we tearing down apart a fully functional and operations piece of equipment, but rather building up a brand new, exponentially better collection of thoughts, ideas, and designs into a brand new, off-grid, home.

Beginning with the floor and moving up, construction commenced. The following is a detailed list of the steps taken to transform the steel box that is a gutted school bus into the framework that would eventually turn into an inhabitable space:

A. Floor:

1. The entire steel floor ground down to exposed steel to remove any large quantities of rust
2. Rust holes squared off with cut off wheels on angle grinders to allow for easier coverage with steel patches
3. Rust converter applied to the entire steel floor to stop the chemical reaction that causes rust to form
4. All bolt holes covered with pennies and silicon
5. Squared rust holes patched with primed sheet metal and Liquid Nails construction adhesive and silicon
6. The entire floor primed using Rustoleum Metal Primer
7. The entire floor painted using Rustoleum
8. The entire floor and 4 inches of the wall where it meets the floor coated with multiple layers of Flex Seal rubber coating to create a hopefully near perfect watertight base layer
9. 1”x2”x8’ pine boards cut and placed around the perimeter of the floor
10. 1” insulation board (R-Value 6.5) placed and secured (Liquid Nails) across the entire floor with 1”x2”x8” boards cut and sandwiched in between
    - Each side of each sheet of insulation board lined with aluminum tape to prevent any air movement as well as act as an additional water-tight sea
        - Spray foam used to fill any cracks between sheets and boards

11. 4’x8’x.75” OSB plywood acted as the subfloor for the bus, secured to the 1”x2” boards with construction screws
12. Vinyl tongue and groove flooring applied to entirety of floor, on top of bathroom wheel well, and around pantry
    - This step was completed after the steps C.1-4

B. Insulation

1. See Step A.10 for flooring insulation
2. Wall panels underneath of, and in replace of, windows utilized 1.5” insulation board (R-Value 7.5)
3. Sheet metal in between steel framing members on the ceiling also utilized 1.5” insulation board
    - Mated to sheet metal with Gorilla Glue spray adhesive
    - Insulation board cut to fit each window panel in 3 sections to allow for the most accurate of fit
    - Spray insulation used to fill cracks

4. Fiberglass insulation (R-Value 13) placed over and around each wheel well, within the framework explained in step C.1
    - Insulation board cut into thin strips to account for the arched roof shape
    - Spray insulation used to fill cracks

C. Framing

1. Each wheel well boxed in using framing methods with 2”x3” studs and framing nails
    - Surfaced with .5” Sande Plywood

2. Bathroom/shower walls constructed using 2”x3” studs and framing nails
    - Surfaced with .5” Sande Plywood
3. Bed Frame/Garage structure constructed with 2”x4” studs and framing nails for added strength
    - Surfaced with .5” Sande Plywood
    - Piano hinge installed on top surface for access to garage area from within the living quarters
4. Wardrobe framed with 2”x3” studs and framing nails
    - Surfaced with .5” Sande Plywood

D. Electrical

1. All DC lines originate and connect to Batteries underneath the pull-out couch and run to each of their respective locations
    - DC lines used to power all added interior and exterior lighting through household rocker switches
2. All AC lines originate and connect to Inverter underneath the pull-out couch and run to each of their respective locations
    - AC lines used to power all outlets and there for all appliances and chargers connected

E. Kitchen

1. Cabinets designed fully in Solid works to use as reference for cutting exact dimensions in the woodshop

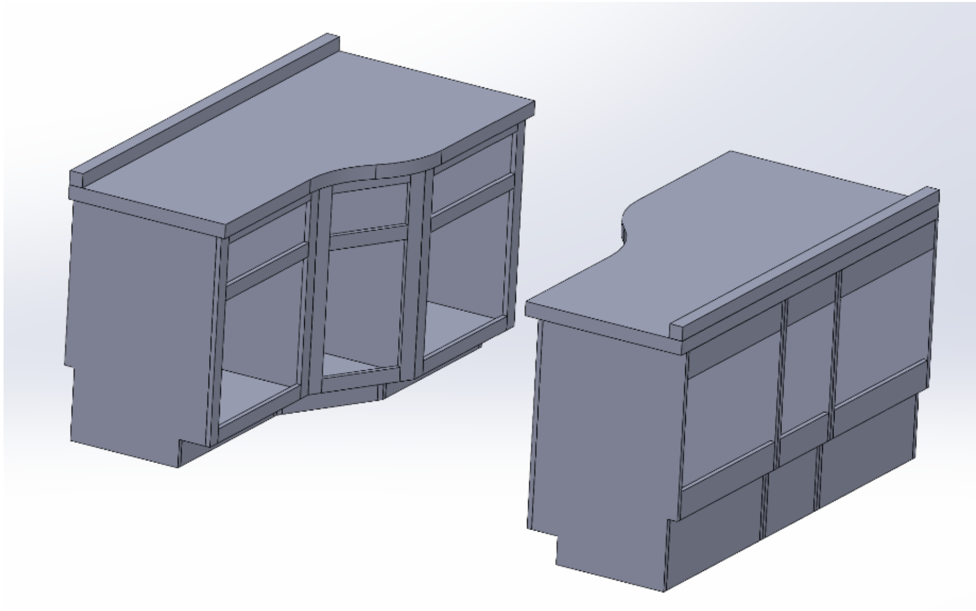


Figure 9: Solidworks Assembly models of Kitchen Cabinetry

2. Each piece of the cabinet boxes made from 6 sheets of .75”, 4’x8’ Birch Plywood
3. Using a cut list curated from the CAD designs and drawings, each piece was cut using a table saw, radial arm saw, miter saw, and circular saw
4. Assembly of each cabinet box utilized brad nails for temporary support and Titebond III wood glue for permanent fastening.
5. Holes partially drilled in the front and back on each side of the inside of each cabinet box from bottom to top to allow for adjustable shelf placement
6. Face frames constructed, assembled, and wrapped with edge banding to hide the layers of birch
7. Each face frame of was attached also with brad nails and wood glue
8. Each brad nail hole was filled with wood filler and sanded flush
9. Cabinet doors cut to size and wrapped with edge banding
10. Cabinet doors mounted to face frame using soft close hinges

11. Drawer faces mimic steps E.8-9
12. Drawer boxes built to size using .5” Sande Plywood and assembled using wood glue and brad nails
13. Drawer boxes installed into cabinet box using spacers and soft close drawer slides
14. Holes drilled in Cabinet doors and drawer frames to mount handles to
15. Using holes from handle on drawer faces, holes drilled into drawer boxes, using the handle screw to secure the drawer face to the drawer box
16. Cabinet boxes, faces, doors, and drawer faces are all painted black using a special cabinet enamel paint and a Wagner paint gun
17. Countertops were milled, cut, and shaped from 11’ live-edge cherry slabs, using wood glue and epoxy tinted black when necessary, to connect boards and fill voids
18. Countertops were finished with 4 layers of oil-based polyurethane, brushed on and sanded by hand in between coats with 220 grit sandpaper
19. When installing the cabinets into the bus, each box was secured together once flush with construction screws
20. Countertops installed to cabinets using floating tabletop fasteners to allow cherry wood to expand and contract with the changing seasons
21. Hole cut to accept deep well sink and faucet
22. Hole drilled to accept plumbing inlet and drain lines
23. Holes drilled to allow passage of electrical lines

F. Pantry

1. Framework installed and constructed from 2”x3” studs
2. Three walls constructed from .75” Sande Plywood constructed to size, matching the curvature of the ceiling

3. A permanent single shelf placed between the first and second wall above the location of the refrigerator, cut from .75” Sande Plywood
4. Adjustable shelf holes applied between the second and third wall to allow for a range of shelf placements
5. Three shelfs placed between the second and third wall, constructed from .75” Sande Plywood
6. Walls and permanent shelf are painted white
7. Adjustable shelves sprayed with a watertight sealer

G. Pull Out Couch

1. Constructed with 2”x3” studs
2. Designed so the transition from couch to bed is a single action sliding motion, using finger joints between the two halves that interlock
3. Framework surfaced with .5” Sande Plywood
4. Cushions are made from 3” thick mattress pad material and sewn into a durable fabric
5. Painted white

H. Dinette

1. Countertop made from a cookie slice of a Black Locust tree and milled flat
2. Mounted to the metal framework of the bus
3. Two repurposed bucket seats mounted through the floor and to the steel frame of the bus chassis

I. Ceiling

1. .5” wood spacers screwed to metal ceiling joists
2. Reflective sheet stapled to wood spacers to add additional insulation

3. .25” tongue and groove knotty pine planks used as visible ceiling material and nailed to wood spacers
    - Each plank was whitewashed for added visual appeal
4. Holes drilled in planks wherever a ceiling light was to be located

Plumbing

To establish a complete plumbing system for the bus, the team first established what areas to have a flow of water to reach and exit. This thought process involves the kitchen and bathroom. It was decided that one faucet was sufficient, due to keeping the bus spacious, and only planned for the kitchen sink and faucet, without a separate sink and faucet for the bathroom. It was also decided to build a shower into the bus, requiring water flow. Through consideration of the design process, the team concluded that the toilet would be better suited and simplified as a composting toilet. This is because the grey water tank underneath the bus takes up a fair amount of space and routing the toilet black water would be a complicated process. One of the complications found was the exhaust system runs underneath on the driver’s side of the bus, limiting the location of the plastic grey/black tanks underneath the bus to the passenger side at the rear. By using a composting toilet, the toilet can be placed on top of the wheel well of the bus and make use of an area with less head space, while also eliminating the need for a black water tank. With the plumbing layout determined, the insulation, framing, walls, cabinets, countertop, and flooring were built and secured according to determined layout. With the aforementioned in place, the team secured the plumbing equipment, with the intention of keeping it hidden from general view, unless maintenance was required.

Next, the team ascertained what general plumbing equipment was required to complete the system. Based on the selected plumbing system above, the team required:

- Freshwater tank

- Greywater tank
- Pump
- Piping for freshwater
- Piping for greywater
- Water heater
- Sink and faucet
- Shower trim/head valve
- P-trap and drain for sink
- Shower drain
- Additional materials for water-tight connections

Through research, it was determined that PEX piping was the best method for freshwater distribution, as it is cheaper than copper piping, easier to handle and install, more durable, more resistant to freeze breakage, immune to corrosion and mineral build up, and is not affected by electrolysis. The team purchased blue and red PEX piping to distinguish hot and cold lines going into the faucet and shower valves. Utilizing crimp rings and a PEX crimping tool, the team secured necessary elbows, tees, and other fittings where necessary. Additionally, the team purchased schedule 40 PVC piping to route the greywater from the sink and the shower to the greywater tank. PVC primer and cement were used to secure the greywater piping together.

The freshwater tank lays underneath the bed with an inlet and outlet. The inlet to the tank is connected to piping that is redirected outside so that the tank can be refilled. A hole saw was utilized to cut through the hull of the bus, and a camper housing was installed and sealed to the bus, connected to the inlet piping. This housing allowed for the tank to be filled from the outside of the bus, which also has a lock code to open for access.

The freshwater outlet is connected to the inlet of the pump via a short blue PEX pipe. The pump pushes freshwater out the outlet into blue PEX piping that runs within the framing of the bed utilizing 90-degree elbows. The cold water was split via a tee fitting to allow it to reach the shower valve. The other line from the tee fitting continues running, utilizing 90-degree elbows until it reaches near the water heater, where another tee fitting was utilized to run cold water into the water heater. The other line of cold continues to the faucet. Coming out of the water heater is the red PEX piping, distinguishing the hot water. The hot line enters a tee fitting to split the line where hot runs to the faucet and the other runs back to the shower valve. All the PEX piping is secured to the framing of the built walls, with either nail secured clips, or supported by running through studs that were hole sawed to fit piping through. A simplified diagram of the plumbing system can be found below in Figure 10.

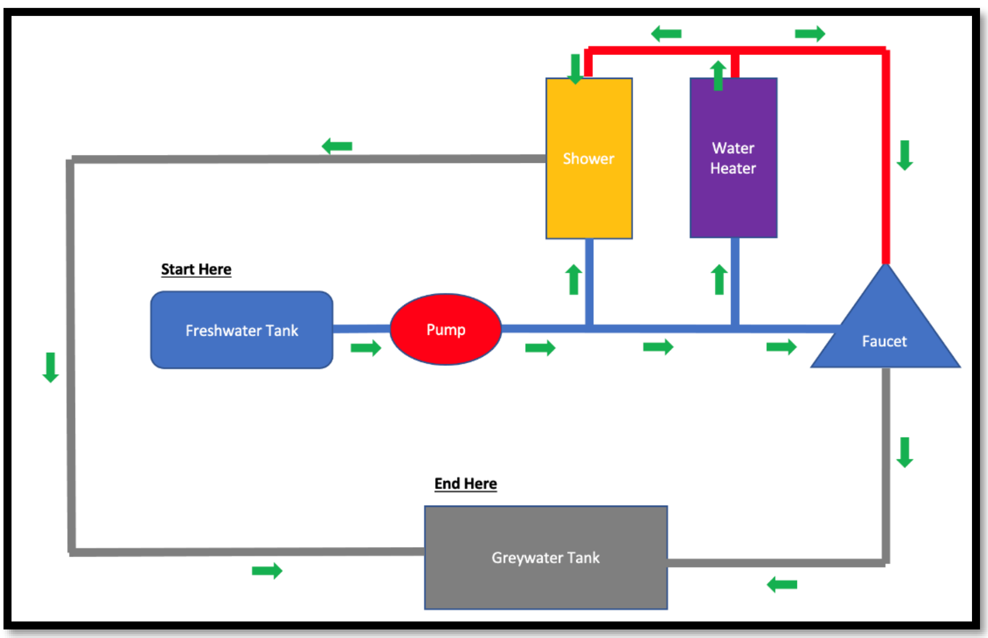


Figure 10: A Simplified Plumbing Diagram

A hole was cut out of the countertop to allow for the sink to be secured and positioned. A sink drain was selected and secured to the sink using silicone to create a watertight seal. The drain is connected to a P-trap that runs the greywater line back to the wall. After the P-trap, the PVC does a 90-degree turn to head toward the rear of the bus at a slight downward angle until it reaches above the greywater tank. A hole saw was used to drill through the floor of the bus to give access for the piping to reach the greywater tank underneath the bus.

The faucet was then placed through the hole at the back of the sink, and the nut from the bottom of the shaft of the facet was fastened up to the underside of the sink to hold the faucet securely in place. A deck plate was used to cover the extra holes for hot and cold handles because this faucet utilizes a single valve on the side of the faucet spout. The two supply lines were connected to the red and blue PEX piping with Teflon tape.

In order to create an ergonomic shower, the main shower valve must be placed at a reasonable arm length height that is easy to operate and manipulate for temperature control. With a height selected, the main valve is first secured to the framing wall. This process is delicate, as the depth must be calculated as perfectly as possible. The shower trim that covers the hole access to the valve needs to sit properly against the wall to create a water-tight seal, while not causing any problems with the shower handle opening the valve fully. Once secured, PEX FNPT female adapters were attached to the left, right, and top sides of the valve, using Teflon tape and liquid Teflon. The red and blue PEX lines were then connected to the left and right adapters using crimps. A reasonable height was selected for the showerhead and a PEX barb female pipe thread adapter 90-degree drop-ear elbow was fastened to the wall. A PEX pipe was connected between the drop-ear elbow and the FNPT adapter at the top of the shower valve to allow the mixed hot and cold water to reach the showerhead.

Next, the shower walls were installed with hole cutouts where the valve and showerhead need to connect. The shower trim was placed first, with the handle on top, connected to the valve by a set screw. The trim was pressed against the wall with silicone to create a water-tight seal. The showerhead was attached to the drop-ear elbow using Teflon tape and liquid Teflon. The showerhead trim was slid forward to cover the remaining visible hole.

The shower pan was placed and secured to the floor using liquid nails, and a hole saw was utilized to cut through the shower pan, flooring, and the bottom hull of the bus to grant access to the greywater tank directly underneath. The drain was secured to the shower pan by a press-fit, and water-tight with silicone. A short length of PVC schedule 40 pipe was used to connect the drain to the greywater tank.

The complete plumbing system is simple, but effective in design. Additionally, access to the pump is available by removing a wooden cover plate in front of the bed frame. With a full freshwater tank and an empty greywater tank, the bus is ready to sustainably live off-grid with a working faucet and shower.

Electrical Systems

Some define "off-grid" as removing themselves from the expense of the fixed utilities or reducing their carbon footprint. Disconnecting from the grid is neither easy nor cheap unless you are prepared to give up some of the conveniences of modern life. While solar panels can make reducing electricity relatively easy, securing potable water and disposing of human waste is just as important. The team chose some modern life amenities to include in their electrical system including a running water, refrigerator, indoor and outdoor lighting, electrical outlets, and fans. The team designed both AC and DC circuits throughout the bus.

Figures 11 and 12 are the AC and DC electrical circuits, respectively. Figure 11 shows the AC circuit, which provides 120V AC around the bus, powered by the inverter. This 120V circuit is carried around by 14-gauge solid core wire, all secured to wooden framing to prevent flexing. All circuits are restricted by 15-amp fuses. The AC is run off the inverter, which is run off the batteries. Figure 12 shows the DC circuit, which powers the overhead lights, security lights, and fans. The DC circuit is run off of the batteries directly. Each DC circuit is restricted by an appropriate fuse in the fuse panel.

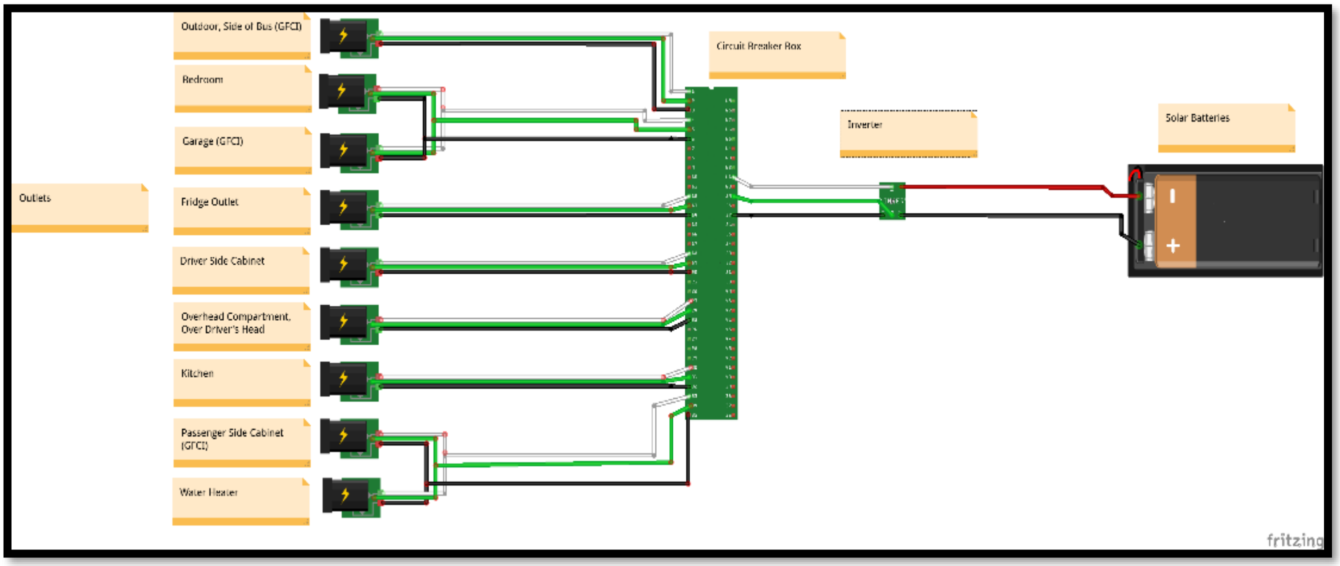


Figure 11: AC Circuit

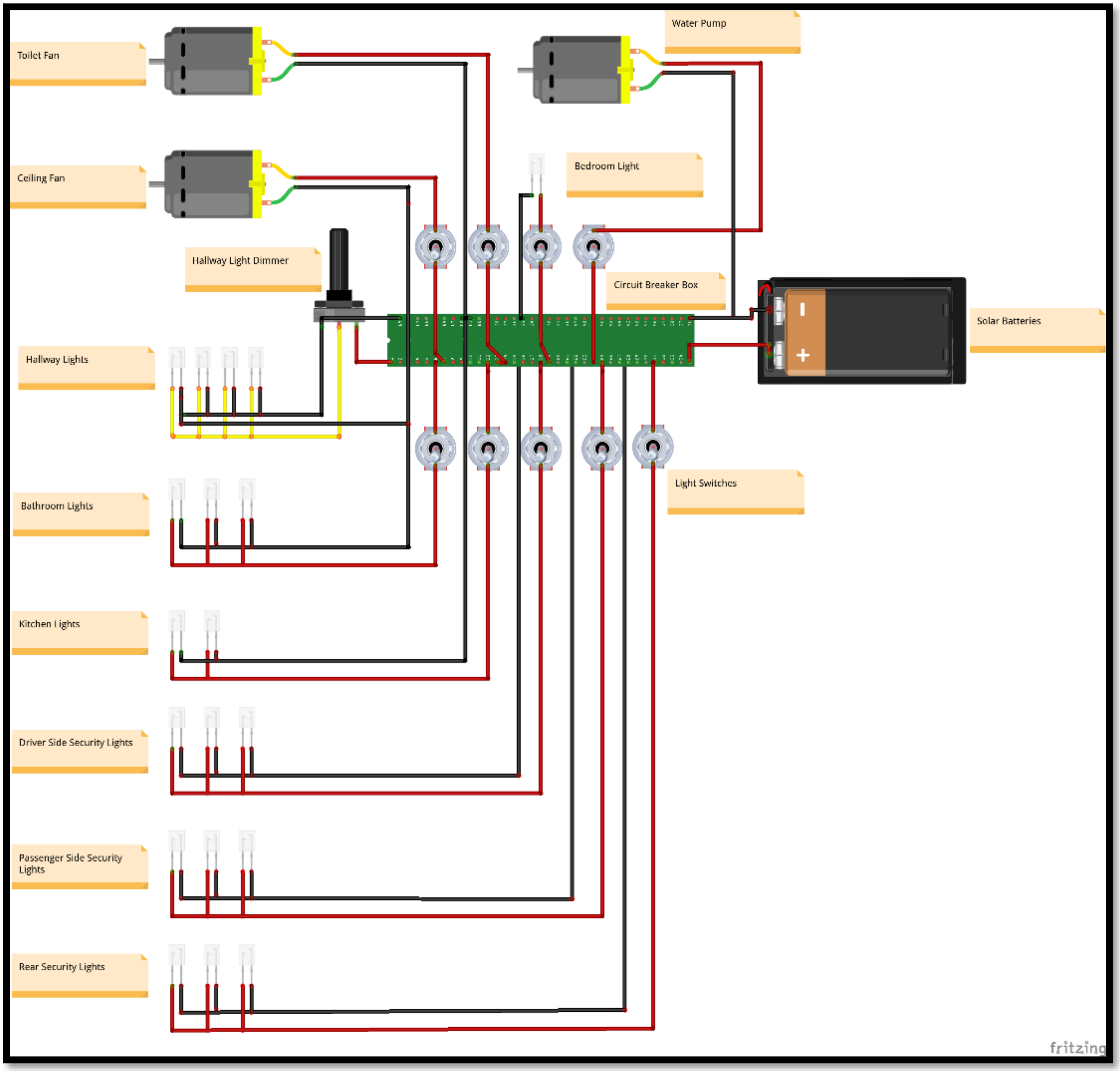


Figure 12: DC Circuit

Manufacturers develop individual PV cells to design and produce a PV module. Manufacturers utilize those PV modules to create a PV panel that is a standardized and proven efficient collection of PV modules. Those PV panels are sold commercially, and the design team of Hafler, Nicholas, Owen, Willis, and Zehentbauer purchased PV panels to build their desired PV array.

The team decided that their needs would be best met by an off-the-grid photovoltaic system for the electric generation. The tiny mobile home will not be connected to the grid and will require a larger photovoltaic (PV) system and a large battery pack. The basic diagram, shown in Figure 13 for the Off-the-Grid PV system begins with the PV Array collecting sunlight energy in the forms of direct and diffuse. The PV Array outputs DC electricity that feeds the Charge Controller. The Charge Controller has a DC output and a DC Circuit Bypass. The DC output from the Charge Controller passes through a DC Disconnect and leads to the storage battery. The DC Disconnect is not pictured in figure 13. The DC Disconnect is an added safety feature for if the team ever needs to work on the solar system. Both the DC output from the storage battery and the DC output bypass from the Charge Controller lead into the inverter. The inverter produces an AC output that leads into the breaker panel. From the breaker panel, the electricity is distributed to where it will be needed in the tiny home.

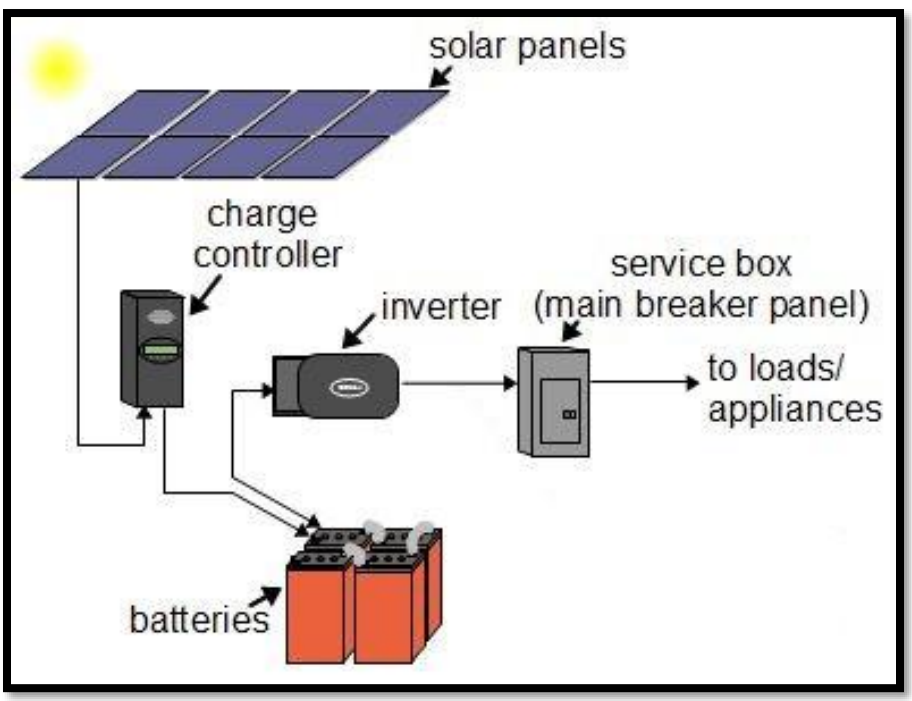


Figure 13: Overview of Electrical System

The off-the-grid PV system needed to be roof mounted because of the nature of the tiny home. The team considered a ground system that would need to be set up when parked and disassembled for travel. For convenience and ease, the team opted for the roof mounted system. Because the team chose to securely mount the solar panels to the roof, there was a decrease in efficiency due to the inability for the panels to rotate in either direction to maximize insolation intake. This had to be taken into consideration with determining our panel electric generation capacity.

The team had to determine the amount of electric generation that was necessary for the planned usage. During the design process, the team determined the amenities that were to be included in the tiny home and their respective electric pull. Table 1 lists out each electronic device, the watts required for the device, and the amps required with the assumption of 120V. The team determined the anticipated average hours of operation per day for each electronic device, and thus calculated the amp-hours of operation anticipated using average amps pulled, by the length of time that current needs to be supplied for. With the calculated electrical pull for the bus, the team was able to determine which model of PV panel to purchase and utilize as well as the battery type and battery storage capacity.

Skoolie Electric Pull Calculator					
	Electronic Device	Watts Required	Amps Required (assume 120V)	Avg hours of operation (in one day)	Amp hours
Toilet	Natures Head toilet fan	8.5	0.070833333	24	1.7
Fridge	Magic Chef 4.5 cubic foot	110	0.916666667	24	22
Water Heater	Tankless (propane)	42	0.35	2	0.7
Water Pump	1/3 1 hp	250	2.083333333	2	4.166666667
Lights	aprox 20 led lights	260	2.166666667	6	13
Computer	recharge	200	1.666666667	3	5
Projector		50	0.416666667	3	1.25
Xbox		150	1.25	2	2.5
Smart Phone	recharge	20	0.166666667	3	0.5
				Total Electric Pull in 24 hours	50.81666667
				2 Days with No Solar Input	101.6333333
				Keeping Batteries at least 50%	203.2666667
				Total storage needed	**203.2666667**

Table 1: Electric Pull Calculator

After determining the off-the-grid system and the rooftop mount, the team's next decision was picking which type of commercial PV modules to utilize. There are three different commercial PV modules: Monocrystalline, Polycrystalline, and Thin Film. Monocrystalline panels consist of monocrystalline silicon PV cells which are made from an ingot of a single crystal of silicon, grown, sliced, then doped and etched. Without considering costs, monocrystalline silicon is the best PV cell. Their efficiency ranges from 17-20% and manufactures typically offer a guarantee of 25 years at 75-85% of nameplate rating.

Polycrystalline panels are composed of polycrystalline silicon cells which are the next best PV cells with an efficiency range of 13 to 16% and reliable manufacturers guarantee them for 25 years at 70-80% of nameplate rating. These PV cells are less expensive, and the manufacturing process is less intensive.

Polycrystalline silicon cells are made up of various silicon crystals formed from an ingot. They are sliced, doped, and etched.

The most cost-effective type of PV Cell is a Thin-Film PV Cell which are used to develop Thin-film PV panels. During the manufacturing process, the material consumption is lowest with thin-film PV cell production and it is also the cheapest to manufacture. The panel is built with amorphous silicon or some non-silicon combination of metal such as Copper Indium Gallium Selenide (CIGS) and Cadmium Telluride (CdTe). The amorphous cell that the panel is composed of lacks any geometric structure and does not have an ordered pattern characteristic of crystal. Thin-film cells are made by depositing thin layers of PV materials onto a substrate. The substrate could be composed of glass or a flexible plastic sheet. Commercial models typically range in efficiency from 4 to 12%.

To provide context, monocrystalline panels consist of individual hexagonal cells in an array, polycrystalline panels are made up of individual square cells, and thin film panels have a single rectangular cell that is the size of the panel itself. So, the team had to choose between the three options. Monocrystalline is the most expensive but also the most efficient, polycrystalline is both moderately efficient and moderately expensive, while the cheapest and least efficient option is thin film. To decide which type of PV panel to use in the design, the team had to consider the surface area available for the panel installment and how many solar panels would be necessary for the bus's electrical pull.

For the project, the team purchased two 345-Watt monocrystalline solar panels to connect in series. When designing a PV system, the team had to take both current and voltage into consideration to maximize the power output. A typical photovoltaic cell acts as a 0.5V battery. PV modules increase the voltage by connecting the desired number of cells in series and increase the current by connecting the cells in parallel. Because commercial PV is sold in panels, the team did not calculate individual cell performance parameters. Instead, we utilized the performance parameters provided by the manufacturer.

When determining the PV size, some losses had to be taken into consideration. There are many categories of losses including soiling, shading, snow, mismatch, wiring, connections, light-induced degradation, and age. Because of the anticipated use of the bus for travel, there was no feasible way for the team to determine precise and accurate values for these losses. The team determined the losses based on prior experiences with solar panels and knowledge learned from classes to assume values in order to calculate the total anticipated loss for our PV system.

The next step of solar system was to determine the other components of the electrical system including the battery storage, the charge controller, and the inverter. Batteries are an important part of the electrical system. The team chose to use lithium-ion batteries, over other types for a few reasons. Lithium-ion batteries are more effective in the cold than deep-cycle batteries, and lithium ion are more scalable. This means that compatibility with additional batteries in the future are easily integrated with lithium ion, whereas deep cycle is not efficiently integrated with older deep cycle batteries.

Another important feature was the charge controller. The charge controller sits between the energy source, the solar panels, and the storage, the batteries. Charge controllers prevent batteries from being overcharged by limiting the amount and rate of charge to the batteries. They also prevent battery drainage by shutting down the system if stored power falls below critical capacity and charge the batteries at the correct voltage level. This helps preserve the life and health of the batteries. In most charge controllers, a charge current passes through a semiconductor which acts like a valve to control the current. Charge controllers also prevent overcharging by reducing the flow of energy to the battery once it reaches a specific voltage. Overcharging batteries can be particularly damaging to the battery itself so charge controllers are especially crucial.

Charge controllers also offer some other important functions:

- Overload protection: Charge controllers provide the important function of overload protection. If the current flowing into the batteries is much higher than what the circuit can handle, the system may overload. This can lead to overheating or even fires. Charge controllers prevent these overloads from occurring. In larger systems, it is also recommended to include a double safety protection with circuit breakers or fuses.
- Low voltage disconnects: This works as an automatic disconnect of non-critical loads from the battery when the voltage falls below a defined threshold. This will prevent an over-discharge.
- Block Reverse Currents: Solar panels pump current through the battery in one direction. At night, panels may naturally pass some of that current in the reverse direction. This can cause a slight discharge from the battery. Charge controllers prevent this from happening by acting as a valve.

The solar system was one of the more complex designs for the bus conversion. The team determined the electric pull required for the tiny and then determined the size of the photovoltaic array. The solar system utilized in the build will fit the needs of the design group. If in the future, the team decides the electricity demand is more than the system can supply, the team will be able to improve the system by increasing the number of solar panels and storage capacity accordingly.

Budget | Legal Considerations

5-Step Budget Process

In a project of this magnitude, a chief concern is the budget and the subsequent organization therein. The team followed a very simple 5 step process when establishing the budget for Project Weretogo following the Izquierdo Organizational Method for Projects (Izquierdo 2020)

Step 1: Identify Project Scope

In order to properly understand and consolidate an effective budget, the team looked to the problem statement for the project direction and necessary points of consideration. The team placed a large emphasis on the off-grid capability and the sustainability aspect of the home.

Step 2: Define Resources

Main resources in consideration by the team were determined to be Staffing, Installation Equipment, Facilities, and Raw Materials. These key factors organized the cash flow and maintained perspective on this project vision post-undergrad.

Staffing: The team completed all work under advisement of trained professional carpenters, electricians and plumbers that gave advisement pro-bono due to family ties. Additionally, the team members performed all the work on the project without pay. In a professional setting, most of the work performed would have been contracted out and not performed by the design engineers. Notably, this project has certainly benefited from the low-cost operation in the instance of staffing, the team notes this will not be the case in industry. The labor value of this project without these circumstances was estimated to be at approximately $50,000.

Installation Equipment: Much of the installation equipment was consolidated between the already existing tools of Zehentbauer and Hafler. It was estimated that no extra money would be spent on basic construction equipment such as respirators, bits, hole saws, and tape measurers.

Facilities: In terms of storage, the best option for the team was to utilize the facilities of Hanover Farms, a local family farm where team member Zehentbauer was raised. The Hanover Farms facility included a full 4 bay, 50 ft x 100 ft enclosed shop that included heating and air conditioning. The team found this workspace very suitable for all the bus building needs and would like to extend a very special thank you to Hanover Farms and the Zehentbauer family for hosting all workdays. There was no monetary cost associated with this option and was unanimously selected as the primary facility for all operations.

Raw Materials: Building a home, no matter the size, includes a great deal of consideration when approaching the raw materials. An aspect as broad as this can be left very general in this initial stage of the 5-step process. Therefore, the team concluded on a general definition of the raw materials as all non-original parts that will be added to the bus to complete the home construction. This included, but is not limited to all paints, insulations, paneling, electronic systems, solar system, tanks for grey and freshwater, upholstery, etc.

In initial meetings the team determined the biggest hitters to the budget considerations would be the Solar System, Kitchen Cabinets/Counters, and the Bus Purchase itself. Once initial estimates for those systems were received, the cost would be approximately $10,000 to complete the project. That initial number was taken and added a factor of .5 to account for other, smaller purchase points in the project, leaving a consolidated budget of $15,000 USD. Mr. Zehentbauer was the sole fundraiser for the project in its entirety, and as Project Leader, was the final say on all purchases related to the project itself.

Step 3: Assign Amounts

Staffing-$0

Installation Equipment-$0

Facilities-$0

Raw Materials. $15,000

Step 4: Build and Organize

The overall Budget was housed in an interactive excel document. The overall Bill of Materials page seen below contains 15 subcategories that all are found on the subsequent pages of the budget excel sheet. Each of the subcategories includes a description, a part count and the cost of completion for the area. This Cost of Completion is added and placed directly under the budget number to allow for easy visualization of budget trends. Please see the appendix for the full budget sheets for each subcategory.

Overall Bill of Materials	
Team	Wendigo
Approved via	Dr.Deckler
Approved date	9/10/2020
Total Hours (per member)	620
Total Hours (total for team)	3100
Budget	$ 15,000.00
Total Cost	$ 13,640.57

(this number has been updated from $12,000 to $15,000 to reflect a solar system install)

Contact Information
zpz1@zips.uakron.edu

	Area of Build	Link to Individual	Description	Part Count	Cost of Completion for Area
1	Bus Purchase	Link	2007 | Blue Bird	1	$ 3,500.00
2	Solar	Link	Solar system will allow the team to sustain off-grid electronic living full-time	9	$ 3,930.00
3	Insulation	Link	Overall insulation R-values of 17 on ceiling, 7.5 on walls, and 8 on floor	174	$ 1,000.13
4	Floor-Wall-Ceiling	Link	Flooring: once all seats and subfloor were removed, floor was rust converted, patched, rust prevent primered and painted, and sealed using flex seal. Next layered is soundproofing and water resistant barrier then vinyl/rubber flooring to create 100% waterproof and wear resistant floor, ceiling is a white washed smooth knotty pine	0	$ 733.96
5	Skylight-Roof Deck	Link	2 Skylights in the build: Over the Bed and Over the Common Living Area, High powered Fan will be placed in emergency exit to cool the bus in the hot summers	0	$ 78.98
6	Electrical	Link	Electric system is powered via Solar and Shure power 300 AH of storage. This runs all 10 puck lights, LED light strips, water pump, 8 outlets (4 GFCI, 4 Reg), Fan, Fridge/Freezer, charging capacity for all elctronics. *Note* E System is separate from the bus starting batteries.	0	$ 271.78
7	Water Storage	Link	75 gallons fresh water, 30 gallons of grey water storage. Water supplies hot and cold to both kitchen and on board shower.	27	$ 621.35
8	Kitchen	Link	Live-edge Custom Cherry Countertops, Single well sink with a	8	$ 1,622.63
9	Living Area-Entryway	Link	Custom built couch that pulls out into a full-size mattress, dinet with 2 captians chairs (with seatbelts), stairs are sealed using truck bed liner, and flex seal.	0	$ 213.15
10	Cockpit	Link	CB radio | bull-horn	0	$ -
11	Bedroom	Link	All bedroom supplies will be sourced from already purchased furnisings	0	$ -
12	Bathroom	Link	Composting Toilet, Shower Walls, and Shower Faucets	5	$ 935.78
13	Security	Link	Locks for all doors and fill ports	0	$ -
14	Exterior	Link	Ford Tractor Grey exterior paint | black rustoleum | truck bedliner	0	$ 519.66
15	Misc.	Link	misc items see section for more details.	0	$ 213.15

Overall Bill of Materials | Hourly Work | Bus Purchase | Solar | Insulation | Floor-Wall-Ceiling | Skylight-R

Figure 14: Team Weretogo: Overall Bill of Materials c2021

Step 5: Approval and Implement

The team approved the budget via vote and project manager after consideration from Edward Jones Finances. The budget was then officially populated with materials as purchased. Once the project was complete, the overall spending of the project was consolidated as UNDER BUDGET by approx. $1,400.00 USD. The Solar System came out as being the biggest hitters financially, followed by the Bus Purchase, Kitchen Area and the Insulation (See figure 15 below). Overall, the organization structure worked well, and showcased an easy visual representation of what all goes into a project of this magnitude.

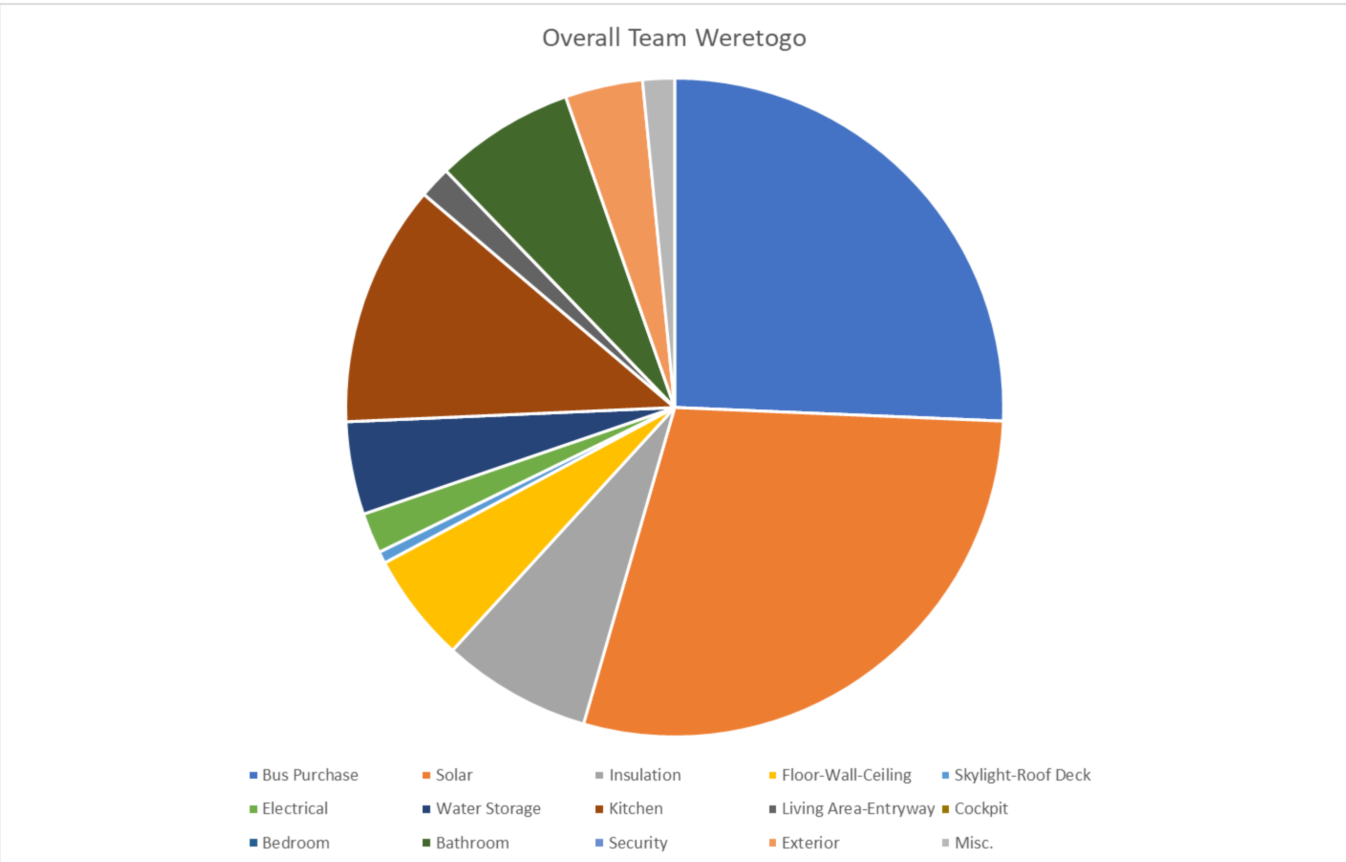


Figure 15: Overall Spending team Weretogo c2021

Legal

Title/Registration

Registration and legality of changing a title from one type of vehicle to another is a fairly straightforward process. To transfer the title from a bus to an RV, the owner, Zehentbauer, must sign an official Ohio Title Office affidavit claiming that the RV he was transferring the title to in fact met the specifications of an RV in the State of Ohio: Confirm that the unit contains a sleeping area, a cooking area with cooking utilities, capacity of storing food long term. Once signed, the title could be transferred into an RV title from a School Bus title. The next step was getting RV plates to replace the temporary tags received from the dealer via the BMV. Once the title was transferred and the plates were received from the BMV the team got the bus insured for full coverage.

The benefits of getting the title transferred from a school bus to an RV motorhome mainly was to get insurance to cover the project upon completion was considerably easier than to get coverage as a school bus. Most insurance lenders so not provide coverage from busses, however they do cover RVs so a title change was necessary. For personal reasons, the name of the insurance provider and all other information regarding Title and registration has been omitted, with any further questions please see the team reference emails.

Operation

Being registered as a motorhome, the team did not have to apply for a CDL license. Additionally, the bus was under the 60 ft, 26,000 lbs USA so no further licensing was needed. For road operation, the bus could not be yellow, contain any school bus hardware such as stop sign or walking bar. For light operation, the only requirements via the Ohio State Highway Patrol is that the emergency stop lights do not operate as emergency stop lights. The team completed all requirements without problem and are legal to travel any state/federal maintained road where the journey takes them.

Engineering Standards

1. According to the DMV and www.SkoolieSupply.com, to legally qualify as a recreational vehicle (RV) and no longer a bus, each of the following be exist within the conversion:
   - Seats removed (seating for fewer than 16 passengers)
   - Cooking appliance
   - Refrigerator unit
   - Sink
   - Toilet
   - Heating or AC unit
   - 120V power supply
   - Sleeping area
   - Painted a color other than yellow
   - A vehicle inspection
   - A VIN inspection
   - A current clean title
   - Bill of Sale
   - ID/Driver's License
   - Weight Certification
   - Proof of Insurance
2. In respect to plumbing, in accordance with ASTM F876 – Standard Specification for Crosslinked Polyethylene (PEX) Tubing, a hot and cold-water system was designed to supply both the

kitchen sink and the shower with hot and cold water. Running through from freshwater tank, through an in line hot water heater when necessary and plumbed to each appliance inlet

3. Also, within the plumbing department, citing ASTM D 1785: Specification for poly (vinyl chloride) (PVC) plastic pipe, Schedule 40, 80, and 120, a system was designed and implemented to drain both the kitchen sink and shower into a gray water tank
4. While designing the electrical systems, the team followed the specifications listed within the U.S. National Electrical Code (NEC) for both the AC and DC circuits
5. When framing, the 1994 Uniform Building Code Sec. 2318. Wall Framing, and Sec. 2326.11.1. Size, Height, and Spacing. was used as a reference to maintain a level of structural rigidity that the team was confident in

Discussion of Results

This senior design project gave this group an opportunity to demonstrate the knowledge gained through schooling and their education. The plumbing system in place allows the user of the bus to have a faucet and shower. With a faucet, dishes can be washed and re-used, and with the use of soap, the user can maintain clean hands which is very important during these trying times of COVID-19. Additionally, the easy access of water makes it easy to help with any food related washing or cleaning. It can be used as a source of drinking water as well. The shower allows the user to maintain proper body hygiene while on the road. As long as the freshwater tank is refilled and the greywater tank emptied, the user can continue to have a water source at their disposal.

The overall budget and project organization proved to be very valuable. In the long run, the ability to view the individual pieces of each section of the build was very beneficial when explaining the project to other students and staff the team communicated with during the project's course. Being organized in a large capital project such as this, gave great experience into the real world of large project engineering work in a technical workplace. The work was tedious, but necessary. In the future, a more streamlined excel sheet could be created to show the workspace more interactively, and the budget proposal could be shown to employers to both visually and numerically show results.

The electrical system demonstrates the ability to utilize both direct current and alternating current side by side, to maximize efficiency and safety. The solar system provides an excellent way to harvest natural resources and use them as a source of power, allowing appliances to run while remaining off-grid. The solar system then provides power to the charge controller, which uses logic to control the charging of the batteries and display the amount of power being produced by the panels. This powers the batteries, which in turn power both the inverter and the DC connections in the circuit breaker box. The inverter provides AC power to the breaker box, rendering it the central hub for both AC and DC power. This system maximizes efficiency and safety, resulting in 120V AC power throughout the bus, and DC power provided where needed. All are fused correctly in the breaker box, ultimately providing a safe, simple, and effective electrical solution for off the grid living.

The layout, from conception to a nearly finished product, fully tested the Engineering Design Process. Through iterative brainstorming, the team decided upon the necessary components to furnish this project with. Once a final design was chosen, departmental design could begin independent and simultaneous to one another (Kitchen, Bathroom, Living area, Bedroom, etc.). Cabinets were designed piece by piece in Solidworks to create a precise cut list for ease of assembly. And each of the other constructed features within the bus were rigorously measured and custom fit to achieve the closest final result to match the chosen layout.

Follow ups

The NHTSA discusses how Extreme Cold can affect school bus operation via a gel-ed up engine, which occurs at approx. 17.5 deg F (-8.1 deg C) when the outside temperature causes diesel to turn from a liquid into a gel-like substance and can no longer be pumped through the engine. Future projects will implement a better engine block heater to combat this when the bus travels to colder climates.

Conclusions

The design team of Hafler, Nicholas, Owen, Willis, and Zehentbauer started their collegiate careers in 2016. Throughout their years at The University of Akron, they gained knowledge about many different aspects. Their senior design project provided them an opportunity to showcase their knowledge and apply it to a real-world engineering application. Zehentbauer was inspired and began researching school bus conversion projects in his spare time. As the team was finishing up their fourth-year classes and brainstorming ideas for their senior design project, the team and the world was presented with a new challenge that no one predicted—COVID-19. As the team was under turmoil due to the COVID-19 Pandemic of 2020-2021, Zehentbauer presented an idea. The idea was an escape from the confines of quarantine. With the rest of the members on board, the team developed their senior design project, a sustainable, off-grid living option, a school bus converted to a tiny home. Team Weretogo was formed officially in the fall of 2020 by the research and design team of Hafler, Nicholas, Owen, Willis and Zehentbauer. After initial deliberation with team members the project goal was refined to fully design, purchase, and construct a mobile tiny home in a decommissioned school bus. The bus was purchased in October 2020 and was completed in May 2021. Over the past eight months, the design team removed the interior, rebuilt and sealed the floor, insulated the interior, added skylights, ran plumbing, rewired the DC circuit, added an AC circuit, furnished the unit, and refinished the exterior to fully convert the school bus into a mobile tiny home. The design team learned much about electrical systems, plumbing systems, time management, the financial aspects of an engineering project and much more. This was a great experience and provided an opportunity to apply the knowledge we learned in class to a real-world engineering application. Although the team did not learn the specifics of plumbing in class, we learned the theory and the mechanics of plumbing and the team applied that knowledge to design and assemble a functional plumbing system. This can be said about all aspects of the bus.

Recommendations

For this school bus renovation, the team has a few recommendations to streamline a more efficient build of the bus. In addition, there were a few compromises made to complete this project due to time constraints. In general, there are many improvements that can be made in all areas, but the team decided to highlight the sections below.

- Flooring installed prior
  - In regard to the flooring, the team initially decided on a roll of vinyl flooring, so the plan was to connect the cabinets and framing to the floor of the bus first, and then lay the flooring material. When the team was shopping for flooring material, a decision was made to lay tongue and groove flooring due to water and sound proofing benefits, as well as a better color scheme for the bus layout. Due to this change, the flooring process became much more difficult to complete. It is recommended that if tongue and groove flooring is to be used, to lay it first, and secure the framing and cabinets through the flooring material to ease the process.
- Pay better attention to measurements for framing
  - For framing, some measurements were slightly miscalculated and not as perfect as the team would have liked. These small issues caused the team to have further difficulties. It was manageable to work with, but definitely frustrating. A few instances were encountered where the team resorted to demolishing and reconstructing framing to prevent further issues. Additionally, fewer mistakes on measurements would have wasted

less material that was purchased. The team highly recommends a framing nailer, as the process for framing was much easier to manage than if the team hand nailed everything.

- Buying a bus not as rusty
  - Several issues were encountered because the bus that was purchased had many rust spots that had to be dealt with. It was a very time-consuming process. If the bus purchased was in use in the southern part of the US where it is warmer, less salt contact from snowy roads could have reduced the rust issues.
- Low side dimmer switch, instead of a high side
  - Low side dimmer switches are far more common than high side. The team wasn't aware that low dimmer switches needed to tap into the grounds to work and grounded every light into the frame. The most effective solution was to simply use a high side dimmer, applying resistance to the positive side of the circuit instead of the low side.
- Timing of solar panel install
  - The team fell behind in organizing what was needed for the solar system and ended up ordering the parts needed later than desired. Along with COVID-19 delays, the solar system and parts came later than anticipated, and they were not installed at the time of presentation. The solar system will be installed prior to the graduation ceremony of the five team members.
- Installation of air admittance valve
  - Within the plumbing system, the team is looking into installing an air admittance valve. Along the PVC piping after the P-trap from the sink, an air admittance valve could be installed to allow for proper ventilation of the greywater plumbing system. This allows the water to drain properly. Because this is only greywater, there is no significant smell

issue venting back into the bus, so the design team made the decision to forgo the valve with the current design.

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Appendices

Images of Complete Project

Honors College Reader Email Certification

Reader: Michael McGroarty, Graduate Assistant | Staff | University of Akron School of Music

Email: mdm159@uakron.edu

Zebediah Zehentbauer

From:	Michael McGroarty
Sent:	Monday, May 3, 2021 5:49 PM
To:	Zebediah Zehentbauer
Subject:	Re: Reader message for senior design project

Hi Zebediah,

This rough draft of your report was very interesting to read and I'm very impressed with the effort of your team. I approve of the work you've done and grant my consent to be listed as an official reader.

Let me know if you'd like any help addressing any formatting or grammatical issues, as I'm far more equipped to help with those than any of the engineering aspects, as you know.

Nice work, and thanks very much for including me in this process.

Best,

Michael McGroarty
Graduate Teaching Assistant, Choral Department

From: Zebediah Zehentbauer <zpz1@uakron.edu>
Sent: Monday, May 3, 2021 4:01 PM
To: Michael McGroarty <mdm159@uakron.edu>
Subject: Reader message for senior design project

Hi Michael,

I have attached the rough draft of our report, please give it an official read through.

Professionally, I appreciate you looking at this. All you need to provide us back with is an email with our consent to use your name as an official reader for the report, and whether you approve of the work we have done.

I appreciate all of your help,

Zebediah Zehentbauer
Mechanical Engineering Undergraduate
University of Akron – Class of 2021
Williams Honors College

Phone: 330-341-1219
Email: zpz1@uakron.edu

U.A. College of Engineering Dean's Team
U.A. Student Ambassadors
U.A. Choral Engagement Coordinator

https://www.facebook.com/uanuance/

Reader: Elizabeth Clifford, Graduate Assistant | Staff | College of Engineering

Email: ejc@uakron.edu

From: Owen Hafler
Sent: Monday, May 3, 2021 8:25 PM
To: Elizabeth Clifford <ejc46@uakron.edu>
Subject: RE: Weretogo Bus Conversion | Official Reader Approval

Liz,

Thank you so much for the time and effort you put into reading our report.

We are very proud of the product that has come from this semester of hard work!

The first trip is hopefully one that will never end, crossing boarders from state to state all the way from the Pacific to the Atlantic!

Thanks again and Best regards!

Owen Hafler
The University of Akron | BSME

From: Elizabeth Clifford <ejc46@uakron.edu>
Sent: Monday, May 3, 2021 8:19 PM
To: Owen Hafler <och7@uakron.edu>
Subject: Re: Weretogo Bus Conversion | Official Reader Approval

Owen,

Please find the edited report attached. The project is quite impressive! I correct some grammatical errors as well as pointed out areas I believe could be expanded upon to benefit the reader.

I accept the role as reader for your report. Please see the electronic signature below.

Congratulations to you and your team members on graduation and the completion of an impressive project! Where's the first trip planned to?

Also, you should reach out to the college of engineering's social media. This project would be a great feature on their Instagram!

Best of luck,

Elizabeth Clifford

Liz Clifford
PhD Candidate, Mechanical Engineering

From: Owen Hafler <och7@uakron.edu>
Date: Monday, May 3, 2021 at 7:26 PM
To: Elizabeth Clifford <ejc46@uakron.edu>
Subject: Weretogo Bus Conversion | Official Reader Approval

Good Evening Liz,

Thank you so much for considering being an official reader for our Honors Senior Capstone project. I have attached the full report for you to review.

If you could please respond when you have finished the review with any comments or suggestions you may have on how we could improve upon the report as well as physically type that you accept the role of being a reader for our report. Also, for the Williams Honors College, a form of signature is required as proof of identity, an email signature is all that is needed for this.

Thank you so much again and we look forward to your input!

Best regards,

Owen Hafler
The University of Akron | BSME

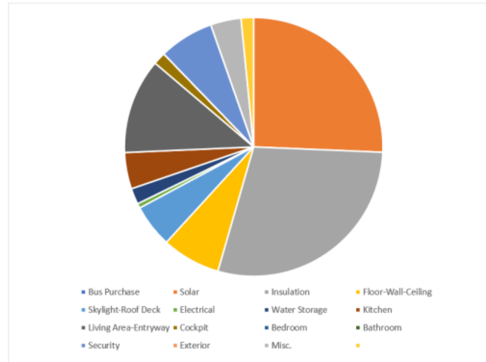
Budget Calculation Workbook

Overall Bill of Materials	
Team	Wendigo
Approved via	Dr.Deckler
Approved date	9/10/2020
Total Hours (per member)	620
Total Hours (total for team)	3100
Budget	$ 15,000.00
Total Cost	$ 13,640.57

Contact Information
zpz1@zips.uakron.edu

(this number has been updated from $12,000 to $15,000 to reflect a solar system install)

	Area of Build	Link to Individual	Description	Cost of Completion for Area
1	Bus Purchase	Link	2007 Blue Bird	$ 3,500.00
2	Solar	Link	Solar system will allow the team to sustain off-grid electronic living full-time	$ 3,930.00
3	Insulation	Link	Overall insulation R-values of 17 on ceiling, 7.5 on walls,	$ 1,000.13
4	Floor-Wall-Ceiling	Link	Flooring: once all seats and subfloor were removed, floor was rust converted, patched, rust prevent primered and painted, and sealed using flex seal. Next layered is soundproofing and water resistant barrier then vinyl/rubber flooring to create 100% waterproof and wear	$ 733.96
5	Skylight-Roof Deck	Link	2 Skylights in the build: Over the Bed and Over the Common Living Area, High powered Fan will be placed in emergency exit to cool the bus in the hot summers	$ 78.98
6	Electrical	Link	Electric system is powered via Solar and Shure power 300 AH of storage. This runs all 10 puck lights, LED light strips, water pump, 8 outlets (4 GFCI, 4 Reg), Fan, Fridge/Freezer, charging capacity for all elctronics. *Note* E System is	$ 271.78
7	Water Storage	Link	75 gallons fresh water, 30 gallons of grey water storage. Water supplies hot and cold to both kitchen and on board	$ 621.35
8	Kitchen	Link	Live-edge Custom Cherry Countertops, Single well sink	$ 1,622.63
9	Living Area-Entryway	Link	Custom built couch that pulls out into a full-size mattress, dinet with 2 captians chairs (with seatbelts), stairs are sealed using truck bed liner, and flex seal.	$ 213.15
10	Cockpit	Link	CB radio | bull-horn	$ -
11	Bedroom	Link	All bedroom supplies will be sourced from already	$ -
12	Bathroom	Link	Composting Toilet, Shower Walls, and Shower Faucets	$ 935.78
13	Security	Link	Locks for all doors and fill ports	$ -
14	Exterior	Link	Ford Tractor Grey exterior paint | black rustoleum | truck	$ 519.66
15	Misc.	Link	misc items see section for more details.	$ 213.15



started team work january 9th		pre January 9th work	
weeks worked	15	extra work weeks (2 team members)	5
Full team started		Hours worked per week	36
			360
		people	5
		hours	12
		days	3
		# weekends	15
		Total hours Worked per person	540
		Total Group Hours Work	2700
		Total Group Hours adjusted	3100
		ADJUSTED HOURS FOR EACH MEMBER	620

Bill of Materials

Team	**Wendigo**
Section of Build	**Bus Purchase**
Approved via	
Approved date	
Part Count	**1**
Section Total Cost	**$3,500.00**

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Bus Name	Wendigo		2006 Blue Bird			$3,500.00
Bus info	Engine Serial		WAX37962			
	Chassis		241373			
	Transmission		6510653480			
	Front Axle		97953			
	Rear Axle		96308			
	Rear axle Ratio		5.29			
	Catalyst No. And Date		257 9013 F156A			
	Brake Drum		43874			
	Brake Drum		43877			
	Rear Axle Differential		43339			
	Chassis Service No.		FA3FE10239120			
	VIN		1BABDCKA67F241373			
			1BABDCKA67F241373			
			7F241373			

Bill of Materials

Team	**Wendigo**
Section of Build	**Solar**
Approved via	
Approved date	
Part Count	**9**
Section Total Cost	**$3,930.00**

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Solar System	Solar system provided by Country View Hardware		See notes for comprehensive quote			
	345 Watt panels			2	$239.00	$478.00
	Rh-no Solar Controller		60 AMP	1	$250.00	$250.00
	Inverter		2000 Watt/ Charger to allow solar and Shure power	1	$1,200.00	$1,200.00
	Solar Breaker		Includes Box	1	$80.00	$80.00
	Inverter Fuse Box			1	$32.00	$32.00
	Inverter Cables			1	$40.00	$40.00
	Battery		300 Amp hour Lithium ion Battery. Can be taken below 50%. Single battery unit 40% faster charging than 6 Amp series batteries	1	$1,650.00	$1,650.00
	Installation		labor for hook ups and all connection	1	$200.00	$200.00

Bill of Materials

Team	Wendigo
Section of Build	Insulation
Approved via	
Approved date	
Part Count	174
Section Total Cost	$1,000.13

Contact Information

zpz1@zips.uakron.edu

	Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
	Seal the Floor	Pennies		Old pennies	150	$0.01	$1.50
	Seal the Floor	Silicone Sealant		GE Silicone II K&B White 10.1 oz	5	$6.57	$32.85
	Seal the Floor	Silicone Sealant		GE Silicone II K&B Clear 10.1 oz	1	$6.57	$6.57
	Seal the Floor	Silicone Sealant		GE Silicone II W&D Clear 10.1 oz	1	$6.57	$6.57
	Seal the Floor	Silicone Sealant		GE SIL I All Purpose 10.1 oz	1	$5.37	$5.37
	Seal the Floor	Rust Converter		Rustex - 1 gallon	2	$17.00	$34.00
	Seal the Floor	Rustoleum Primer		Gallon VOC primer Rustoleum	1	$34.98	$34.98
	Seal the Floor	Rustoleum Green		Gallon F&I JD Green	2	$35.99	$71.98
	Seal the Floor	Flex Seal		Spray (14 oz) Black	2	$12.98	$25.96
	Seal the Floor	Flex Seal		Cans (Pint) Black	7	$29.98	$209.86
~~Option 1~~	~~Spray foam insulation~~			~~OG Quotes put it at Aprox $4K to do the whole bus (Over budget)~~			
Option 2	Insulation (Floor)	Insulation -foil tape		Nashuma Multipurpose Foil	1	$7.73	$7.73
	Insulation (Floor)	Insulation -foil tape		General Foil Tape	1	$8.00	$8.00
	Insulation (Floor)	Insulation		1/2 4x8 Super Tuff R value 6.5	6	$12.35	$74.10
	Insulation (Floor)	Spray Insulation		Great Stuff Gaps and Cracks	4	$3.78	$15.12
	Insulation (Floor)	"Sleepers"		1x2x8 ft Select Pine Board	14	$6.15	$86.10
	Insulation (Floor)	"SubFloor"		23/32 4x8 OSB Subfloor	6	$36.48	$218.88
	Insulation (Floor)	Liquid Nails (Subfloor)		28 oz (Subfloor)	4	$4.78	$19.12
	Insulation (Floor)	Liquid Nails (Poly)		28 oz (Heavy Duty)	1	$4.97	$4.97
	Insulation (Floor)	Liquid Nails (Poly)		10 oz (Heavy Duty)	2	$2.37	$4.74
	Insulation (Floor)	Liquid Nails (Poly)		10 oz (Projects) - On Sale	1	$1.77	$1.77
	Insulation (Floor)	48" floormuffler (100 sf)		used as a water proof barrier and sound deadening material to go underneath the vinyl flooring	2	$ 64.98	$129.96

Bill of Materials

Team	
Section of Build	F-W-C
Approved via	
Approved date	
Part Count	
Section Total Cost	$ 733.96

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Ceiling fan	Fan tastic fan (Dometic)	https://www.facebook.com/marketplace/item/843822276436718/?referralSurface=messenger_lightspeed_banner&referralCo	RV Vent/Fan Sold camper and never installed these brand new, in the box Fantastic Fan. Top of the line Dometic RV fan with rain sensor and remote control. Too late to return them, paid $300, will sell for $175	1	175	$ 175.00
Flooring	Shadow Hickory lifeproof Flooring		Vinyl Shiplap Waterproof flooring LIFEPROOF 10 year guarentee 200 sq Ft			$558.96
					1.97	$ -
					11.97	$ -
						$ -

Bill of Materials

Team	
Section of Build	S.L.- R.D.
Approved via	
Approved date	
Part Count	
Section Total Cost	$ 78.98

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Skylight	Lexan 36x48 (skylight)		Skylights will be built out of 2 conts	1	$ 78.98	$ 78.98

Bill of Materials

Team	
Section of Build	Electrical
Approved via	
Approved date	
Part Count	
Section Total Cost	$ 271.78

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Dimmer Switch	12 Volt PWM Light Dimmer Switch, DC12V 24V Rotary Dimmer for LED Lights	https://www.amazon.com/gp/product/B089N9WYGT/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1	12-24V rated at 7 amps with electric surge protection, works for DC 12-24 V circuit	1	24.9	$ 24.90
Waterproof LED strips	Waterproof Led Strip Lights 50ft, Led Lights for Bedroom with Remote and Bluetooth App Control,	https://www.amazon.com/gp/product/B08C62VVWM/ref=ppx_yo_dt_b_asin_title_o03_s01?ie=UTF8&psc=1	50 ft, Multiple colors, Waterproof and dustproof, Easy Install	1	29.99	$ 29.99
LED lights for driving an security	Nilight 4.5 Inch Round 27W Spot LED Work Light Fog	https://www.amazon.com/gp/product/B07F17ZPG5/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&psc=1	27 Watt 10 pack Flood/driving lights 4.5 inches in diamer	1	53.99	$ 53.99
Puck LED lights	acegoo RV Boat Recessed Ceiling Light	https://www.amazon.com/gp/product/B012ZOI3ZW/ref=ppx_yo_dt_b_asin_title_o09_s02?ie=UTF8&psc=1	acegoo RV Boat Recessed Ceiling Light 4 Pack Super Slim LED Panel Light DC 12V 3W Full Aluminum Downlights, Warm White (White)	2	29.99	$ 59.98
outlets (singles with USB)	ANTEER 4.8A USB Wall Outlet Fast Charge	https://www.amazon.com/gp/product/B088HD3STD/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1	4.8A USB Wall Outlet Fast Charge - Dual High-Speed Charger Electrical Outlets - ETL Listed Duplex 15A Tamper Resistant Socket USB Outlets Receptacle (Black,4-Pack/Wall Plate)	1	37.37	$ 37.37
outlet cover (outdoor and garage use)	Sealproof 1-Gang Weatherproof In Use Outlet Cover	https://www.amazon.com/gp/product/B07HLX6G3P/ref=ppx_yo_dt_b_asin_title_o00_s01?ie=UTF8&th=1	Sealproof 1-Gang Weatherproof In Use Outlet Cover | One Gang Outdoor Plug and Receptacle Protector, Lockable, UL Extra Duty Compliant, 18 Configurations	2	8.29	$ 16.58
outlets (singles water resistant)	GFCI Outlet 20 Amp	https://www.amazon.com/gp/product/B08159L787/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1	GFCI Outlet 20 Amp, UL Listed, Tamper-Resistant, Weather Resistant Receptacle Indoor or Outdoor Use, LED Indicator with Decor Wall Plates and Screws (White)	2	12.49	$ 24.98
kitchen outlet	Webang 20 amp GFCI outlet	https://www.amazon.com/gp/product/B086C1QBJ9/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1	WEBANG 20 amp GFCI Outlet Outdoor, TR WR Self-Test Duplex Receptacles, Ground Fault Circuit Interrupters with LED Indicator Light, Screws Wall plate Included(2 Pack, Black)	1	23.99	$ 23.99

Bill of Materials	
Team	
Section of Build	Water Storage
Approved via	
Approved date	
Part Count	27
Section Total Cost	$ 621.35

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)	
Hot water heater	Camplux inline water heater	https://camplux.com/camplux-10l-2-64-gpm-high-capacity-indoor-	The 120 volt power cord powers the internal exhaust fan and color screen, safe electronic ignition system. The operating propane gas pressure is 0.4 PSI with maximum power output 68,000btu/hour.	1	249	$ 249.00	
Fresh System	tank	N/A	75 gallon fresh water tank purchased for $150 from facebook marketplace	1	150	$ 150.00	
Gray System	tank	N/A	Ripped out of an old RV, will be used as the grey tank (34 gallons)	0	0	$ -	
Gray System	Shower Drain 2"		Drain for shower to feed into PVC	1	$ 8.30	$ 8.30	
Gray System	1-1/2" elbow PVC		-	1	$ 2.97	$ 2.97	
Gray System	1-1/2" DWV Female adapter		-	1	$ 1.03	$ 1.03	
Gray System	1-1/2" DWV trap adapter		-	1	$ 1.38	$ 1.38	
Gray System	1-1/2" x 6" tailpipe adapter PVC		-	1	$ 2.31	$ 2.31	
Gray System	Solvent weld adapter		Use to attach piping	1	$ 3.84	$ 3.84	
Gray System	1-1/2" P-Trap		P-trap removes the smell from the grey tank	1	$ 3.84	$ 3.84	
Gray System	Tailpeice Sink 1-1/2 x12"		-	1	$ 2.86	$ 2.86	
Gray System	90 deg street elbow		-	1	$ 1.97	$ 1.97	
Gray System	8 oz all purpose primer		-	1	$ 9.47	$ 9.47	
Fresh System	1/2" PEX coupling (10 pack)		-	1	$ 13.47	$ 13.47	
Fresh System	1.2 PEX pro pinch Clamp (100 pack)		-	1	$ 49.99	$ 49.99	
Fresh System	1.2" Standard Clamp (25 pack)		-	1	$ 5.97	$ 5.97	
Fresh System	1/2" PEX Tee (25 pack)		-	1	$ 34.97	$ 34.97	
Fresh System	Spring Sink Strainer		-	1	$ 11.63	$ 11.63	
Fresh System	1-1/2 PVC 10"		-	1	$ 2.98	$ 2.98	
Fresh System	1/2 PEX elbow (40 Pack)		-	1	$ 38.97	$ 38.97	
Fresh System	1/2 x 5ft PEX pipe (1 B 1R)		-	2	$ 1.97	$ 3.94	
Fresh System	1/2 x 10ft PEX pipe (3B 2R)		-	5	$ 2.98	$ 14.90	
Gray System	1-1/2" x 10' PVC pipe		-	1	$ 7.56	$ 7.56	
						$ -	return 2 boxes

Bill of Materials

Team	
Section of Build	Kitchen
Approved via	
Approved date	
Part Count	8
Section Total Cost	$ 1,622.63

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Fridge	4.5 cubic foot fridge	https://www.homedepot.com/p/Magic-Chef-4-5-cu-ft-2-Door-Mini-		1	213.43	$ 213.43
Sink	Deep Single Well	N/A	Purchased from Auction	1	$10	$ 10.00
Cabinets and Countertops	Hafler Handworks	N/A	Owen Hafler custom built cabinets and countertops from Sandiply and Cherry Wood	1	1300	$ 1,300.00
Faucet	WEWE restatraunt style faucet	https://www.amazon.com/gp/product/B08BHX8SGZ/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1	Matte blackDeck mount single hole system. Includes all hardware	1	61	$ 61.00
Home Depot	Shelf support Spoon		supports for cabinet shelves	1	$ 8.45	$ 8.45
Home Depot	Short Rivets AL		-	1	$ 5.98	$ 5.98
Home Depot	#8 1-1/4 " screws (100 count)		-	1	$ 5.78	$ 5.78
painting assistance (paint sprayer only used for cabinets)	Acetone for paint sprayer		Dilutes paint so it can be sprayed	1	$ 17.99	$ 17.99

Bill of Materials

Team	
Section of Build	L.A.- Entr
Approved via	
Approved date	
Part Count	
Section Total Cost	$ 213.15

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Jo Ann Fabrics	Temp VFF Chenille Fabric		Fabric for Chairs (4yds @$9/yd)	4	$ 9.00	$ 36.00
General	Stencil		decoration	1	$ 3.13	$ 3.13
Bus Seats	Double Pointed Needle		Needle for Bus seats	1	$ 10.99	$ 10.99
Steps	1 " angle aluminum		to be used as edging on steps	1	$ 20.58	$ 20.58
Steps	2 " angle aluminum		to be used as edging on steps	2	$ 29.48	$ 58.96
Full Bed	Mattress		3.5 inch foam matteress Full Bed	1	0	$ -
Full Bed	Cover		High impact resistact mattress cover, costom sewed by Lindsey Gastios	1	68.53	$ 68.53
General	Needles			2	4.49	$ 8.98
General	Thread			2	2.99	$ 5.98
Full Bed	Velcro			4	0	$ -

Bill of Materials	
Team	
Section of Build	Bathroom
Approved via	
Approved date	
Part Count	5
Section Total Cost	$ 935.78

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Toilet	Natures Head Toilet		The Natures Head composting Toilet is the latest design, the best value, and the most reliable choice for portable, self contained, urine separating dry toilets -- on the water, on the land, or on the road. This toilet or head, (the marine term for toilet) was designed by two long time sailors who sought to create a more user friendly version than anything else on the market.	1	750	$ 750.00
Shower Head	Handheld shower system	https://www.amazon.com/gp/product/B086KX2JPK/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1	Matte Black, includes all hardware	1	110.87	$ 110.87
Shower wall	FRP waterproof board		Lowes: White pebbled flexibkle board will cover 3 of the walls in the shower	3	24.97	$ 74.91

Bill of Materials	
Team	
Section of Build	Cockpit
Approved via	
Approved date	
Part Count	
Section Total Cost	

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
						$ -

Bill of Materials	
Team	
Section of Build	Bedroom
Approved via	
Approved date	
Part Count	
Section Total Cost	$ -

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
						$ -

Bill of Materials

Team	
Section of Build	Security
Approved via	
Approved date	
Part Count	
Section Total Cost	$ 123.96

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Main and Garage Door Security Lock	SUMBIN Jimmy Proof Deadbolt Lock with Keyed (Black)	https://www.amazon.com/gp/product/B07WSSY55Z/ref=ppx_yo_dt_b_asin_image_o01_s01?ie=UTF8&psc=1	Diecast Deadbolt lock with shutterguard that prohibits tampering, fits door 1.25 inch to 2.25 inches thick.	2	17.99	$ 35.98
Floodlights for driving and security	Nilight 4.5 Inch Round 27W Spot LED Work Light	https://www.amazon.com/gp/product/B07F17ZPG5/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1	10 Pack, LED 12V Waterproof light fixture, puts out 27 Watts in a 4.5 inch round light. To be used as both new headlights and security lights for arount the bus	1	53.99	$ 53.99
Battery Box Lock	WINOMO Travel Trailer Lock Stainless Steel Rv Door Latch Heavy Duty Flush Mount Handle Latch for Toolbox	https://www.amazon.com/gp/product/B077TMHZ4M/ref=ppx_yo_dt_b_asin_title_o03_s01?ie=UTF8&psc=1	2 matching keys, Stainless Steel RV Door latch.	1	21.99	$ 21.99
Deisel Door Lock	Combi-Cam 7850R-L Chrome Large 1-1/8" Combi-Cam Combinated Cam Lock	https://www.amazon.com/gp/product/B000W7DBWA/ref=ppx_yo_dt_b_asin_title_o03_s02?ie=UTF8&psc=1	Keyless Security 3 number code, pick proof, Rust resistant	1	12	$ 12.00
						$ -

Bill of Materials

Team	
Section of Build	Exterior
Approved via	
Approved date	
Part Count	
Section Total Cost	$519.66

Contact Information
zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Misc Paint and supplies				1	$519.66	$519.66

Bill of Materials	
Team	
Section of Build	Misc.
Approved via	
Approved date	
Part Count	
Section Total Cost	$654.80

Contact Information

zpz1@zips.uakron.edu

Section Name	Product Name	Link to Product	Description	Quantity	Unit cost ($)	Ammount ($)
Insulation	Caulk Gun 29 oz.			1	$11.97	$11.97
Insulation	Caulk Gun 10 oz.			1	$3.27	$3.27
Insulation	Paint Brush		3.0 flat brush	1	$1.68	$1.68
Insulation	Construction Screws		1.25 inch 5lb box	1	$24.97	$24.97
Insulation	Plastic Roller Tray		9 inch	1	$1.97	$1.97
Insulation	Glue Remover		Glue Gone Pro Power Spray-24 oz	1	$7.84	$7.84
Insulation	Facemask		FG Cloth Facemask Gray 10 pk	1	$17.88	$17.88
Painting	Paint Roller		Roller CVR polyes 2 pk 9x3/8 in	2	$2.95	$5.90
Painting	Paint Roller		Roller Frame 5 wire 9 in	2	$3.19	$6.38
Painting	Paint Brush		2.5 inch chip brush	1	$0.79	$0.79
Painting	Paint Brush		1 inch chip brush	1	$0.47	$0.47
Painting	Paint Tape		MSRFACE 1.41 in x 60 YD	2	$7.75	$15.50
Painting	Drop Sheet		Cloth Drop Plastic 9x12ft	2	$3.99	$7.98
Respirator	Respirator			1	$44.99	$44.99
Respirator	Respirator catridges			1	$19.99	$19.99
Respirator	Scotch tape		Scotch 1.41 inch masking tape	1	$2.97	$2.97
Sanding	Grinder Sanding		Diablo 4.5 in conical polishing disc	1	$7.97	$7.97
Sanding	Orbital Sander disc		Diablo 5 in sanding disc (Mesh) 60pk	1	$29.97	$29.97
Sanding	Orbital Sander disc		Diablo 5 in sanding disc (Paper) 15	1	$9.97	$9.97
Sanding	Sandpaper (Orbital)		220 Grit orbital sandpaper	1	$2.39	$2.39
Sanding	Sandpaper (Sheet)		5 inch 220 Grit 5 pack	1	$3.99	$3.99
Bumper Extension	steel cost for bumper extension		Dan Paumeir custom built bumer extension approx 33 inch wide to accomidate a motercycle	1	200	$200.00
Painting	HR Paint cabinet and trim		BEHR Paint cabinet and trim	2	39.98	$79.96
Seals	Bus door seals			1	146	$146.00