Responding to Canadian Wildfires:
Tinderbox Wildfire Shelter Kits

by

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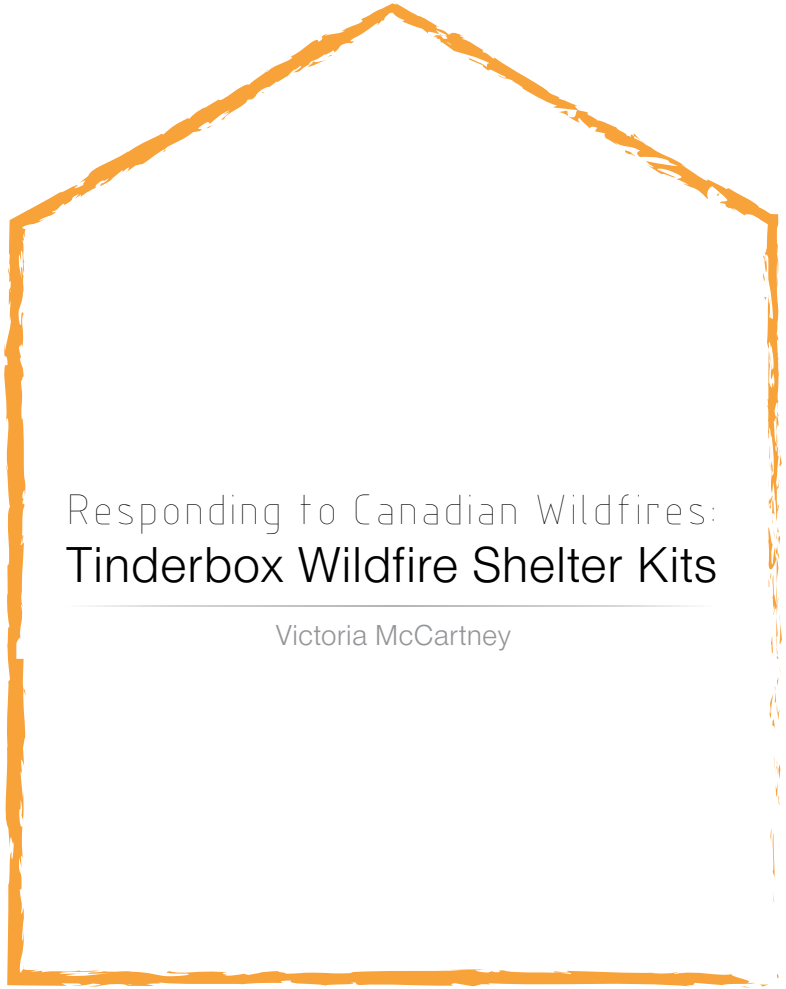

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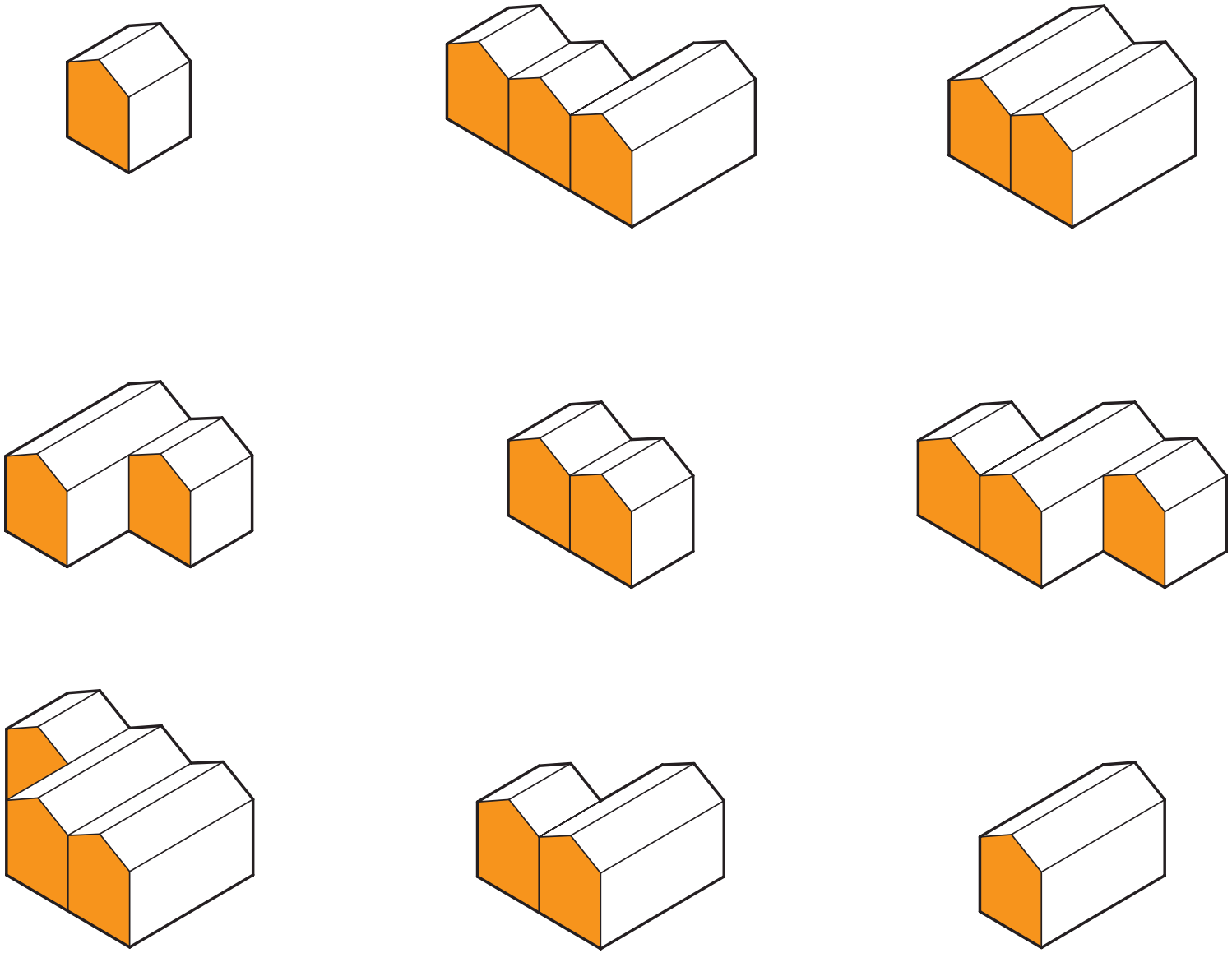

ABSTRACT

Every year, thousands of Canadians are evacuated from their homes due to wildfires. Many of these evacuees are forced to stay in community evacuation shelters, which are often overcrowded, have minimal sanitation and cooking facilities, little privacy, and offer no control of an individual's immediate environment. Victims of natural disasters are prone to heightened levels of stress, anxiety, and mental health issues. These issues are exasperated in community shelters, where living situations are unstable and insufficient.

This thesis conducts two interwoven studies. First, the existing protocols of Canadian wildfires will be researched, looking into the specifics of response operations and evacuation procedures. Second, the psychological effects of experiencing a natural disaster will be analyzed, as well as additional stress factors that may occur as a result of post-disaster protocols. Through these two studies, this thesis will propose new community planning initiatives for wildfires, as well as a design for a post-disaster housing system entitled Tinderbox. Tinderbox challenges existing building technologies by exploring innovative methods of modularity, assembly, portability, construction, and prototyping, with a final objective of designing an effective shelter system for wildfire evacuees.

ACKNOWLEDGEMENTS

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Part 1

INTRODUCTION & METHODOLOGY

1.1 INSPIRATION

When I first began thinking about my thesis, I was interested in developing a piece of temporary and portable architecture. This led me to think about temporary emergency housing. Given that there are numerous emergency shelters that already exist, I wanted to find a niche; a type of disaster and demographic that has yet to be explored. I thought back to the devastating Fort McMurray wildfire of 2016 – newspapers and media outlets broadcasting vivid imagery of the blaze, the cramped arenas, and the ash covered aftermath. This inspired me to develop a post-disaster housing system for Canadian wildfire evacuees.

The name Tinderbox is a play-on-words to describe the shelters' use and function. Where 'tinder' represents that the system is used for wildfires, and 'box' represents its flat-pack portability.

1.2 METHODOLOGY

This thesis relies on data and statistics collected from the Government of Canada and media sources to support its main arguments. These articles are beneficial to the thesis because they reflect how wildfires affect communities from the public perspective.

In addition, this thesis analyzes published psychological journals that use small study groups to investigate how natural disasters affect the mental health of evacuees.

Tinderbox is a research by design project. After determining the specific needs of wildfire evacuees, several design variations were determined, and a half-scale prototype sectional model was constructed. This model is used to verify the project feasibility by analyzing: the modularity, structural durability, scale, and efficiency of the assembly process. Based on the findings of the sectional model, a final design was developed.

[Figure 2] Charred belongings and ash litter the streets after the Fort McMurray wildfire in 2016

1.3 OBJECTIVE

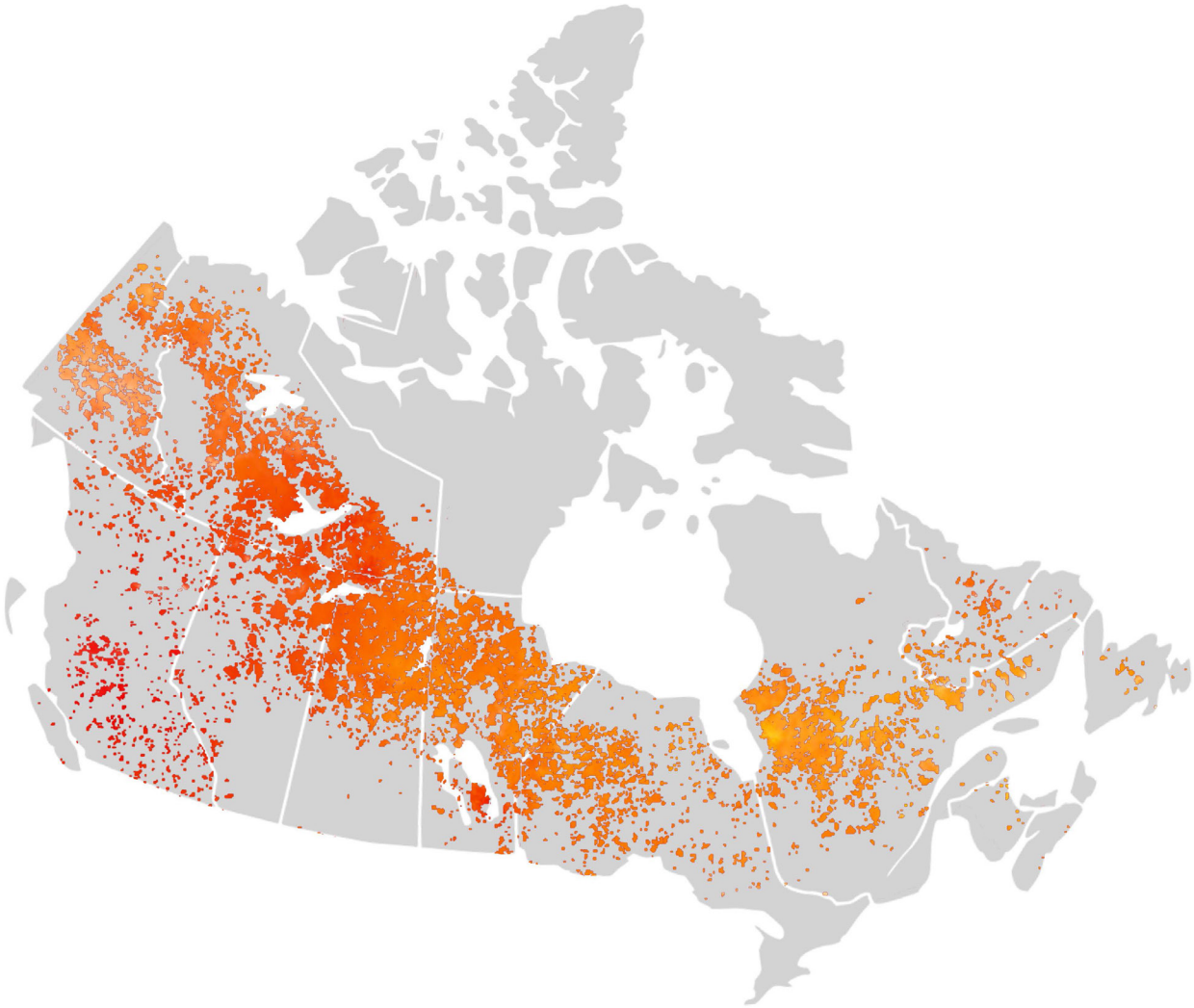
The needs of evacuees vary; therefore, the design of a modular interlocking system allows the proposed shelters to shrink, expand, and link together, modifying to meet the user specific space requirements. The modular pieces will be lightweight and easy to assemble. This ensures community-rebuilding processes do not require heavy machinery or specialized labor, services that are not readily available during the recovery process. The modular pieces are sized so they can be carried with ease and transported in a standard family van or pickup truck. This home design aims to reduce construction delays, and reliance on delivery services. Tinderbox is designed to facilitate an assembly time of approximately two days by two adults. When the community is rebuilt, and Tinderbox is no longer needed, it can be disassembled and deployed to the next community in need.

1.4 OVERVIEW

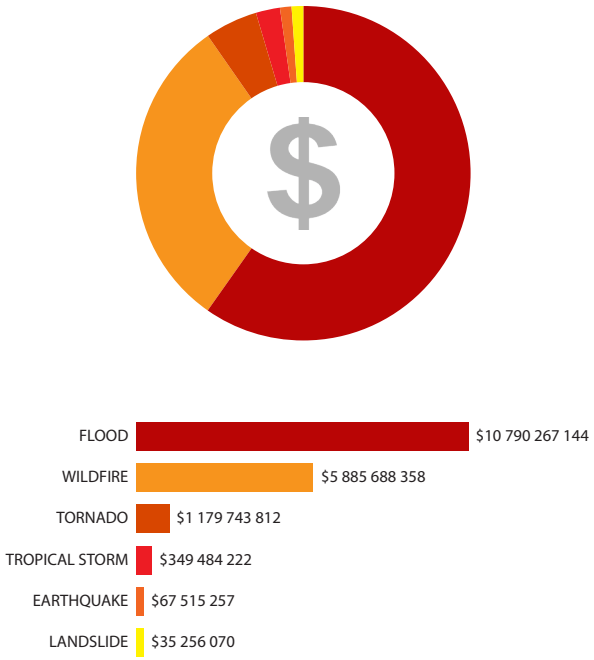
Canada contains 9% of the world's forests, amounting to 347 million hectares. The majority of forested area is boreal forest, which primarily consists of coniferous vegetation, such as fir and pine trees. The boreal forest experiences the most wildfires, affecting areas in southern Yukon and Northwest Territories, and northern British Columbia, Alberta, Saskatchewan, Ontario, and Quebec.[1]

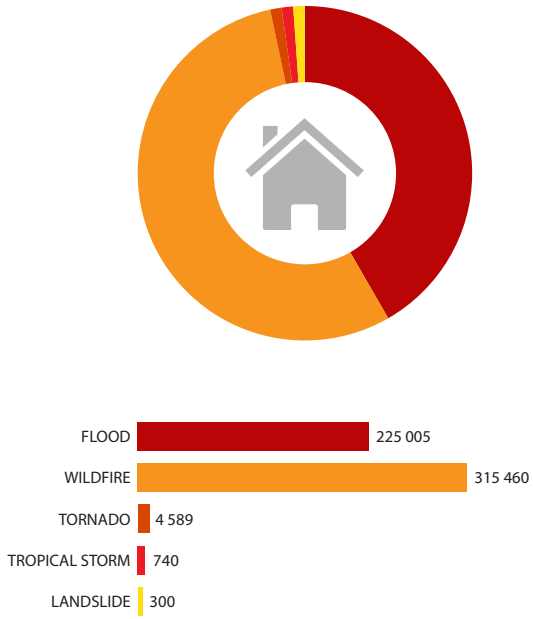
An average of 8,000 wildfires occur every year, burning approximately 2.1 million hectares.[2] Between 1986 and 2015, over 75 million hectares of land burned. [Figure 3]

Wildfires cost approximately 180 million dollars every year, making it the second costliest type of disaster behind flooding. [Figure 4] This amount is a sum of damages to the forestry industry and property, as well as mitigation and evacuation costs. In Canada, wildfires have significantly more evacuees than all other disasters, with an average of 8,500 evacuations annually.[3] [Figure 5]



[Figure 3] Canadian Wildfire Perimeters 1986-2015. The orange pattern illustrates the 75 million hectares of land that burned within that time.





[Figures 4&5] Cost of disasters in Canada compared to the number of evacuees per disaster in Canada, 1986-2017

1.5 PLANNING & PREPARATION

For Canadian wildfires there is little in the way of planning and preparedness in the event of an evacuation. The evacuation process is handled on a case-by-case basis, despite the frequency of Canadian wildfires. The response varies depending on the severity of the fire, the number of people affected, and the success of the suppression efforts. This lack of planning was evident during the 2016 Fort McMurray wildfire, where evacuees were given insufficient notice to evacuate their homes, rendering them unable to gather personal belongings and plan their evacuation.[4]

In addition, evacuees must rely on municipal emergency reception centres, friends, family, and the generosity of strangers for providing temporary housing. These ad hoc environments are often stressful and overcrowded, and are often an inadequate solution to accommodate the varied needs of evacuees.

There are temporary housing systems that currently exist, all of which present an array of benefits and disadvantages. When accommodating wildfire evacuees, there are very specific challenges that need to be addressed – challenges that are not comprehensively addressed by existing temporary housing systems. It is important to consider specific factors such as longevity, access to household facilities, available material resources, and protection from the elements – including harmful smoke particles. If the specific needs of evacuees are not addressed, people could experience difficulties such as increased mental and physical stress and additional financial hardships.

1.6 CONSEQUENCES OF DISASTER

Psychological studies conducted following the Fort McMurray disaster have investigated the impact of wildfires on mental well-being. These studies suggest that evacuees suffer from issues including post-traumatic stress disorder, anxiety and depression as a result of the disaster.[5] Consequential traumas such as financial loss and unstable accommodation can trigger latent struggles in partner and family relationships, leading to further issues such as domestic abuse, behavioural disorders, and overprotection.[6] Unstable accommodation such as emergency reception centres can lead to close proxemics, personal space invasions, and mass panic. These spaces do not provide evacuees with the necessary privacy to grieve for their losses, express their emotions, and plan their recovery. To reduce the stress and trauma of experiencing a disaster, it should be a priority to provide evacuees with sufficient privacy for themselves and their families to cope with the subsequent difficulties.

The objective of this thesis is to mitigate the consequential trauma by proposing post-disaster community planning strategies and affordable, modular, transitional shelters.

“I literally drove out of the flames. I had ashes hitting me in the face… Everything was jammed. You had people all over the place. The gas station was on fire. It was the biggest chaos I have ever seen.” - Shawn Brett, Fort McMurray fire evacuee [7]

[Figure 6] Evacuees fleeing the Fort McMurray wildfire in 2016.

“The centerpiece of this response should be more effective policies regarding both short- and long-term housing that also consider other critical household needs – income support, transportation, healthcare, and so forth” - Joyce N. Levine, Population Displacement and Housing Dilemmas Due to Catastrophic Disasters [8]

[Figure 7] An arena is used as an emergency reception centre for evacuees of the Fort McMurray wildfire in 2016.

Part 2

UNDERSTANDING CANADIAN WILDFIRES

2.1 INTRODUCTION

This section analyzes the impact that wildfires have on Canadian communities. By investigating current response and evacuation procedures, systematic issues are identified, and used as a baseline for the Tinderbox design. Likewise, through case studies of two previous wildfires, the Slave Lake fire of 2011 and the Fort McMurray fire of 2016, problems with existing protocols are analyzed, with the intention that Tinderbox will address and solve these matters.

2.2 WILDFIRE INFORMATION

Human negligence accounts for 53% of Canadian wildfires with the remaining 47% of fires caused naturally by lightning. Lightning fires often occur in more remote, non-populated areas, and are left to burn out and renew the ecosystem. Fires caused by human negligence typically occur closer to populated areas and properties and must be extinguished before they become a threat to human safety.[9] A small percentage of wildfires are prescribed in an attempt to re-establish a healthy ecosystem.[10] These fires are controlled, reducing the amount of flammable ground cover in forested areas. By burning excess ground cover, the risk of a larger, uncontrolled wildfire is reduced.[11]

There are three primary classifications of wildfires. Crown fires consume the entirety of the trees and ground vegetation. These fires are the largest and most severe, spreading quickly and becoming difficult to extinguish. Surface fires only consume the decaying ground vegetation, and do not spread up into the trees. These fires are significantly more manageable. Ground fires occur below the ground surface, burning dead and dry vegetation. These fires are difficult to see and put out, as their behaviour is unpredictable. In especially dry conditions, a ground fire is capable of burning well beyond wildfire season, and may continue to burn into the following year.[12]

Wildfire smoke spread is a large concern, and can cause significant health concerns.[13] The smoke contains particulate matter, carbon monoxide, volatile organic compounds, atmospheric mercury, and ozone forming chemicals, which can cause harmful, and even fatal effects, primarily effecting the respiratory system.[14] When smoke affects air quality, it is important for people to seek shelter, avoid spending time outdoors, and take appropriate measures to prevent breathing in unfiltered air.[15]

2.3 RESPONSE OPERATIONS

Fire management is important in preventing wildfires from devastating communities and causing evacuations.[16] When a wildfire to poses a threat, the stages of control, and the type of response needed are quickly identified. There are three types of responses:

- Full response specifies that immediate and ongoing fire suppression is required until the threat is deemed to be 'out'.
- Modified response attempts to contain the fire and reduce the potential for spreading and property damage.
- Monitored response is the observation and assessment of the situation, determining if further action is required.[17]

The type of response determines the magnitude of operations that will be put in place.

Municipal, provincial, and federal organizations implement response operations for Canadian wildfires. Non-threatening fires are mediated by regional and provincial firefighting crews.[18] When the wildfire is high-threat, and cannot be controlled by provincial authorities, the Canadian Armed Forces (CAF) will implement Operation Lentus in an attempt to stabilize the crisis and mediate the situation. In previous missions, the CAF provided aircraft, freight, and evacuation assistance to communities affected by wildfires.[19]

“We left with the clothes on our backs. My youngest didn’t even have shoes on.” – Miranda Sneddon, Fort McMurray fire evacuee [20]

2.4 EVACUATION PROCEDURES

Every year, approximately 20 Canadian communities are affected by wildfires, averaging more than 8,500 people needing to evacuate their homes. Natural Resources Canada expects the severity of wildfires and number of evacuations to increase due to worsening climate conditions.[21] Reasons for implementing an evacuation can vary, and can be a result of fire proximity, smoke pollution, or power outages.[22] If the wildfire is deemed a potential threat to inhabitants of a specific area, a 'Stage 1 Evacuation Alert' will be put in place. At this stage, the population will be informed that they are at risk for a potential evacuation, and they should begin preparing to leave. If the wildfire poses an immediate threat to the inhabitants, a 'Stage 2 Evacuation Alert' is put in place.[23] This indicates that an evacuation is mandatory and immediate, and is often followed with police and RCMP going door-to-door to ensure all residents have the opportunity to leave safely. Evacuees often have to act quickly, and in many cases, there is very little time to pack significant belongings.

Once the specified areas are no longer at risk, a 'Stage 3 Evacuation Rescind' will be ordered, allowing residents to return to the evacuated area. This advisory indicates that the area in no longer in danger, however, there is always a risk that the fire will re-manifest, and the area will once again need to evacuate.[24]

Preparing accommodation for evacuees is a complex process, and requires provincial, federal, and charity organizations to meet the needs of evacuees. Local governments determine appropriate emergency reception centres.[25] Once activated, aid workers, relief organizations, and volunteers are deployed to site. These centres are typically large municipal buildings such as arenas, community centres, gymnasiums, and other public institutions. The location and quantity of emergency reception centres depends on the size and severity of the wildfire, and how many evacuees are expected to seek accommodation. The advantage to these centres is that they can accommodate hundreds of evacuees at once, with fold-up cots arranged in a tight grid throughout the premise. There are also numerous disadvantages, including overcrowding, minimal sanitation and cooking facilities, and no privacy for the evacuees.

The duration of an evacuation varies depending on the severity of the events. A study on Canadian wildfires between 1980 and 2007 calculated that 72% of evacuees were able to return to their homes in less than a week, with an additional 26% able to return home within 7-12 days.[26] As of recently, however, the 2017 British Columbia fires around Kelowna had an evacuation period of 3 weeks,[27] and the 2016 Fort McMurray wildfire having an evacuation period of 1 month.[28]

“You have 1000 people living here. Washrooms, other facilities are taxed virtually to their limits…No showers here. In the normal everyday life of the Convention Centre, you don’t really need any showers, right?” – Klaus Lahr, Northern Manitoba fire of 2017 [29]

2.5 CASE STUDY: 2011 SLAVE LAKE FIRE

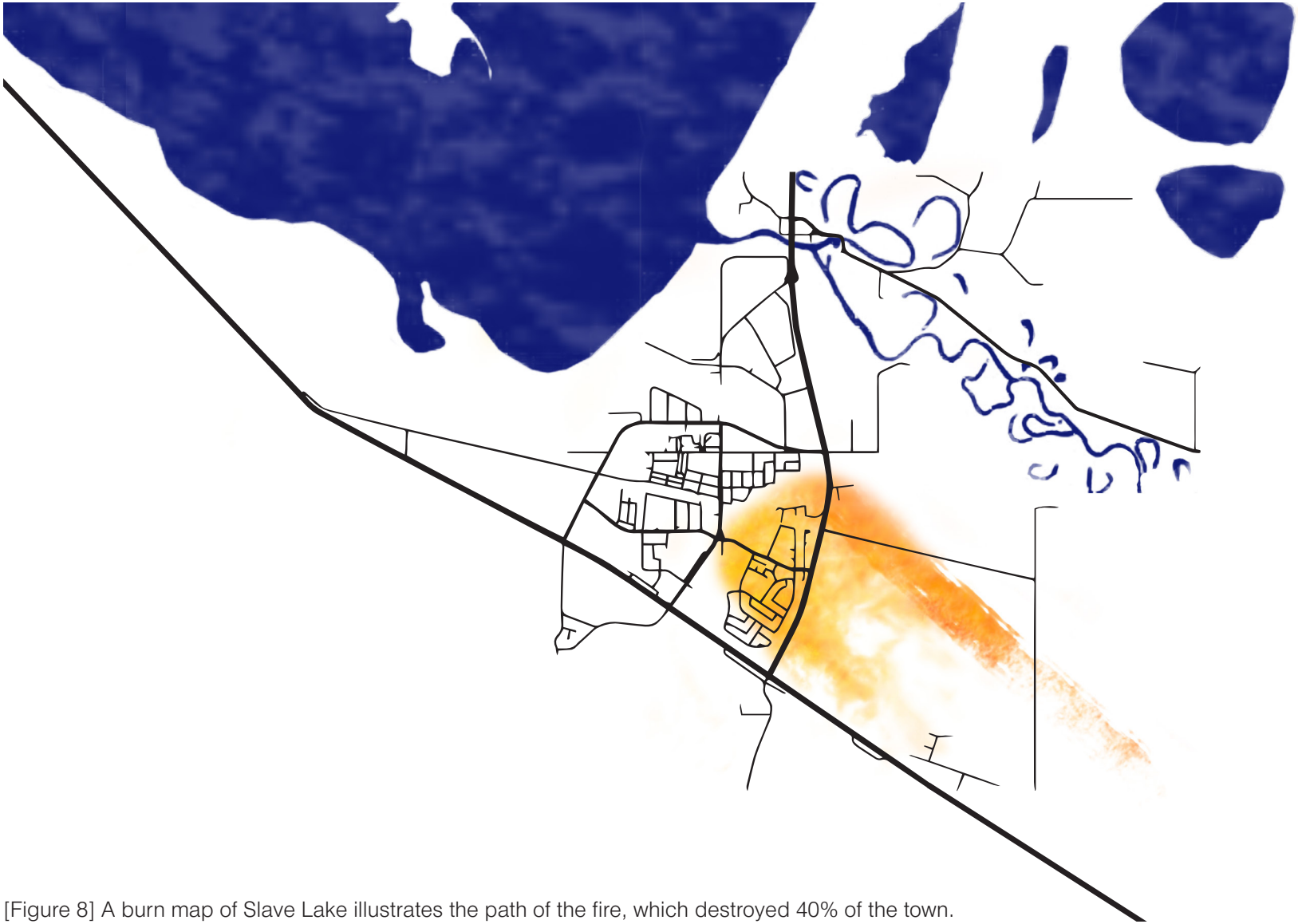
On Sunday May 14, 2011, citizens of Slave Lake, Alberta, observed wildfire smoke fifteen kilometers to the south, with strong winds pushing the fire towards the peripheral communities. The town immediately declared a State of Local Emergency and evacuated over 10,000 people from the township and surrounding area.[30] By Monday, the wildfire had burned through nearly 40% of Slave Lake. The fire, which investigations revealed was caused by arson, burned over 22,000 hectares of land[31] , destroyed 433 buildings, and damaged another eighty-nine buildings.[32] Relief efforts required 1,700 emergency responders from across the province to battle the flames and assist with the evacuation and recovery process. As a result, the wildfire caused over 500 million dollars in damages.[33]

The evacuation period lasted twelve days, and evacuees sought refuge in the surrounding communities of Athabasca, Westlock, and Edmonton.[34] Many evacuees stayed at emergency reception centres, receiving aid through community members and the Canadian Red Cross.[35] Although the fire was no longer a threat after seven days, residents had to wait an additional five days for municipal services to be restored before returning home.[36] Upon returning to the town, over 700 people lost their homes, and had to seek alternative accommodation.[37]

Hotels, campgrounds, and other local accommodation were at capacity. The town struggled to find temporary housing for the residents and out-of-town contractors who were hired to help with the rebuilding process. A work camp was provided to house 200 workers for a period of five months – however this did not help the residents. Around mid-September, some of the residents were able to move into temporary trailers, four months after the evacuation had been lifted. For many it took over a year for the town to rebuild lost property, and allow residents to move back into their homes.[38]

The events of the Slave Lake fire offer insight into the issues of disaster planning, specifically, the need for interim sites and temporary housing. These matters create a baseline for the Tinderbox design proposal. Communities that are at risk of wildfires should establish multiple sites for the purpose of evacuation and recovery. These sites should be large, flat, open plots that are easily accessible, and have easy access to municipal services. The sites should be designed to include designated spaces for housing units, community and health services, and gathering spaces.Once a site and layout are determined, deploying transitional housing becomes more organized and efficient.

"It took us 6 months to get into an emergency trailer. We were allowed back into Slave Lake before that. I believe it was around 2 weeks but we had nothing to go to. We got a condo in Edmonton in the interim. My husband commuted back and forth. Exhausting, but no other options." – Shelley Beazer Leishman, 2011 Slave Lake wildfire evacuee [39]



[Figure 8] A burn map of Slave Lake illustrates the path of the fire, which destroyed 40% of the town.

Insufficient access to municipal services and amenities can prolong the length of an evacuation. To minimize the evacuation period, Tinderboxes are able to support self-sufficient systems such as solar power, batteries, and water storage tanks. These systems can provide essential resources to the evacuees until municipal services are restored. By establishing recovery sites, and arranging transitional housing, evacuees can quickly return to the community, and recovery processes are more organized and efficient.

2.6 CASE STUDY: 2016 FORT MCMURRAY FIRE

On Sunday May 1st, 2016, fire crews conducting a standard patrol noticed a small two-hectare wildfire approximately seven kilometers south-west of Fort McMurray, Alberta.[40] Despite the fire crews' attempts to control the blaze, the fire began to move east, with residents from the south-eastern neighbourhoods evacuating to an emergency reception centre in the north end of the city. By Tuesday May 3rd, a mandatory evacuation for all residents was put in place, and over 90,000 people were given as little as thirty minutes to evacuate their homes.[41] Within hours, the fire moved through the town, significantly damaging properties in the neighbourhoods of Beacon Hill, Abasand, and Waterways. It was not until July 4th, over two months after the fire was detected, that it was finally declared under control.[42] By early July, nearly 600,000 hectares had burned, destroying 2,400 structures[43] and 665 oil sands work camp units [Figure 9].[44] Relief efforts required heavy fire suppression, with over 1,500 emergency workers from across Canada, 60 helicopters, 19 tankers, and 37 pieces of heavy equipment.[45] As a result, the 2016 Fort McMurray wildfire became the most expensive disaster in Canadian history, with nearly 4 billion dollars in damages.[46]

The evacuation notice for Fort McMurray was in effect for 29 days, with residents allowed to return between the 1st and 4th of June.[47] Evacuees traveled across the province to find accommodation for the duration of the evacuation. 7,500 people headed north and sought refuge in the oil sands work camps, which quickly reached capacity. The remaining evacuees headed south where they could access emergency reception centres in Lac La Biche, Edmonton,and other more southern communities.[48]

Thousands of evacuees turned to emergency reception centres for their lodging and other needs, which brought forth various problems, including overcrowding, anxiety, and health concerns. Reception centres had to offer emotional wellness resources to assist evacuees with stress, anxiety, symptoms of post-traumatic stress disorder, and coping with disaster.[49]

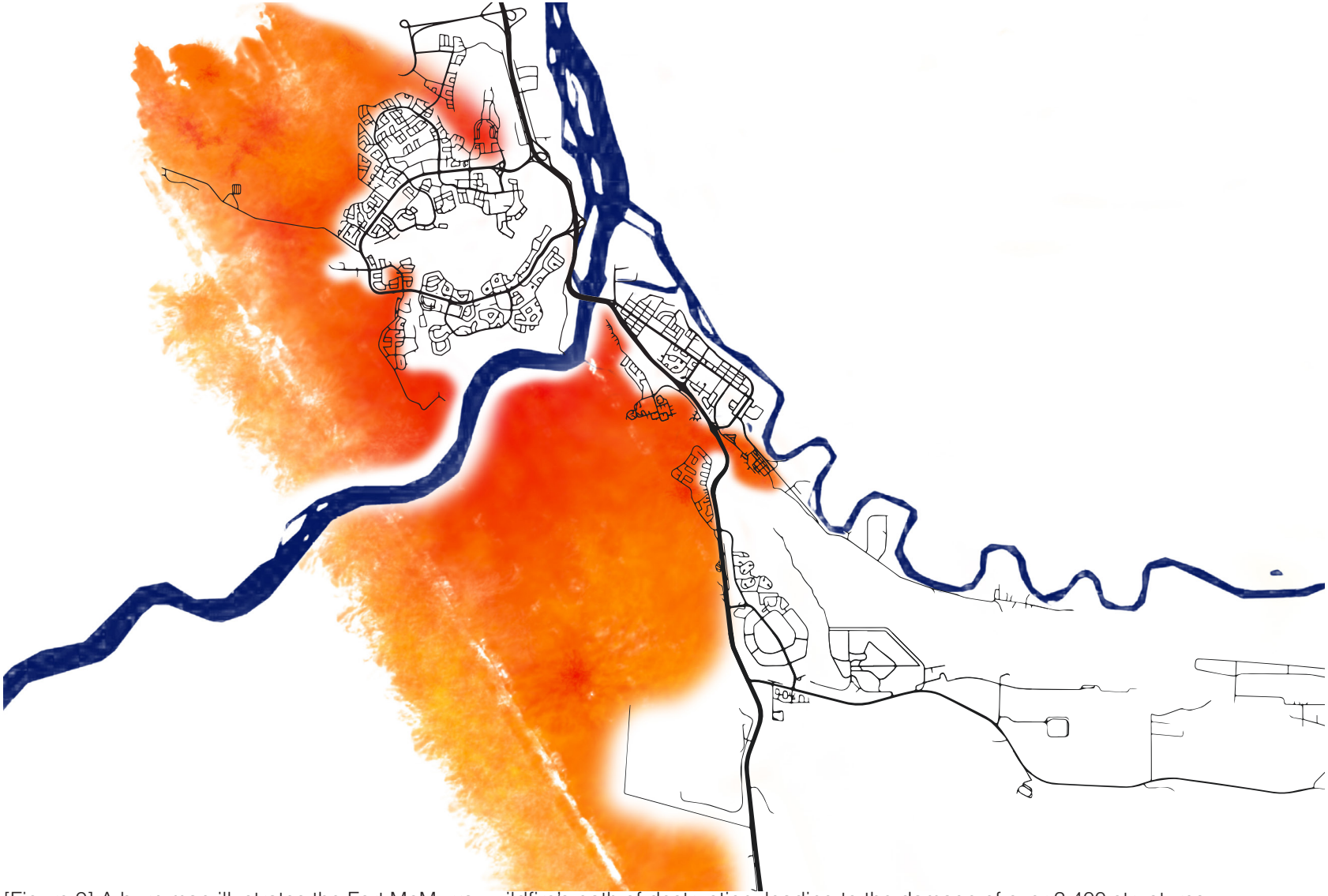
When the evacuation was lifted, it was discovered that a large portion of undamaged homes were still unfit to live in, with hundreds of homes testing positive for toxins in the soil, ash, and air. This delayed the return of hundreds of families, forcing them to seek additional temporary accommodation until it was safe to return.[50]

The Fort McMurray wildfire brings forth various issues with current evacuation and recovery processes that need to be addressed and improved. Due to the lengthy evacuation and return, residents had to seek accommodation in surrounding communities. These communities were unprepared to host the large incoming populations. Similar to establishing in-town recovery sites, surrounding communities should have an emergency plan that defines specific sites for evacuee accommodation. Once an evacuation notice is put in place, these nearby sites can become activated and begin deploying the Tinderboxes. With concise evacuation and recovery locations already determined, evacuees have a clear idea of where they need to travel to for their accommodation, alleviating the stress of being unprepared.

2.7 RESPONSE

The aftermath of the Slave Lake and Fort McMurray fires suggests that the existing evacuation procedures are insufficient, and that an architectural intervention is necessary to mitigate the issues surrounding temporary housing. Emergency reception centres are incapable of providing evacuees with appropriate privacy and facilities – two factors that are necessary for coping with a disaster. In addition, it is apparent that evacuees and site workers require accommodation for months following the evacuation period, something that is overlooked in existing protocols. In response, Tinderbox is designed to provide the users with privacy and facilities, and is constructed to withstand prolonged use.

“The ash has a very high pH which makes it caustic and may cause both skin and respiratory irritation and burns… There’s also heavy metals like arsenic in these samples. As well, polyaromatic hydrocarbons, dioxins and furans have been detected at concentrations above what has been recommended for public health.” - Dr. Karen Grimsrud, Alberta’s chief medical officer of health [51]



[Figure 9] A burn map illustrates the Fort McMurray wildfire's path of destruction, leading to the damage of over 2,400 structures.

Part 3

THE PSYCHOLOGY OF DISASTERS

3.1 INTRODUCTION

Sudden environmental and lifestyle changes can cause stress, anxiety, and mental health issues in wildfire evacuees. Witnessing a wildfire can cause trauma to an individual, and can cause victims to suffer from post-traumatic stress disorder. In addition, the consequences of the fire, such as inadequate accommodation, financial loss, and insecurities can bring forth additional difficulties for evacuees. The objective of Tinderbox is to provide evacuees with the necessary comforts, amenities, and services, minimizing the risk of psychological issues in evacuees.

3.2 POST-TRAUMATIC STRESS DISORDER

Post-traumatic stress disorder, commonly known as PTSD, is a mental health condition that is triggered by experiencing or witnessing a troubling event. Some of the symptoms of PTSD include flashbacks, anxiety, depression, avoidance, behavioural issues, and difficulty sleeping.[52] In the event of a natural disaster, people are subject to high stress after experiencing the event, as well as life-altering and long-term consequences that the event may have caused.

Mental health issues like PTSD can be a result of experiencing the fire, but can also be a result of the consequences of a fire, such as relocation, financial loss, separation, insecurity that more problems will arise, and the uncertainty of what will happen next.[53] By incorporating designated evacuation/recovery sites, the likelihood of separation will be reduced. Similarly, by providing evacuees with a Tinderbox, environmental changes will be less drastic, helping to alleviate the consequential stresses of relocation and insecurity.

Following the Fort McMurray wildfire of 2016, Alberta Health Services opened up multiple community health clinics and reported that over 25,000 people sought out mental health support for their anxiety, depression, and post-traumatic stress disorder.[54] Shortly after the residents return home, psychology students from the Université Laval issued a small-scale questionnaire with follow-up interviews to study the severity of PTSD in evacuees.[55] Of the 379 questionnaires

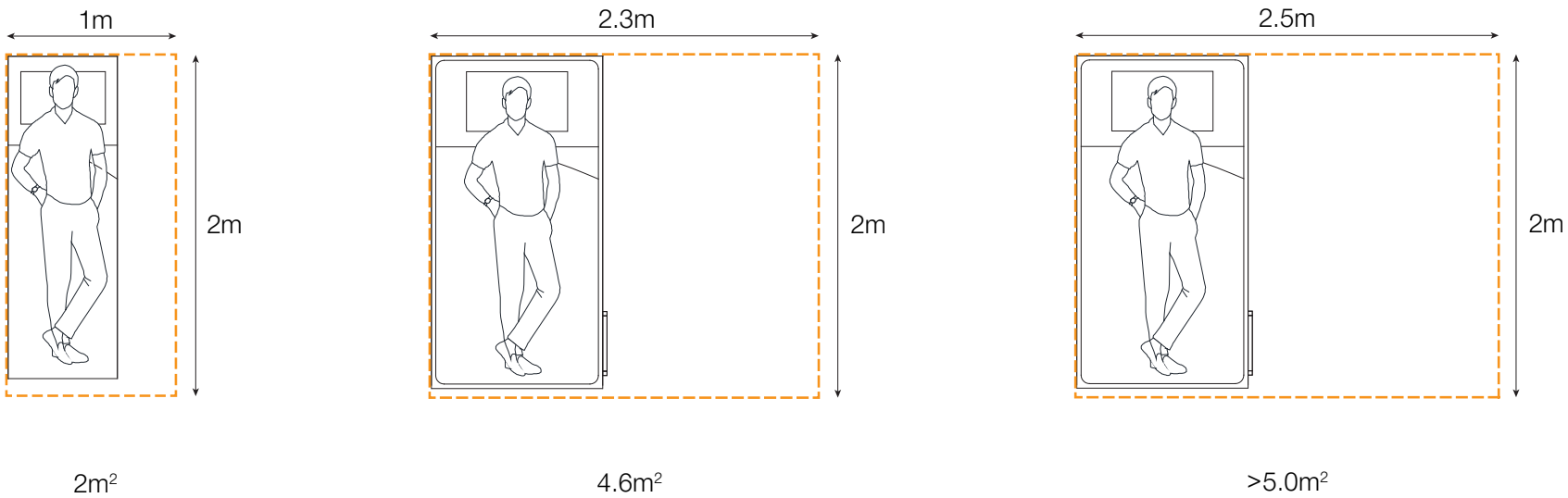
“Despite the mountain of research that’s been done on PTSD in the past, Fort McMurray needs its own studies into the mental health consequences of the wildfire… If you just focus on treating people on the basis of research that has been done elsewhere, it doesn’t take into account the local dynamics.” - Dr. Vincent Agyapong, leading researcher in the Fort McMurray psychological study [56]

and 55 interviews, it was concluded that 29 percent of those tested were experiencing some symptoms of PTSD, with 26 percent suffering from depression, and 36 percent had sleep disorders. The University of Alberta, the University of Calgary, and Mount Royal University are currently conducting a study to investigate the longitudinal psychological effects of the disaster on children. Over the course of three years, they will survey 5,000 grade school students to identify if there are symptoms of PTSD or other mental health issues in the youth who experienced the wildfire.[57]

3.3 PROXEMICS & OVERCROWDING

Proxemics is defined as the spatial distance than humans place between one another, and can vary based on relationship, interaction, and population density.[58] Proxemics is personal space – the amount of area required around one's body to maintain comfort. Overcrowding occurs when an environment does not have the capacity to provide sufficient personal space to the inhabitants.[59] Post-disaster accommodation subject's evacuees to overcrowding and personal space invasions, which can cause feelings of discomfort, unwanted exposure, and stress.

Emergency reception centres are typically large municipal buildings such as arenas, gymnasiums, and community centres, and are used to accommodate hundreds of people during an evacuation. These buildings, which are intended for occasional recreational use, are unsuitable for large-scale residential inhabitation. Each evacuee is allocated approximately 2m2 of unconcealed space, which facilitates a single cot bed and a small aisle. These tight, open spaces promote undesired closeness to strangers, with only a 1m gap between individuals. In instances of shared residential accommodation, such as dormitories, the Ontario Building Code specifies that each individual requires a minimum of 4.6m2 of space, which is not achieved in emergency reception centres.[60] Tinderbox is designed to allow a minimum of 5m2 area per person, enough area for a single bed, a desk, and a chair [Figure 10]. The sleeping areas within a Tinderbox remain small, however the shelters also include a larger living and dining area, allowing for more personal space and dispersion between family members. Without privacy and personal space, evacuees are reluctant to express emotions following the traumatic events due to unwanted subjection and vulnerability.



[Figure 10] Emergency Reception Centre vs. Dormitory vs. Tinderbox. Emergency reception centres offer little space to evacuees, and do not meet building code requirements for a shared sleeping area. Tinderbox exceeds code requirements by providing a minimum of 5.0m² of space per evacuee.

To prevent the discomfort and stress associated with proxemics, Tinderbox is designed to provide adequate space and privacy for families and individuals. Each shelter is designed to allow a minimum of 5m2 per inhabitant. This area is sized to facilitate a single bed, a table, and a chair. One Tinderbox is capable of housing a family, and can expand or shrink to meet the minimum area requirements for the number of occupants. The interior of a Tinderbox can be divided into multiple rooms to offer additional privacy between family members.

3.4 RESPONSE

Tinderbox aims to reduce the prevalence of mental health issues in wildfire evacuees. This is achieved by eliminating the sources of stress that accompany disaster, such as separation and overcrowding. By introducing community-focused evacuation site plans and family-focused disaster shelters, the transition for evacuees will be less drastic, which in turn will minimize anxiety and stress.

Part 4

IDENTIFYING THE NEEDS OF EVACUEES

4.1 INTRODUCTION

This section identifies the specific needs of evacuees during the evacuation and recovery period. It conducts a comparative anaylsis of Tinderbox to other emergency shelters such as: reception centres, tents, yurts, trailers, tiny homes, and Ikea's Better Shelter. The analysis will compare: duration, climate, and facilities, to demonstrate that Tinderbox is able to provide evacuees with the necessary services – services that are not available in existing structural systems [Tables 1, 2, 3]. These comparisons will highlight the inadequacies of current evacuation accommodation procedures, emphasizing that there is a need for architectural intervention.

4.2 DURATION

The duration of an evacuation can vary from a few days to a month. The longest wildfire evacuation period in Canada was the 2016 Fort McMurray evacuation, which lasted 29 days. In addition to the evacuation period, those who suffer property damage or have lost their home may have to wait an additional year before they can return to permanent habitation.[61] This thesis takes the position that any temporary accommodation must be appropriate for both short and long-term use. Additionally, the accommodation must be readily available and facilitate mass distribution in order to house hundreds of people shortly after evacuation. The shelters must be durable to sustain continuous use for up to one year.

4.3 CLIMATE

Canadian wildfires occur in environments that experience harsh climates with hot, dry summers and cold, snowy

winters. Therefore, any accommodation provided to evacuees must be capable of providing protection from the elements year-round. In Fort McMurray, Alberta, the average year-round temperatures range from 23 degrees Celsius in the summer months to -24 degrees in the winter months,[62] averaging 342mm of rainfall and 155cm of snowfall annually.[63] The Alberta Building Code requires all structures to comply to certain insulative value, as illustrated in [Figure 11 and 12]. For an emergency shelter to be appropriate for long-term use in northern climates, must meet the minimum R-values. Therefore, the walls must be at least R-17.5, and the floors and ceiling R-28.5.[64]

4.4 FACILITIES

In addition to having shelter, there are several facilities and amenities that evacuees need access to in order to maintain their physical well-being and mental health. This includes having sufficient access to sanitary facilities such as toilets, showers, and sinks that meet the quantifiable needs of the occupants. For a dwelling unit, there must be 1 water closet for up to 9 persons of the same sex.[65] Similarly, evacuees need to have sufficient access to cooking facilities where they can prepare and cook their food. Lastly, evacuees require access to communication services to keep friends and family informed. Access to electricity will allow evacuees to power mobile phones and laptops for updates and communication.

4.5 COMPARING SYSTEMS

Emergency reception centres are often located in existing facilities that are not designed for residential use, making them impractical for both short and long-term accommodation. Emergency reception centres function well as a meeting point but should only be used as accommodation for a couple of days. If inhabited for a longer period of time, the people using the shelter may begin to experience mental health issues as a result of the prolonged overcrowding.

ZONE

- 6 4000 to 4999 HDD
- 7A 5000 to 5999 HDD
- 7B 6000 to 6999 HDD
- 8 ≥ 7000 HDD

	Zone 6		Zone 7A		Zone 7B	
	No HRV RSI (R)	HRV RSI (R)	No HRV RSI (R)	HRV RSI (R)	No HRV RSI (R)	HRV RSI (R)
Ceiling below attics	8.67 (49.2)	8.67 (49.2)	10.43 (59.2)	8.67 (49.2)	10.43 (59.2)	10.43 (59.2)
Cathedral ceilings and flat roofs	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Above grade walls	3.08 (17.5)	2.97 (16.9)	3.08 (17.5)	2.97 (16.9)	3.85 (21.9)	3.08 (17.5)
Floors over unheated spaces	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Rim joists	3.08 (17.5)	2.97 (16.9)	3.08 (17.5)	2.97 (16.9)	3.85 (21.9)	3.08 (17.5)
Below grade foundation walls	2.98 (16.2)	2.98 (16.2)	3.46 (19.7)	2.98 (16.2)	3.46 (19.7)	2.98 (16.2)
Unheated floors below frost line	Uninsulated		Uninsulated		Uninsulated	
Exterior walls of an attached garage	3.08 (17.5)	2.97 (16.9)	3.08 (17.5)	2.97 (16.9)	3.85 (21.9)	3.08 (17.5)
Walls adjacent to an unconditioned garage	2.92 (16.6)	2.81 (16.0)	2.92 (16.6)	2.81 (16.0)	3.69 (21.0)	2.92 (16.6)
Unheated floors above frost line	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)
Slabs-on-grade with an integral footing	1.96 (11.1)	1.96 (11.1)	3.72 (21.1)	2.84 (16.1)	3.72 (21.1)	2.84 (16.1)
Heated floors	2.32 (13.2)	2.32 (13.2)	2.84 (16.1)	2.84 (16.1)	2.84 (16.1)	2.84 (16.1)
Skylight shafts	3.08 (17.5)	2.97 (16.9)	3.08 (17.5)	2.97 (16.9)	3.85 (21.9)	3.08 (17.5)
Attic access hatch	2.60 (14.8)	2.60 (14.8)	2.60 (14.8)	2.60 (14.8)	2.60 (14.8)	2.60 (14.8)
Windows, Doors and Skylights	See Page 27					

[Figures 11&12] The Alberta Building Code requires buildings to meet a certain level of insulative value based on location.

Tents and yurts are two types of quick-assembly, portable, temporary fabric structures [Figure 13]. Tents are typically designed to handle moderate climates, are durable, but unsufficient for prolonged use.[66] Yurts are more durable and can be insulated to handle colder climates.[67] Both structures are capable of providing privacy between families, but have minimal floor area allocated mostly for sleeping. This tight arrangement could create immediate proxemic issues between family members, making it unsuitable for long-term use.

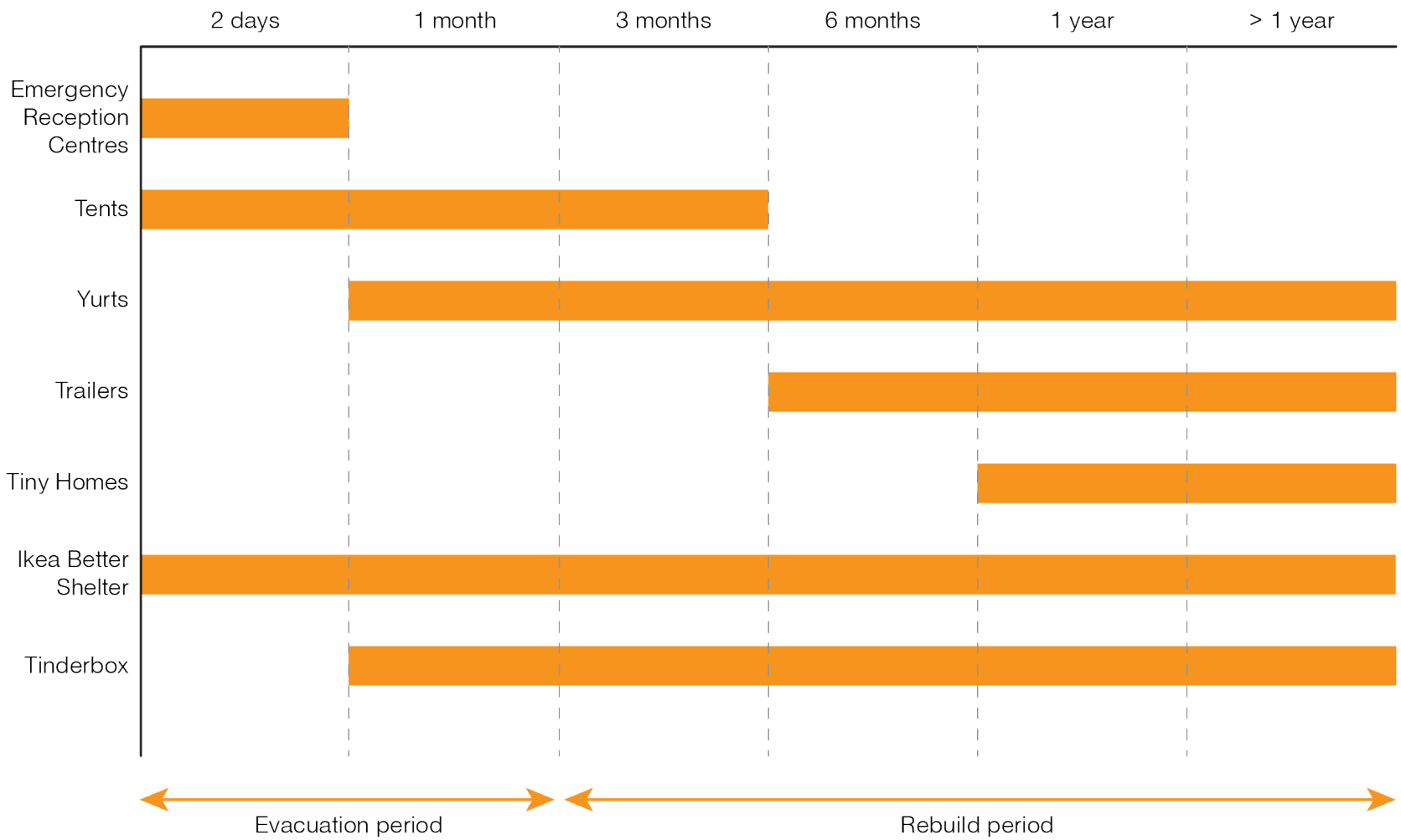
Trailers and tiny homes are two types of portable, long-term residential accommodation. However, due to the cost, size, and complexity of these two structures, they are not readily available, and can take up to a year to build and deploy in large quantities.[68] As a result, trailers and tiny homes cannot meet the immediate needs of evacuees, as they can only provide accommodation mid-way through the rebuild period.

The Ikea Better Shelter is a flat-pack, portable, modular shelter designed for refugees [Figure 14]. Using inexpensive steel framing and thin polyolefin foam panels, the shelters can be assembled within 1 day by 4 people without the need for tools or machinery. The low-cost materials facilitate the shelters to cost approximately $1,500 per unit. The assembly process occurs in 3 stages: steel framing, roof ventilation and solar panel, and the walls. The design and materials facilitate a life span of a minimum of 3 years in moderate climates.[69] The standard single-room unit is 17.5m2 and can provide shelter for a family of five, with 3.5m2 of space allotted per person. Each shelter is equipped with a solar panel that powers a small light for 4 hours daily and charges a mobile phone. Additionally, the Better Shelter's modularity allows the space to adapt, expand, and have sections replaced without dismantling the entire assembly. This shelter is capable of providing sufficient privacy between families, however, it does not have the capacity for the facilities and amenities that are necessary for long-term inhabitation. For long-term inhabitation, the shelter would require additional power for cooking appliances, interior divisions, and sanitation facilities.

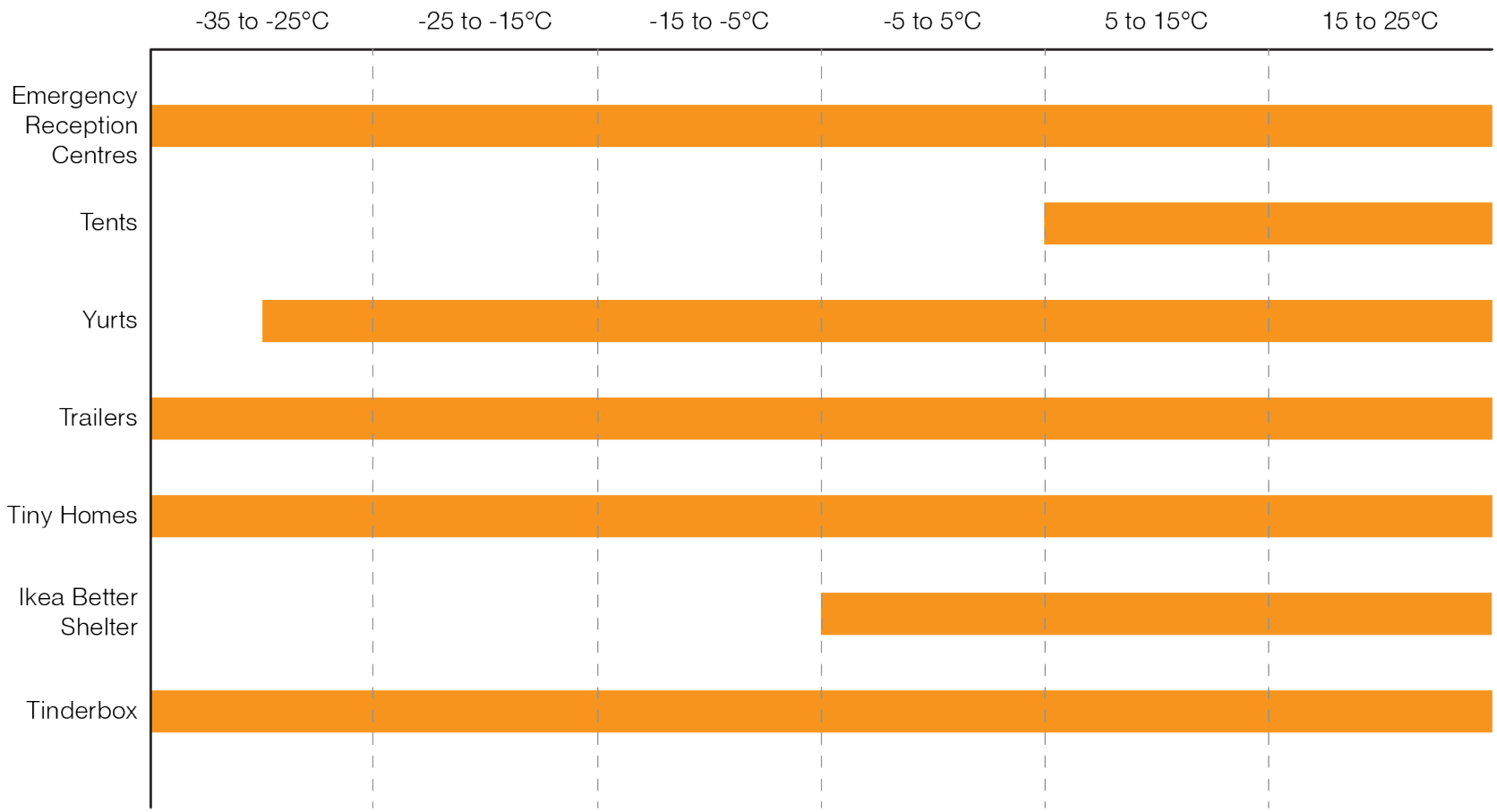
Tinderbox's construction uses accessible building materials like plywood, insulation, and fabric, which enables the shelters to be readily available for deployment following an evacuation. Using a three-layer system of insulated plywood panels, insulated fabric panels, and a fabric weatherproofing layer, the shelter can be assembled within two days by two adults using simple joints, straps, and snaps that do not require heavy machinery or skilled labor. The highly insulated panels meet the thermal requirements set out in the Alberta Building Code[70], allowing the shelter to be used in harsh Canadian climates all year round. The interchangeable joinery design allows for room divisions, giving

the users the freedom to choreograph their own shelter with separate spaces for sleeping, living, cooking, and sanitation. Standardized floor plan arrangements ensure that each individual is allocated a minimum of 5m2 floor area, but with modular panels, the users have the option to reduce or expand the size of their Tinderbox based on their spatial needs. The shelters include designated service areas for installing electrical and plumbing systems, for the purpose of providing power for cooking devices, lighting, and household appliances, and water and waste storage for a shower, a toilet, and sinks. Tinderbox's simplistic design and materiality meets the short-term needs of the evacuees, and its capacity for building services, privacy, and climate compatibility facilitates long-term inhabitation.

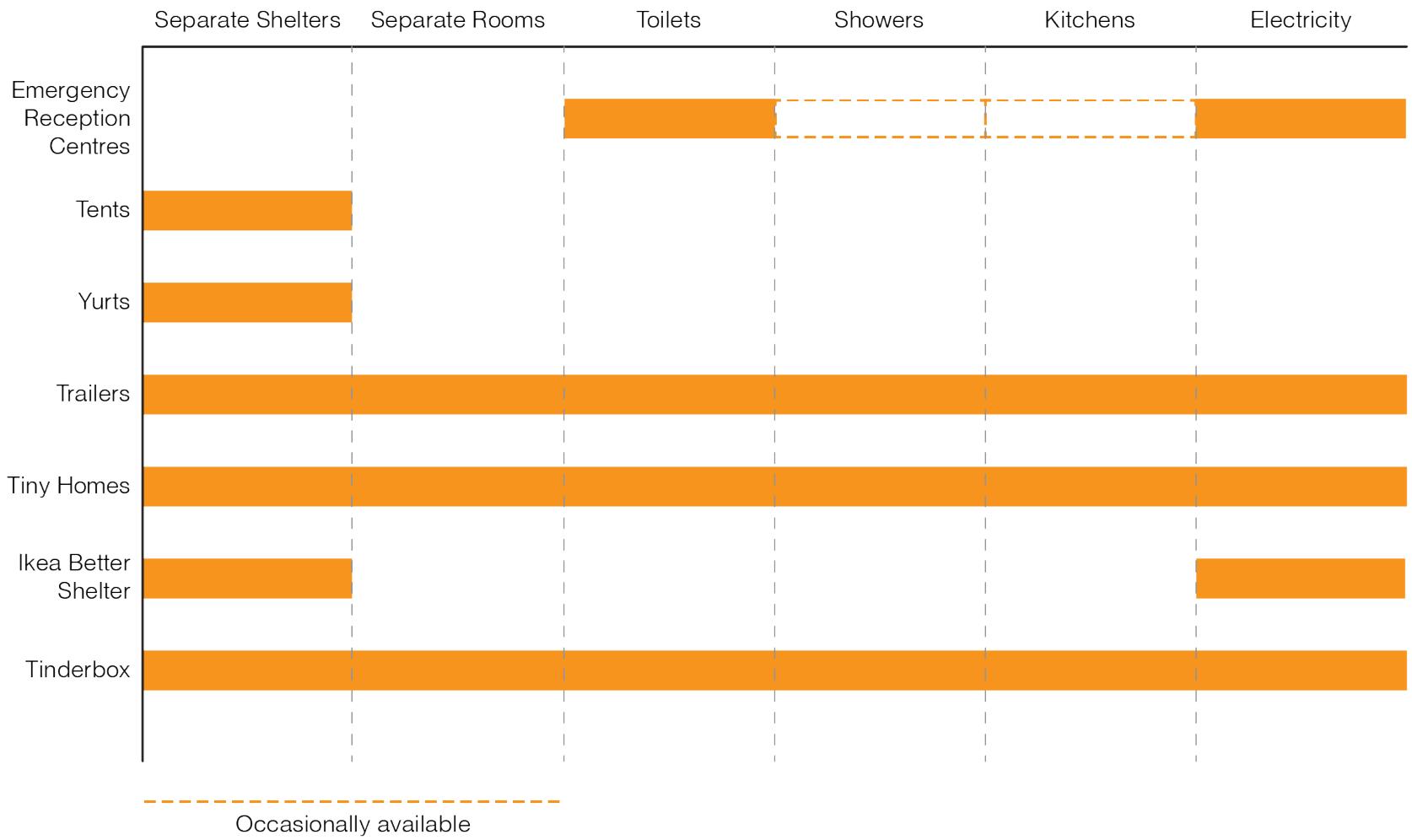
[Figure 13 & 14] Comparing existing systems: yurts and the Ikea Better Shelter



[Table 1] Duration. Very few existing structures have the durability and availability to provide shelter for evacuees on a short and long-term basis. Evacuees need appropriate accommodation for both the evacuation period and the rebuild period.



[Table 2] Climate. Evacuee shelters must have sufficient insulation and weatherproofing to be able to withstand year-round temperatures.



[Table 3] Facilities. To live comfortably, evacuees require access to basic household needs such as privacy and sanitation and cooking facilities

4.6 RESPONSE

The objective of Tinderbox is to establish a shelter that is durable, climate appropriate, and provides adequate household facilities. Despite Tinderbox's aim to provide an improved temporary living environment for evacuees, there are numerous challenges that remain difficult to resolve. Unlike traditional residential construction, Tinderbox's temporary, portable, and flat-pack nature creates difficulties such as size, weight, and construction restrictions. To allow for an assembly process that requires no construction knowledge, the design must be void of complexity. This means limiting the scale of the structure to maintain an achievable assembly time. The result is a living space that remains restricted in comparison to a typical Canadian home.

Although the shelter meets the thermal requirements of the building code, it fails to meet other requirements. The temporary nature of Tinderbox requires the use of non-traditional building methods and materials. This makes it challenging to conform to building code requirements such as foundations, barriers, egress, emergency measures, and environmental protection.

Part 5

DESIGNING FOR DISASTER - TINDERBOX

5.1 INTRODUCTION

This section illustrates the design proposal of Tinderbox and its capacity to provide appropriate accommodation for wildfire evacuees. The design will be discussed for its modularity, materiality, construction, transportation, assembly, and capacity for facilities. Through a combination of designed joints, panels, and exterior cladding, methods of connectivity are explored, and a series of residential floorplan variations are introduced. Additionally, the user-friendly assembly process is explored through instructional diagrams to verify the practicality of the system.

5.2 DESIGNING MODULARITY

During a wildfire evacuation, many services are unavailable or interrupted, resulting in reduced availability of necessary resources. This includes a shortage of material resources, skilled labor, machinery, and shipping apparatus. Therefore, the construction and assembly of Tinderbox must be mindful of available resources. Through modularity, the design of Tinderbox uses standardized dimensions to allow for flexible design variations, accommodating a range of building functions. Its ability to shrink and expand ensures that the users are granted sufficient area to perform daily tasks without experiencing feelings of overcrowding.

The design and proportion of Tinderbox is determined through the standard dimensions of readily available building materials. The design allows for modularity, which in turn reduces construction time and facilitates easy assembly. A standard 2’ by 8’ insulated wall and floor panel is created using ¼” treated dimensional plywood sheathing sandwiched over 2” rigid stone wool insulation board [Figures 15 and 16]. This standard panel defines the width and height, creating the standard 8’ by 8’ baseline proportion for Tinderbox.

The baseline proportion of 8’ by 8’ creates a long, narrow floor plate, which may attribute the users to feelings of close proxemics. To increase the volume of the space, the ceiling adopts a simple vaulted gable [Figure 17]. This design creates a standard 2’ by 4’ 7.5” ceiling panel joined at a 120° angle which is intended to create a comfortable,

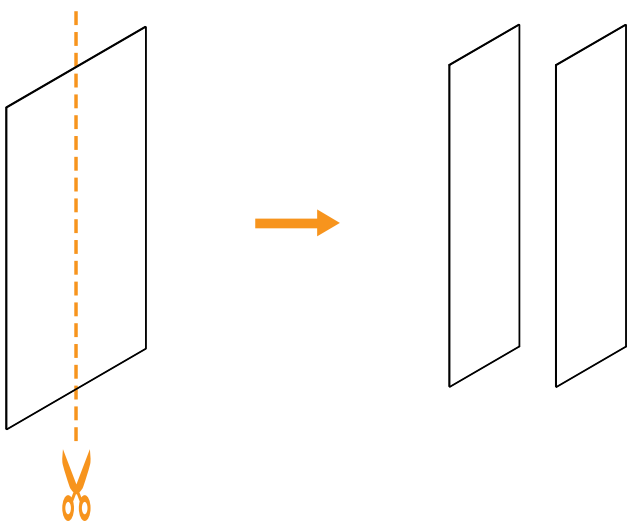
home-like, space for the user. The slope also diverts precipitation and snow away from the shelter, prolonging the durability of the materials.

The modularity and symmetry of the standard wall and floor panels combined with the standard ceiling panels allow for the system to be flexible in its arrangements. By connecting multiple panels, Tinderbox is capable of expanding in length [Figure 18].

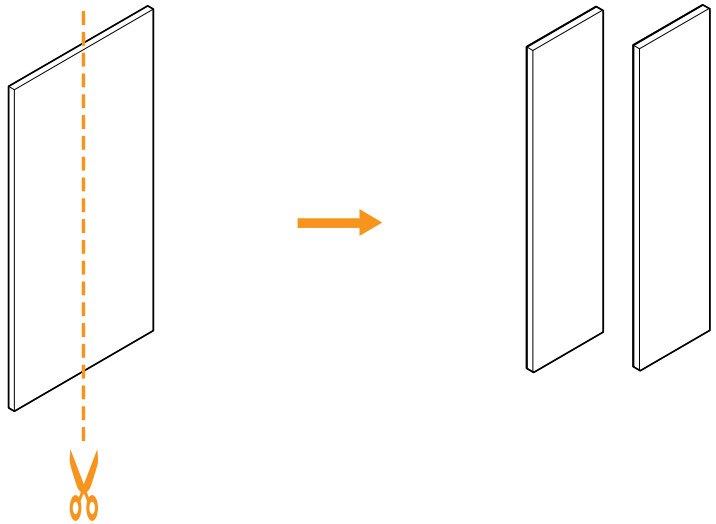
5.3 JOINERY METHODS

The efficiency and effectiveness of Tinderbox relies on its joinery system. The joinery system is simple to use, quick to connect, and requires little machinery or construction knowledge. Because it is a re-usable, low-cost structure, the joinery must be resistant to wear and tear. Several joinery system designs were explored, with a comparative analysis in the annotative text of Figures 19-24.

After investigating various joinery methods, custom combination joints were the most practical joinery system to use for the final Tinderbox design. The joint system consists of six molded, UV-resistant Acrylonitrile Styrene Acrylate (ASA) plastic connectors that slide into each other and bolt into the panels along the outer edges. When using the six pieces in combination with each other, several varying configurations can be made, allowing for numerous connections [Figures 25-31]. The pieces create parallel and perpendicular connections between the walls, floors, ceiling panels, as well as foundation posts and dividing walls. The combination joints allow Tinderbox to expand in both the x and y direction, allowing the units to have unrestricted length and width [Figure 32]. The ability to expand the shelter in multiple directions eliminates space restriction and feelings of close proximity in the users.

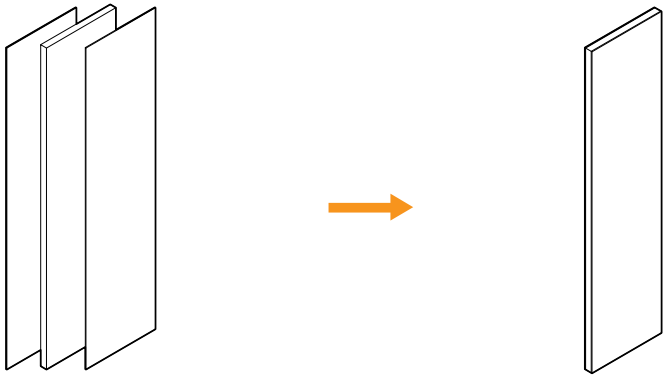


1. Cut 4’ x 8’ plywood panels vertically in half



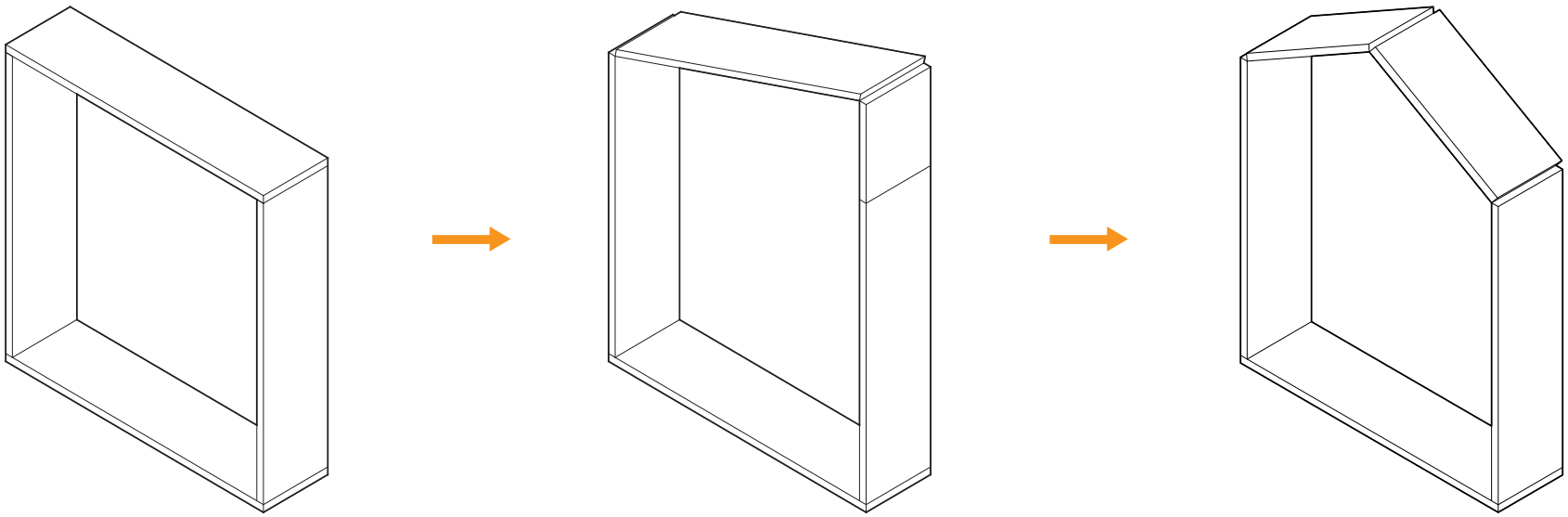
2. Cut 4’ x 8’ rigid stone wool board vertically in half

[Figure 15] The standard panel is created by halving plywood and rigid stone wool insulation.



3. Place the rigid stone wool board between the plywood to create a standard panel

[Figure 16] The cut plywood panel is sandwiched around the rigid stone wool insulation to form the standard panel.



FLAT ROOF

One panel design
Minimal waste
Causes snow load
Limited height

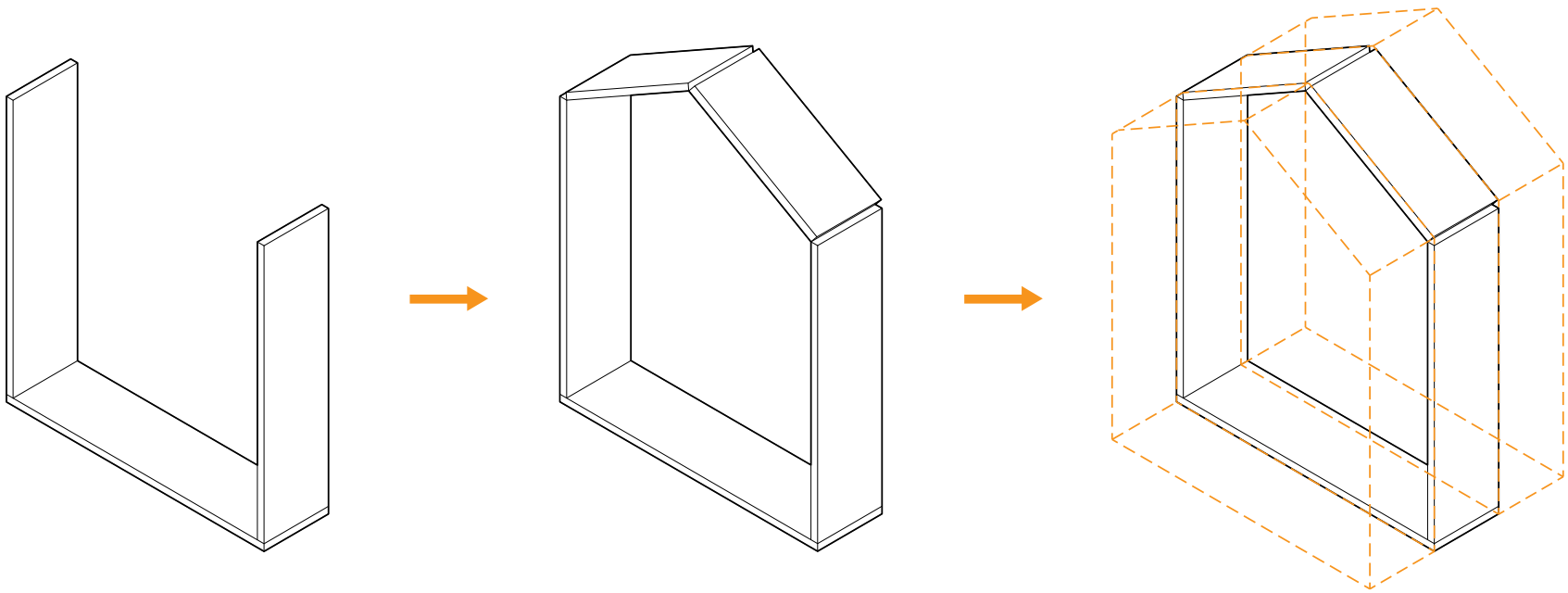
SINGLE PITCH

High ceiling
Handles snow load
Acute angles
Non-standard dimensions

GABLE ROOF

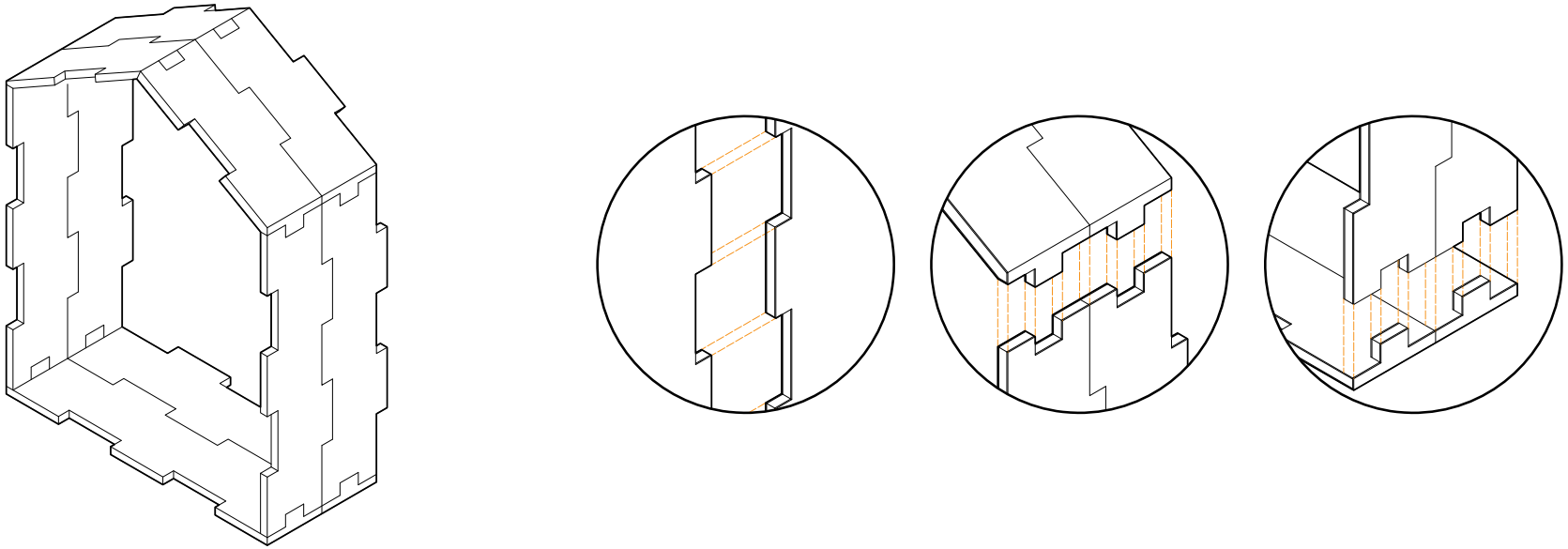
High ceiling
Home-like shape
Handles snow load
Equal 120 degree angles

[Figure 17] Roof variations. The gable is chosen as Tinderbox's roof design.



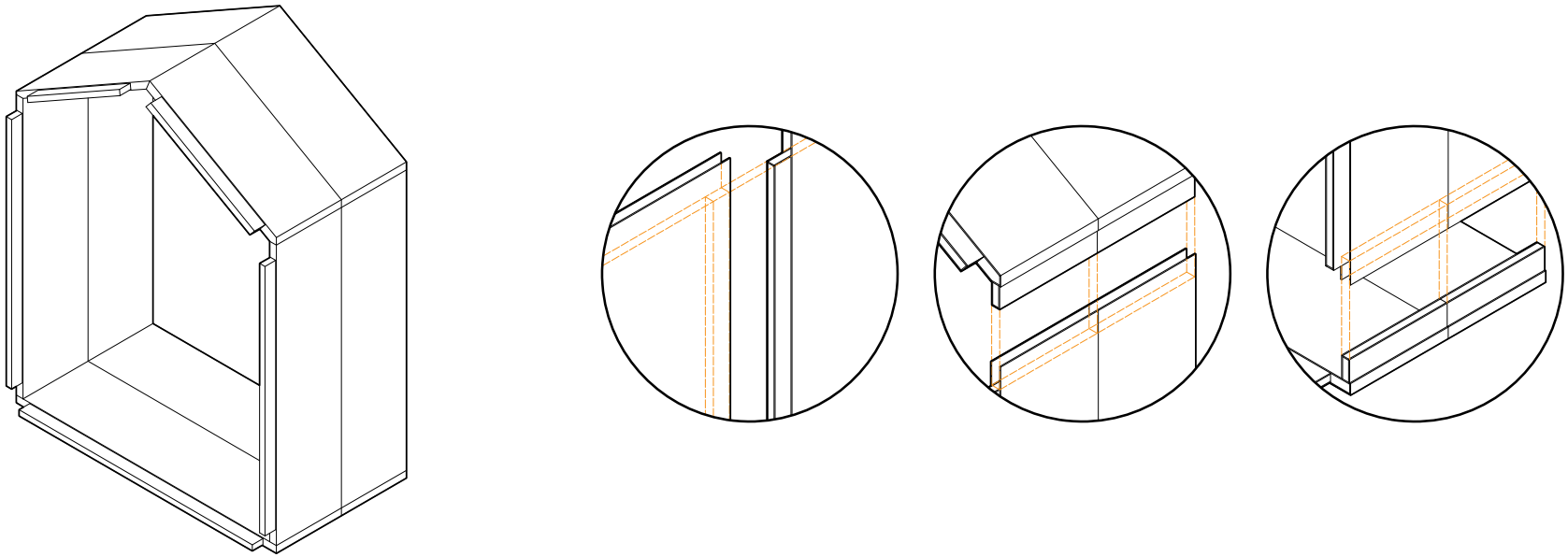
Standard panels form wall and floor, ceiling panels are introduced, system expands in length

[Figure 18] Standard panels and ceiling panels are combined to create the standard dimension for Tinderbox.



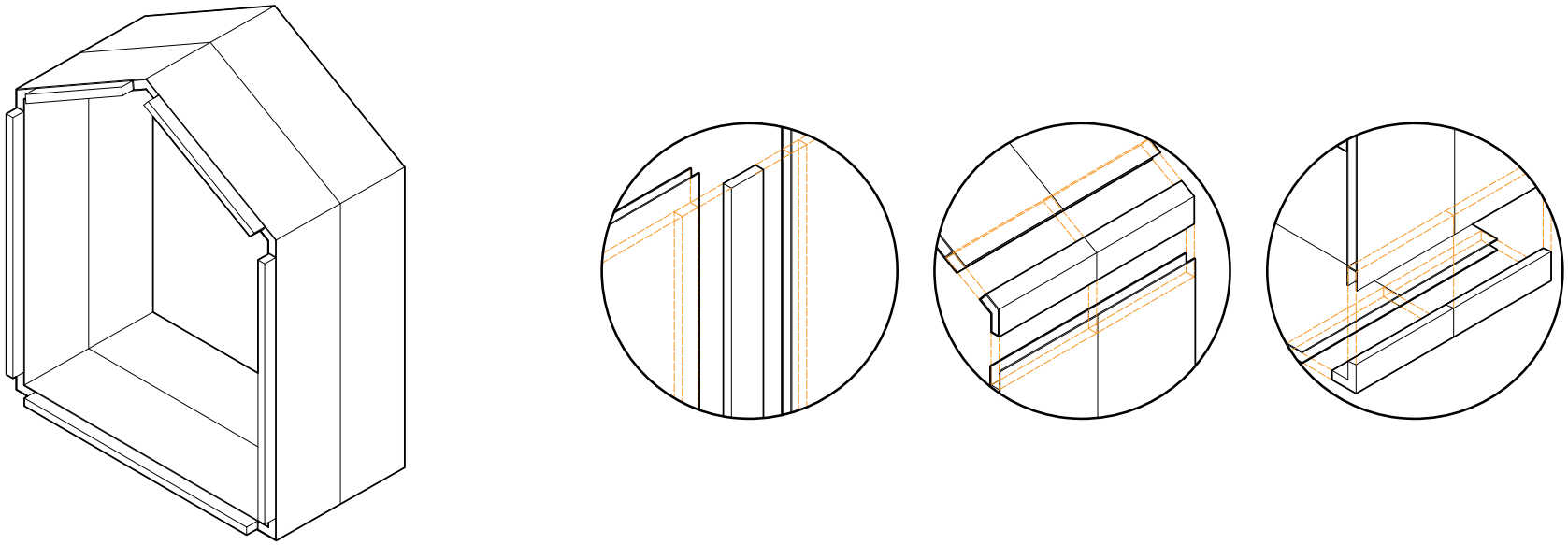
Interlocking Cutouts

[Figure 19] Interlocking cutouts. These joints, which require no hardware, are difficult to secure in place. Intricate panel design could lead to complicated construction.



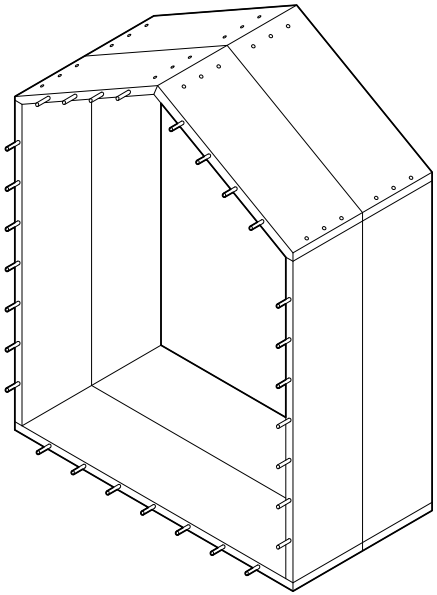
Tongue and Groove

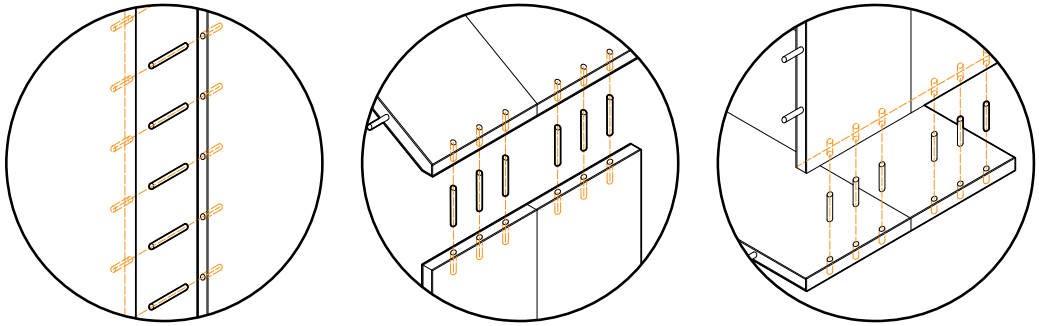
[Figure 20] Tongue and groove. Panels slide into place without hardware. Users would have to align panels perfectly, which could lead to challenging aseembly.



Slide-in Inserts

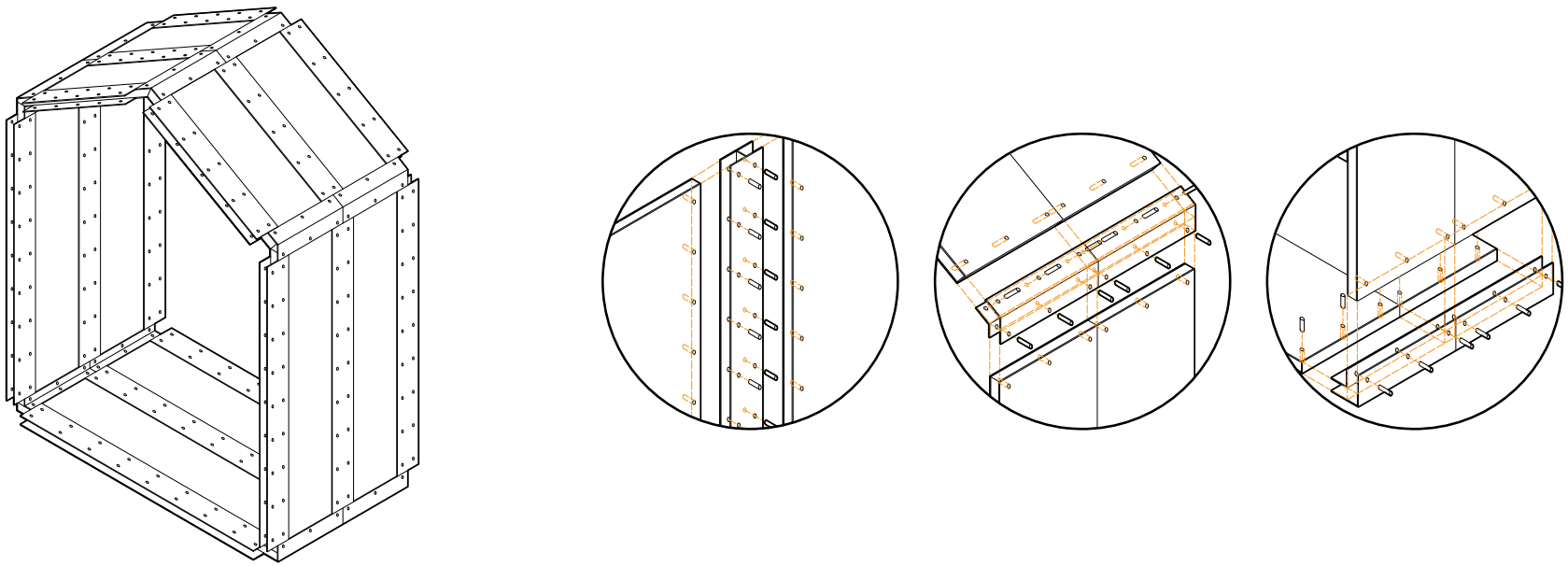
[Figure 21] Slide-in Inserts. Separate pieces slide into gaps in panels. These joints would need for precise alignment, which could make assembly difficult.





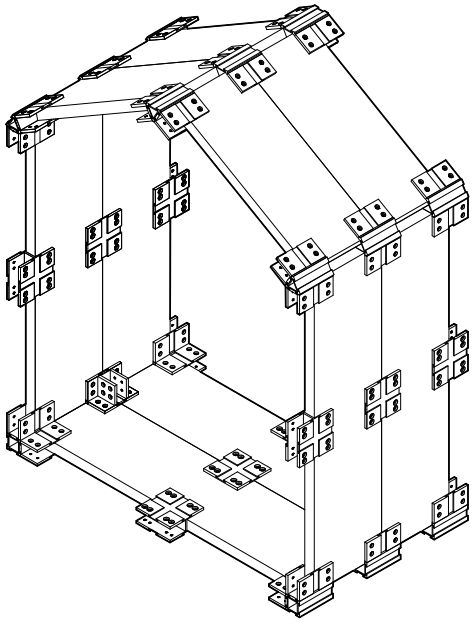
Dowel Inserts

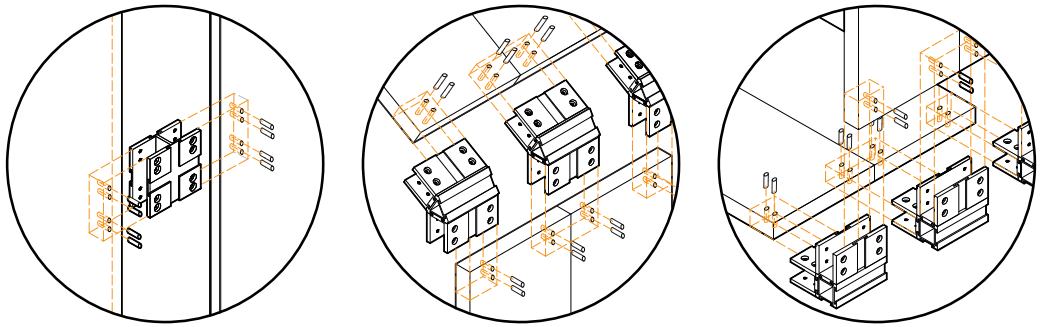
[Figure 22] Dowel Inserts. These panels would slide into each other with wood dowels. This assembly would require precision, and the dowels have a likelihood of breaking.



Bolted H-Frame

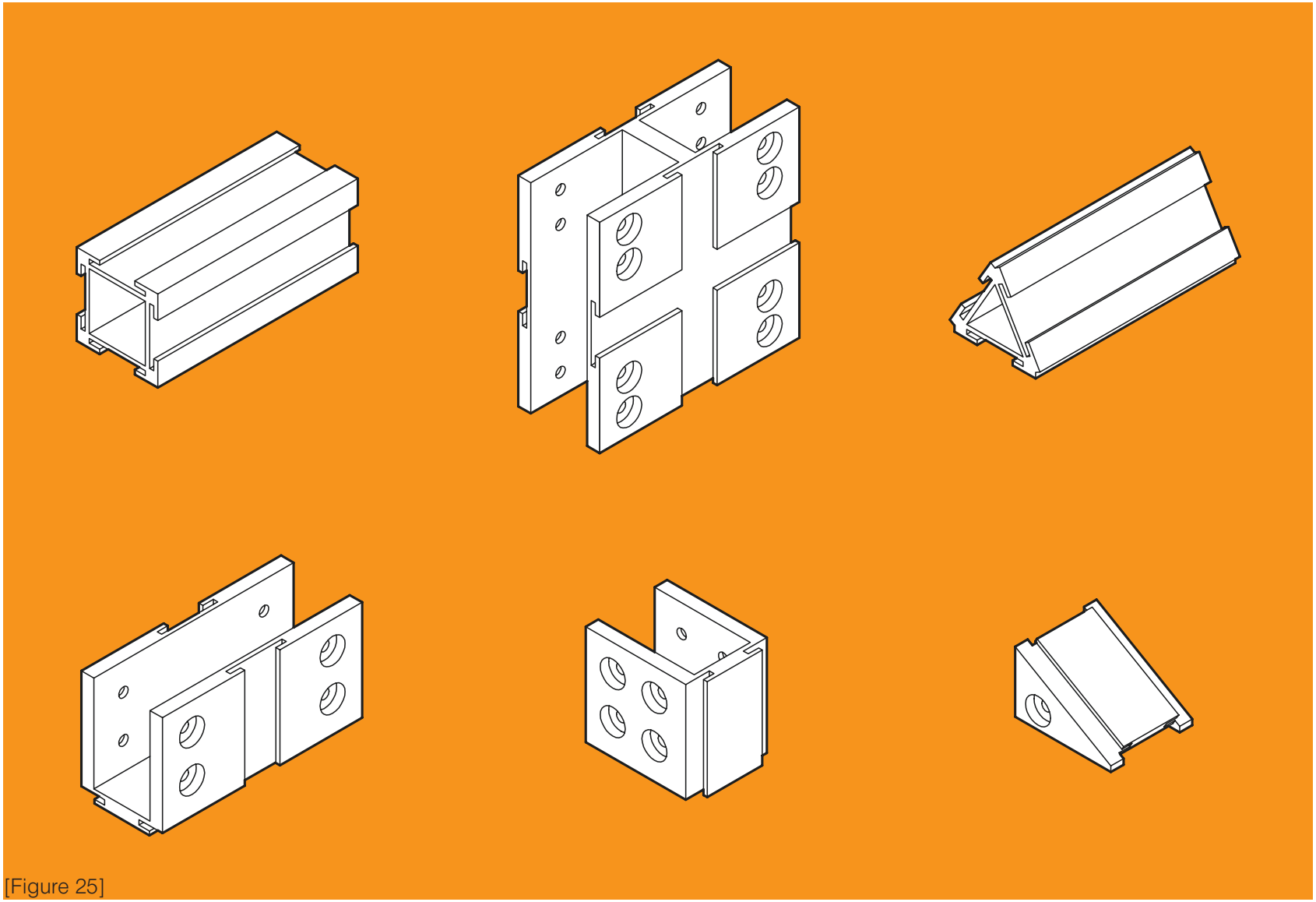
[Figure 23] Bolted H-Frame. These joints would create a strong connection between panels, but have a high material usage.



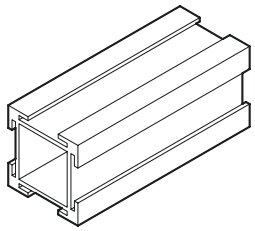


Custom Combination Joints

[Figure 24] Custom Combination Joints. This joinery system uses 6 interlocking pieces to form all required panel connections. These joints are used for the fiinal design of Tinderbox.



[Figure 25]



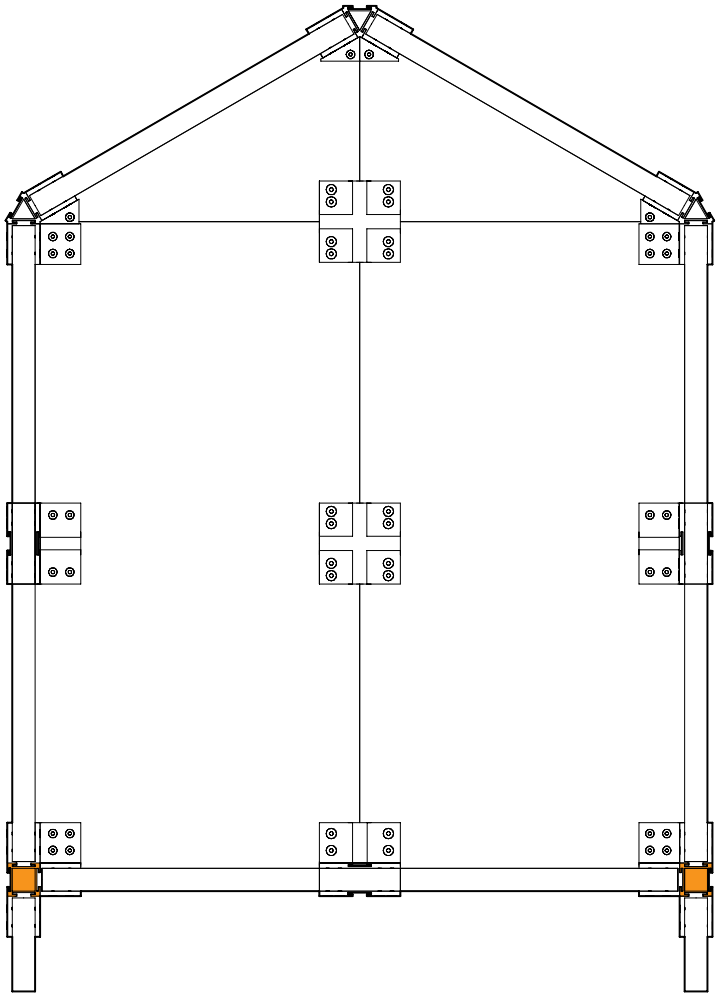
JOINT_01

Height: 3 1/4”
Width: 3 1/4“
Length: 8”

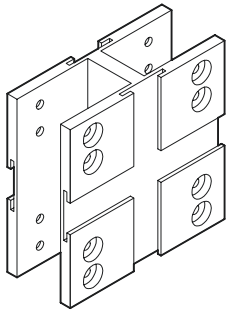
Location: Intersection of walls and floors

Panels Connections: None

Joint Connections: Joint 4



[Figure 26]



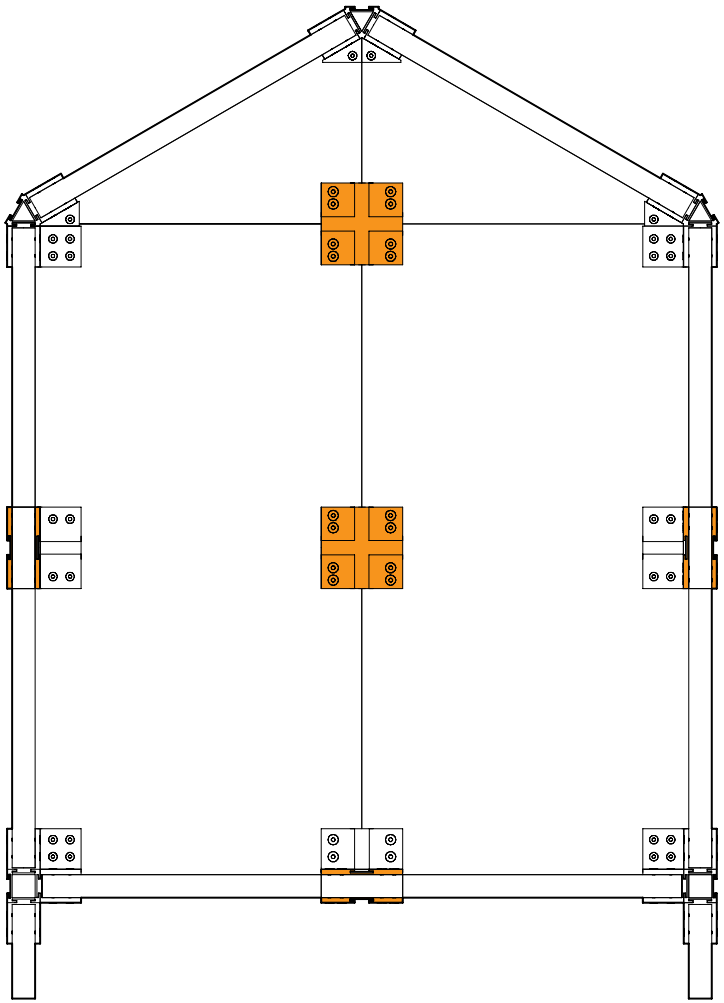
JOINT_02

Height: 8”
Width: 3 1/4“
Length: 8”

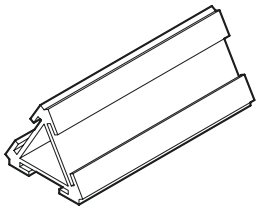
Location: Walls and floors

Panels Connections: Walls and floors

Joint Connections: Joint 4



[Figure 27]



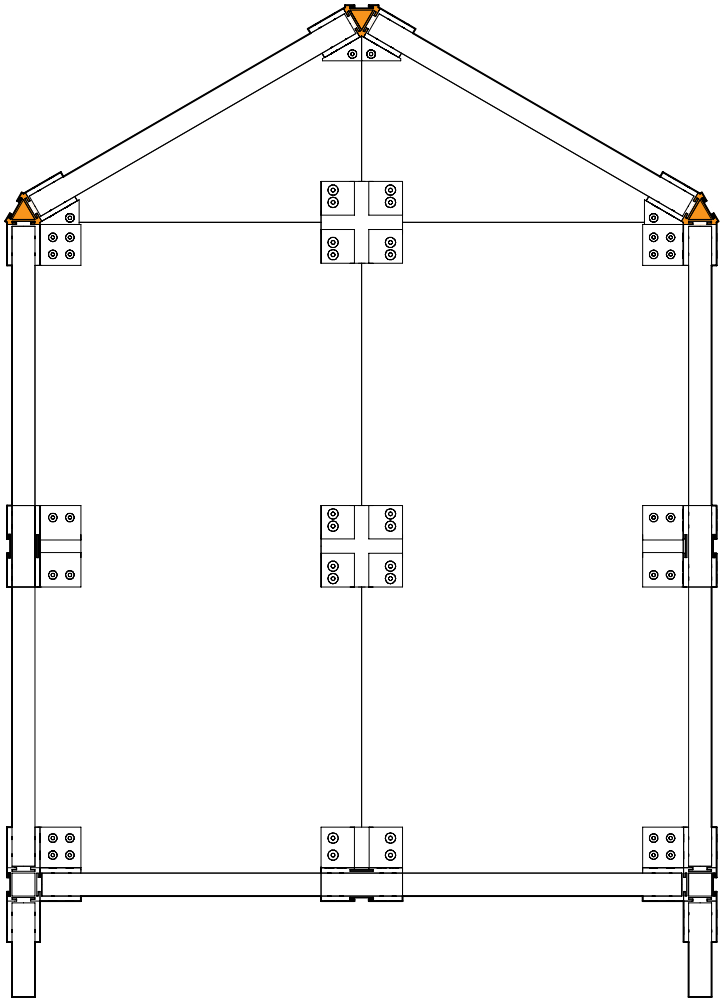
JOINT_03

Height: 3 1/4”
Width: 3 1/4“
Length: 8”

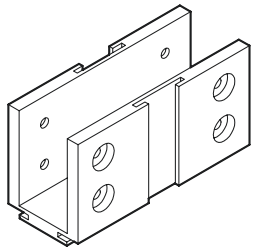
Location: Intersection of walls and ceiling

Panels Connections: None

Joint Connections: Joint 4



[Figure 28]



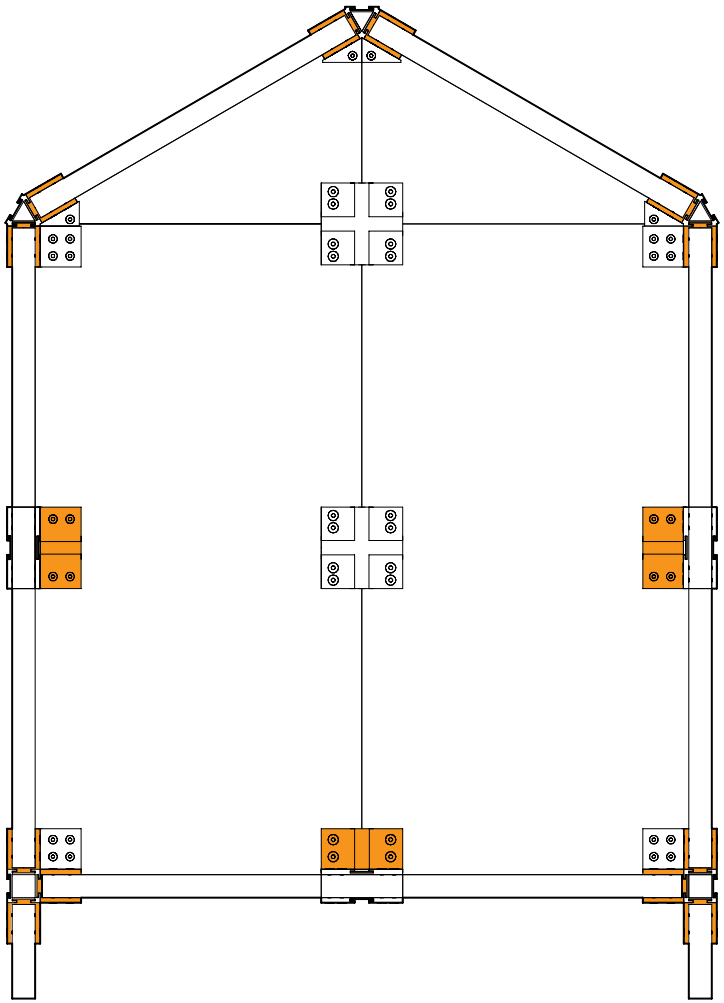
JOINT_04

Height: 4 1/4”
Width: 3 1/4“
Length: 8”

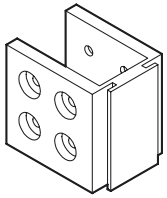
Location: Intersection of walls, floors, ceiling, and foundation

Panels Connections: Walls, floors, ceiling, foundation

Joint Connections: Joint 1, Joint 2, Joint 3, Joint 5, Joint 6



[Figure 29]



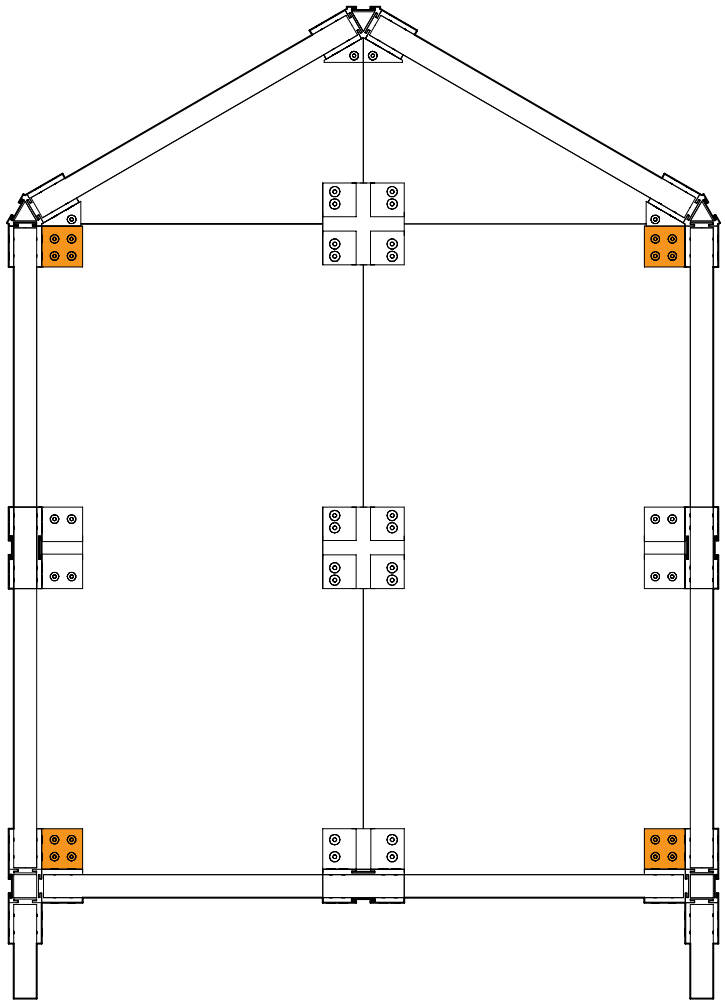
JOINT_05

Height: 4 1/4”
Width: 4 1/4“
Length: 3 1/4”

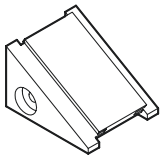
Location: Intersection of
perpendicular walls at top and bottom

Panels Connections: Walls

Joint Connections: Joint 4



[Figure 30]



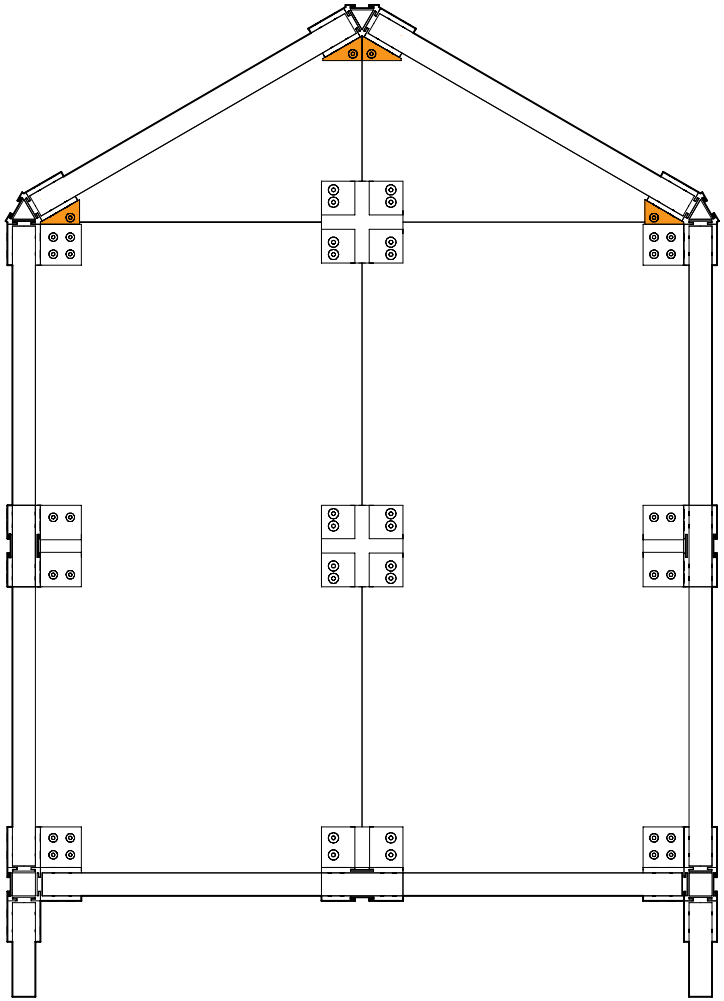
JOINT_06

Height: 4 1/4”
Width: 4“
Length: 3 1/4”

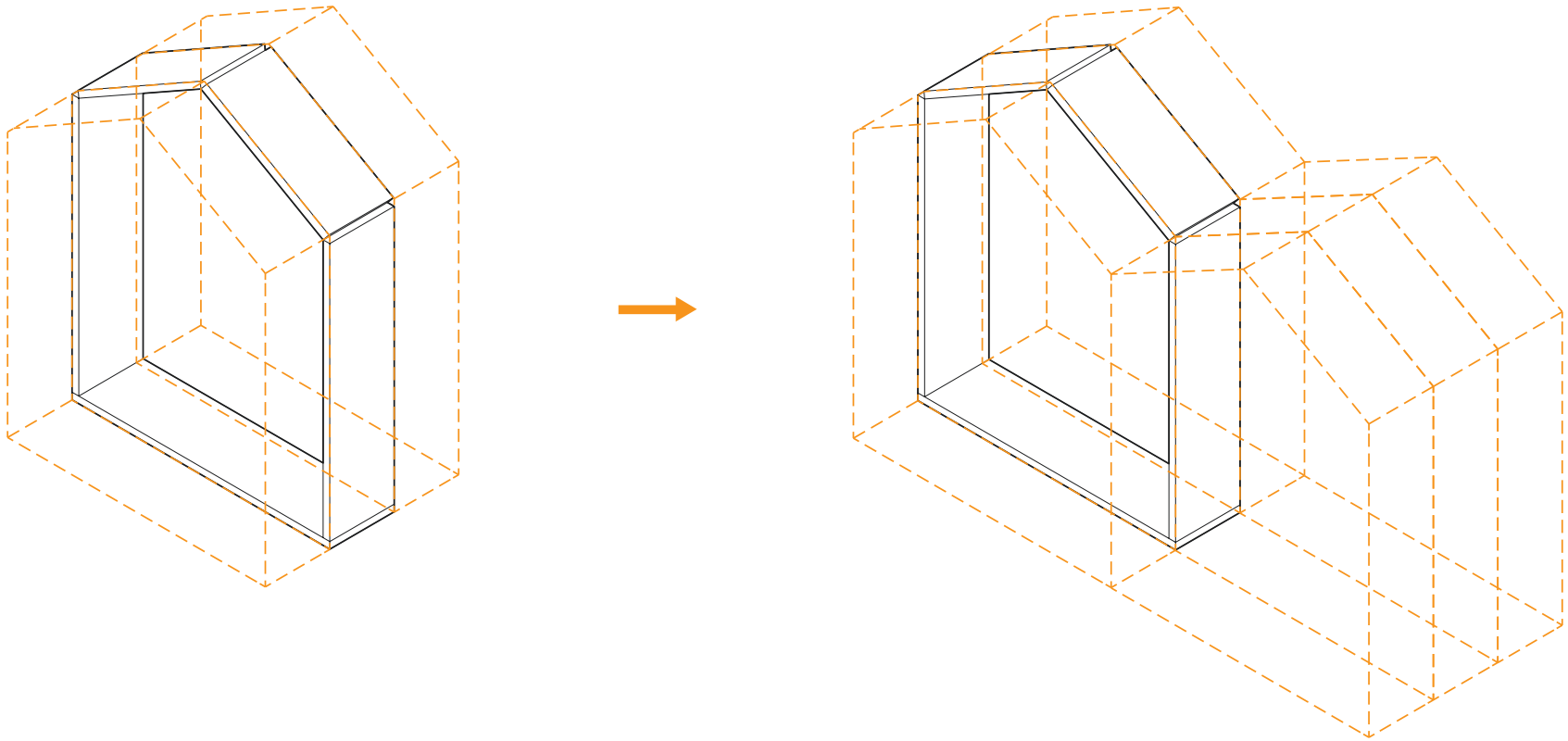
Location: Intersection of
perpendicular walls to ceiling

Panels Connections: Walls

Joint Connections: Joint 4



[Figure 31]



Combination joints allow for expansion in both length and width

[Figure 32]

5.4 PANEL METHODS

In addition to the standard wall, floor, and ceiling panels, there are coordinating modular panel systems that are incorporated into Tinderbox's design. There is a total of nine panel designs within the Tinderbox system [Figures 33-41]. These panels create opportunities for windows, doors, private rooms, perpendicular walls, and for running electrical, plumbing, and venting systems throughout the home.

All panels contribute a thermal resistance of R - 8.62 to the total building assembly. Each panel is drilled with specifically located ½" bolt holes to facilitate the accompaniment of the joinery system. Additionally, all standard wall, floor, and ceiling panels have two ½" by 1 ¾" cutouts to allow for ratchet strap connections. By using ratchet straps in addition to the joinery, the assembly becomes airtight.

Panels that are used on the exterior of the shelter have multiple fabric snaps located along the edges and midpoints. These snaps allow for the insulated fabric layer to easily attach to the panels.

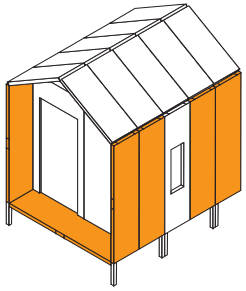
here are three panel designs that are used to accommodate electrical, plumbing, and venting systems, facilitating the installation of sinks, toilets, showers, cooking appliances, and electrical outlets. Panels with cutouts come with optional plugs, which gives users the freedom to choose where they need cutouts in the wall. By designing panels with pluggable cutouts, the need for multiple panel designs is eliminated, maintaining the simplicity of the system.

5.5 INSULATION & EXTERIOR CLADDING

In addition to the insulated plywood panels, insulated fabric panels and a weatherproofing fabric overlay cover Tinderbox's exterior face. The insulated fabric panels attach off-centered to the plywood panels using fabric snaps, making the connection secure and user-friendly while preventing thermal bridging. Similar to the insulated plywood

panels, these fabric panels are modular. There are 10 fabric panel types that are used to create a Tinderbox: standard wall, window wall, wall edge, perpendicular wall, door wall, ceiling pitch, ceiling, ceiling edge, floor, and floor edge [Figure 42-51]. These panels are constructed out of stone wool batt insulation and marine-grade PVC vinyl fabric, which allows the structure to meet the required thermal resistance, and resist weather damage. The insulated fabric wall panels use 3.5" of insulation, which provides an additional R – 14 to the wall assembly – bringing the total thermal resistance for exterior walls to R - 22.62. For the floor and ceiling, the insulated fabric panels use 5.5" of insulation, which provides an additional R – 24 to those assemblies, bringing the total thermal resistance for the floors and ceiling to R - 32.62. The PVC vinyl fabric is UV-resistant, anti-fungal, antibacterial, fire resistant, and can withstand temperatures as low as -40 degrees Celsius.

The weatherproofing fabric overlay is Tinderbox's final exterior layer - this layer is also constructed using marine-grade PVC vinyl fabric, and is positioned off-center to the insulated fabric panels. The objective of this layer is to prevent vapor and moisture from reaching the insulated plywood panels, as it would reduce the lifespan of the materials. In accordance with the rest of the assembly, this layer uses modular pieces that are attached to each other with hook and loop connections. There are six overlay types that are used within the assembly: wall overlay, window wall overlay, window cover, perpendicular wall, ceiling, and ceiling seam [Figure 52]. The fabric wall overlay attaches to Tinderbox's foundation posts using hook and loop straps, keeping the entire overlay assembly in place.



PANEL_01

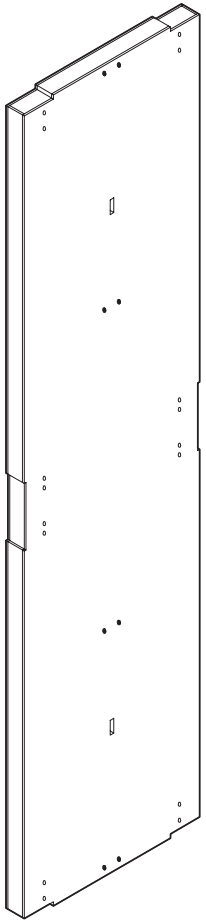
Height: 8’
Width: 2 1/2“
Length: 2’

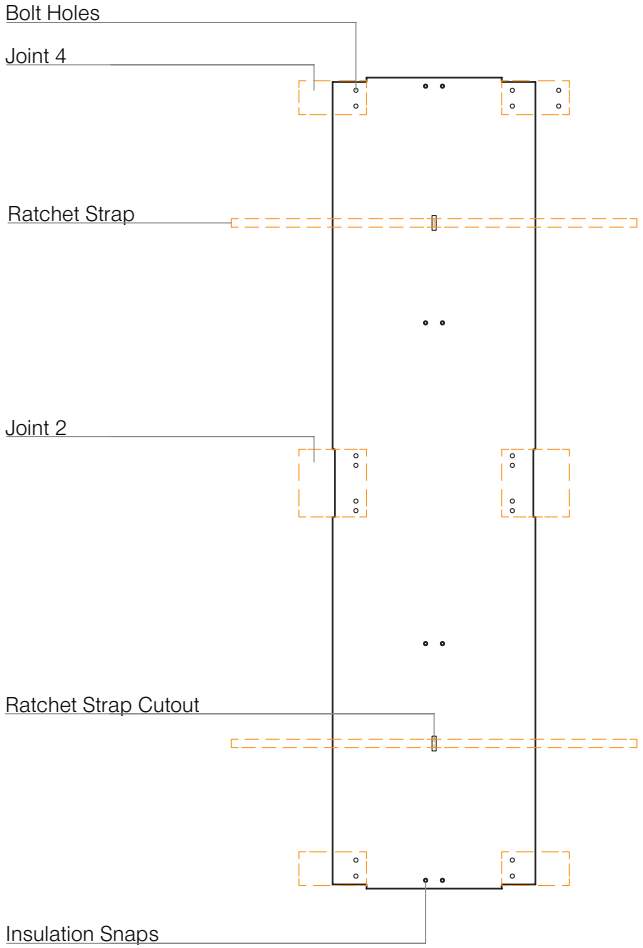
Location: Exterior and interior walls, floors

Joint Connections:
Joint 2, Joint 4

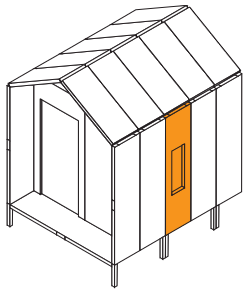
Insulation Connections:
Insul 1, Insul 3, Insul 4

Connects to parallel panels using 1” ratchet strap





[Figure 33]



PANEL_02

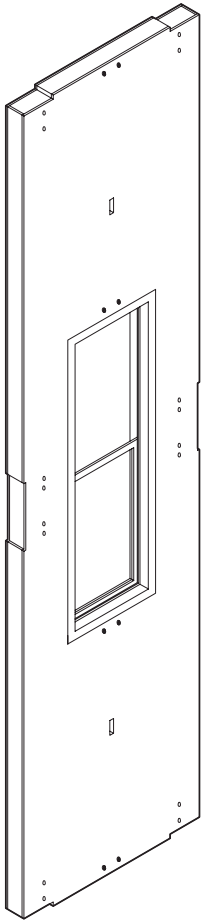
Height: 8’
Width: 2 1/2“
Length: 2’

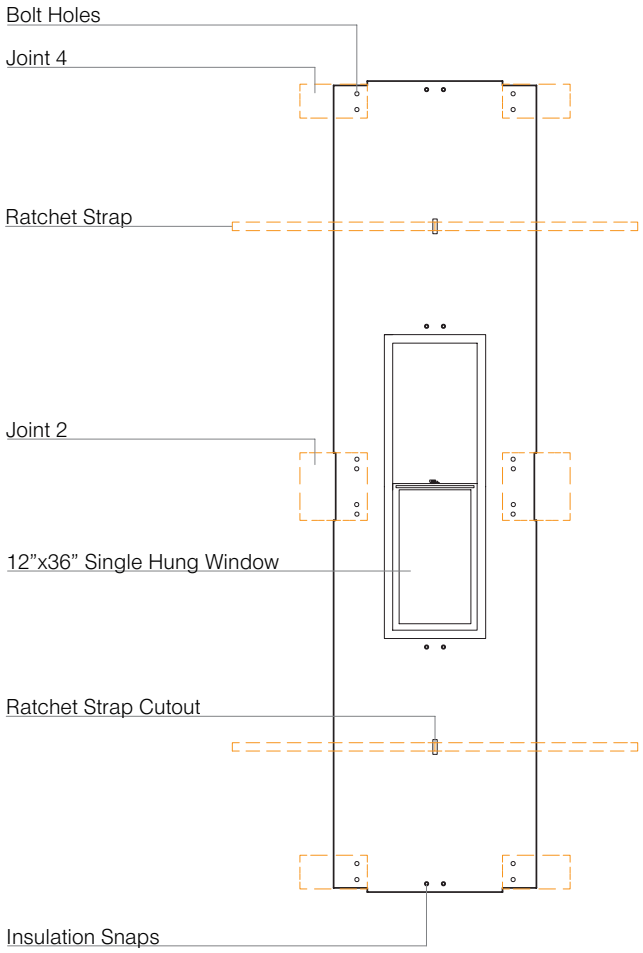
Location: Exterior walls

Joint Connections:
Joint 2, Joint 4

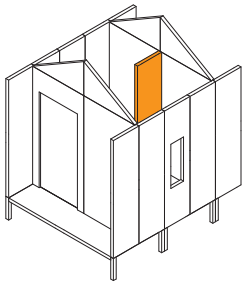
Insulation Connections:
Insul 2

Connects to parallel panels using 1” ratchet strap





[Figure 34]



PANEL_03

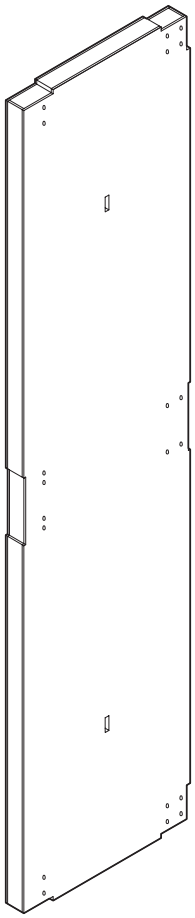
Height: 8’
Width: 2 1/2“
Length: 1’ 10 1/2”

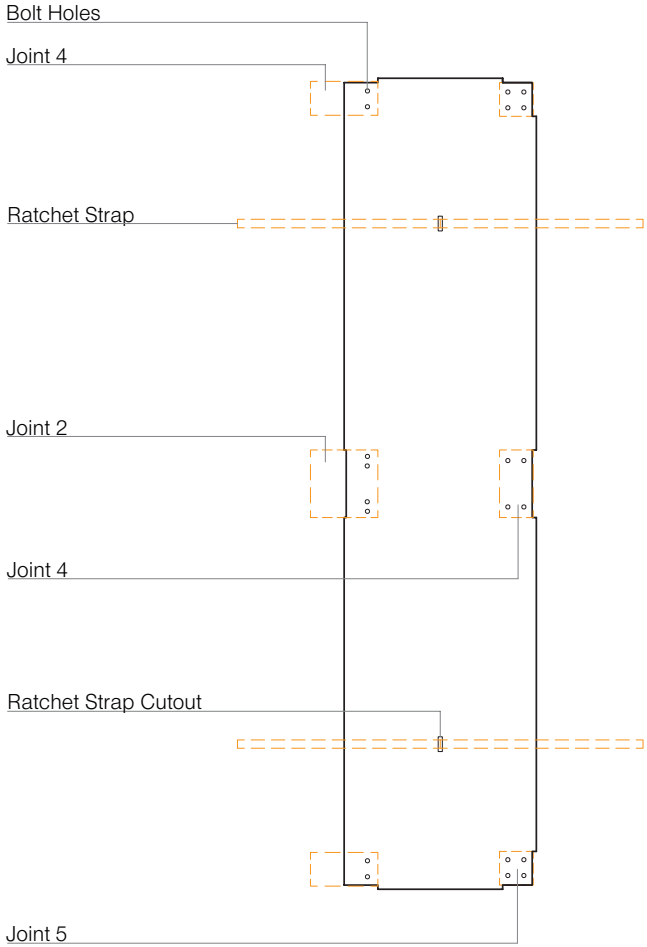
Location: Interior intersection of Panel 6, 7, 8

Joint Connections:
Joint 2, Joint 4, Joint 5

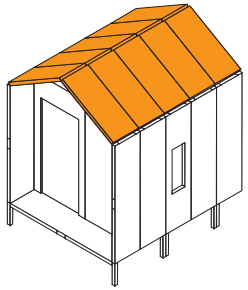
Insulation Connections:
None

Connects to parallel panels using 1” ratchet strap





[Figure 35]



PANEL_04

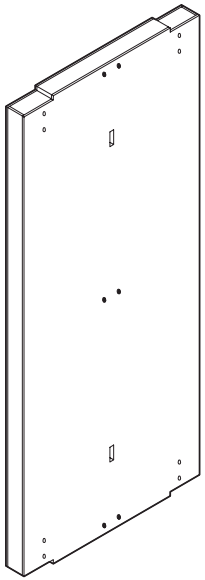
Height: 4’ 7 1/2”
Width: 2 1/2“
Length: 2’

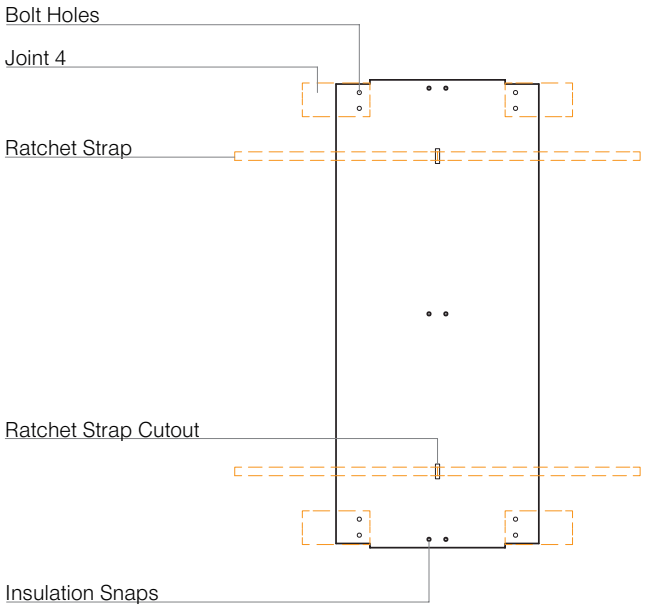
Location: Ceiling

Joint Connections:
Joint 4

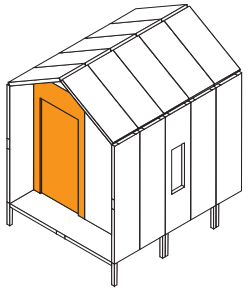
Insulation Connections:
Insul 6, Insul 7

Connects to parallel panels using 1” ratchet strap





[Figure 36]



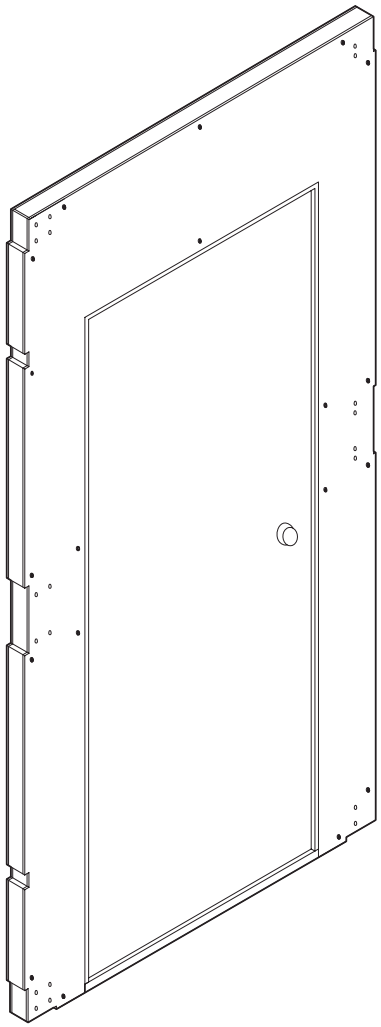
PANEL_05

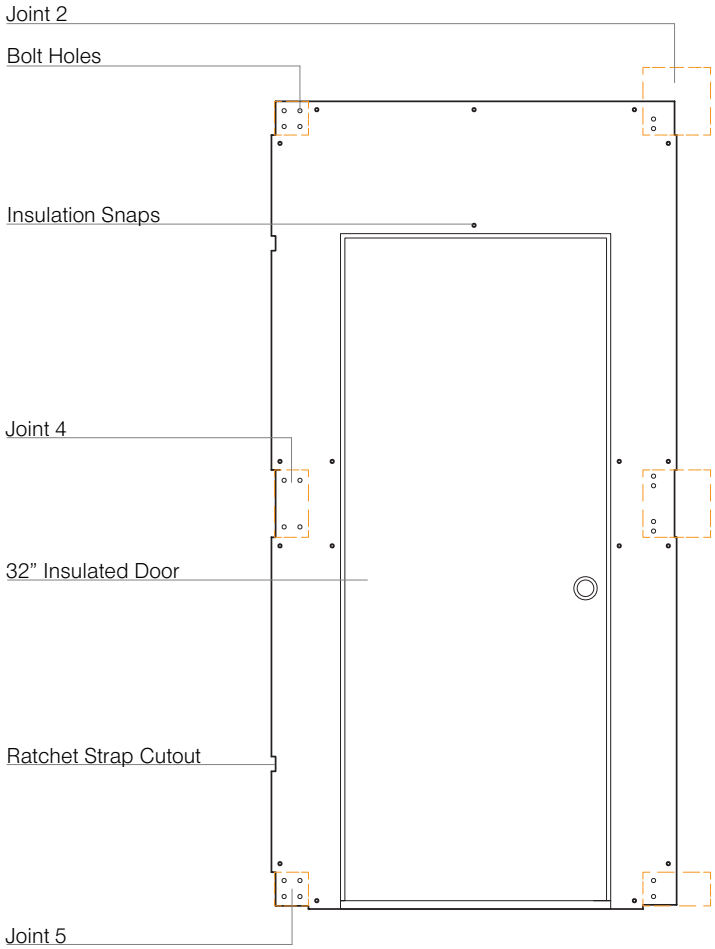
Height: 8’
Width: 2 1/2“
Length: 4’

Location: Exterior and interior walls

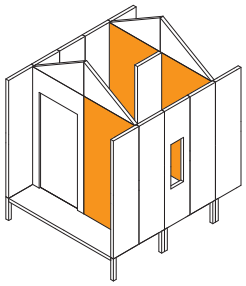
Joint Connections:
Joint 2, Joint 4, Joint 5

Insulation Connections:
Insul 8





[Figure 37]



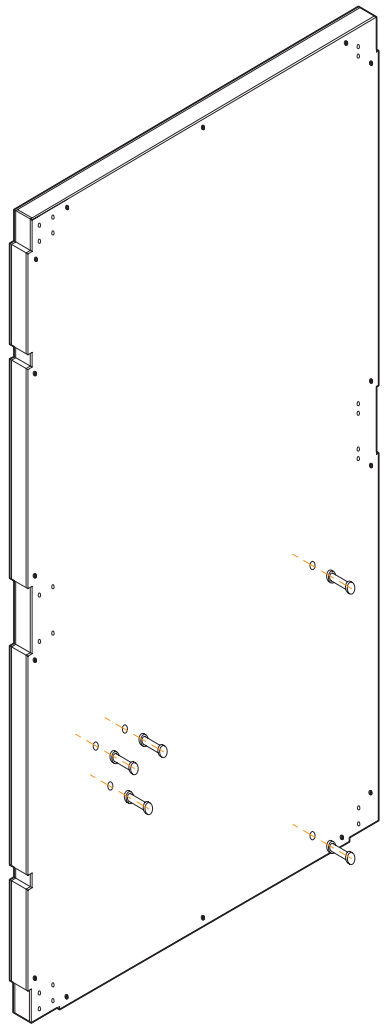
PANEL_06

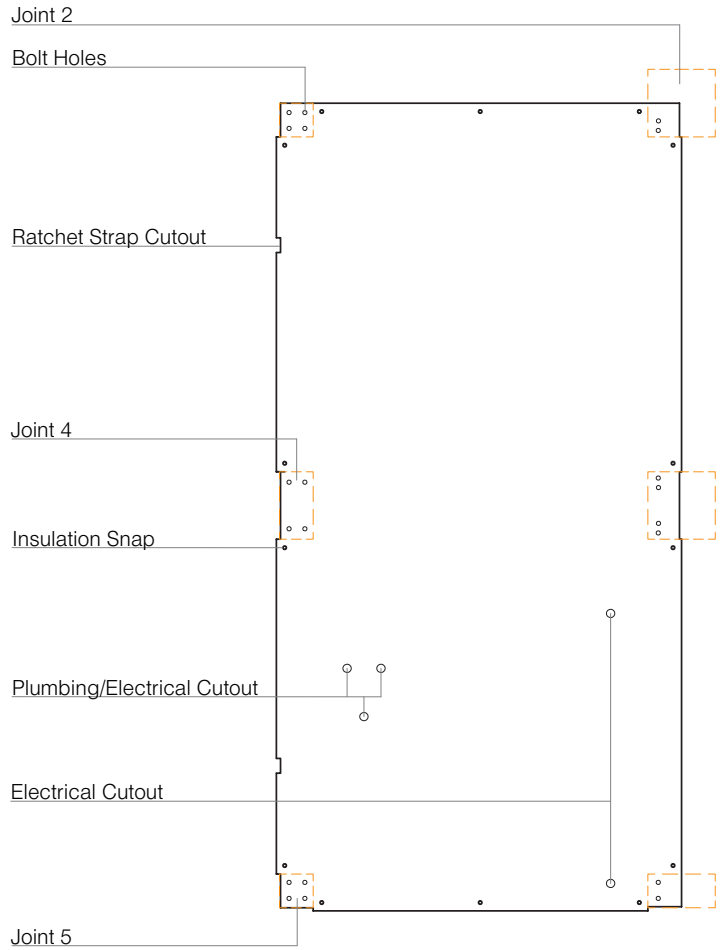
Height: 8’
Width: 2 1/2“
Length: 4”

Location: Exterior and interior walls, adjacent to kitchenette

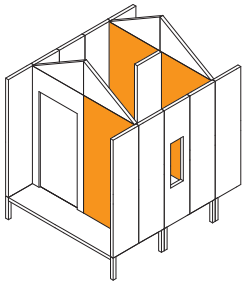
Joint Connections:
Joint 2, Joint 4, Joint 5

Insulation Connections:
Insul 9





[Figure 38]



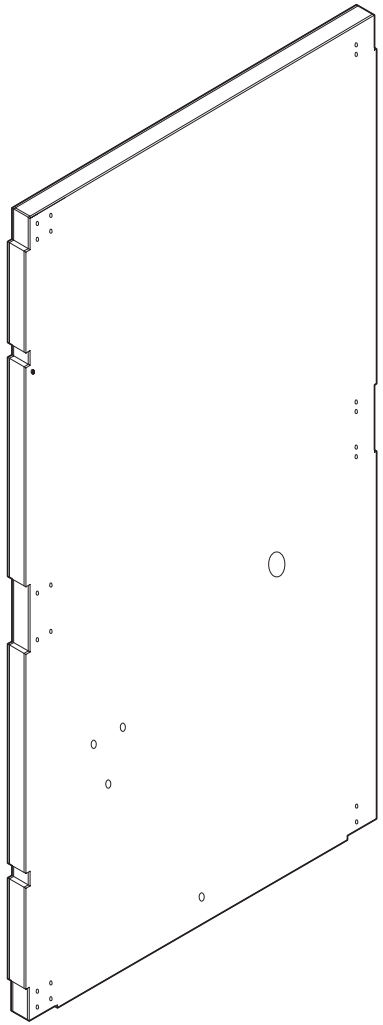
PANEL_07

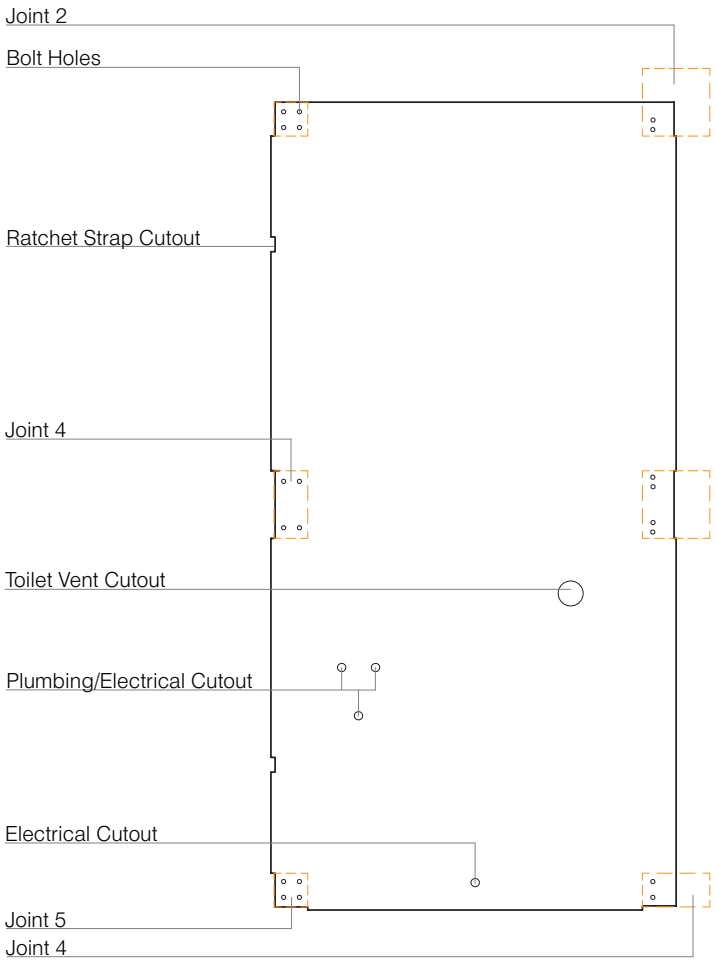
Height: 8’
Width: 2 1/2“
Length: 4’

Location: Interior walls, adjacent to toilet and vanity

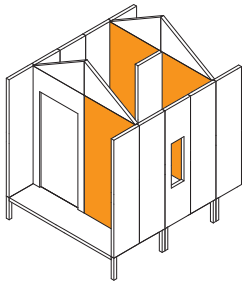
Joint Connections:
Joint 2, Joint 4, Joint 5

Insulation Connections:
Insul 9





[Figure 39]



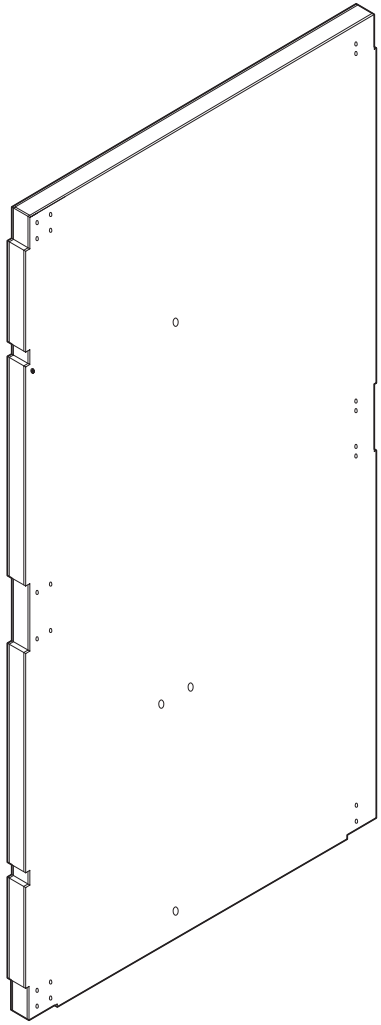
PANEL_08

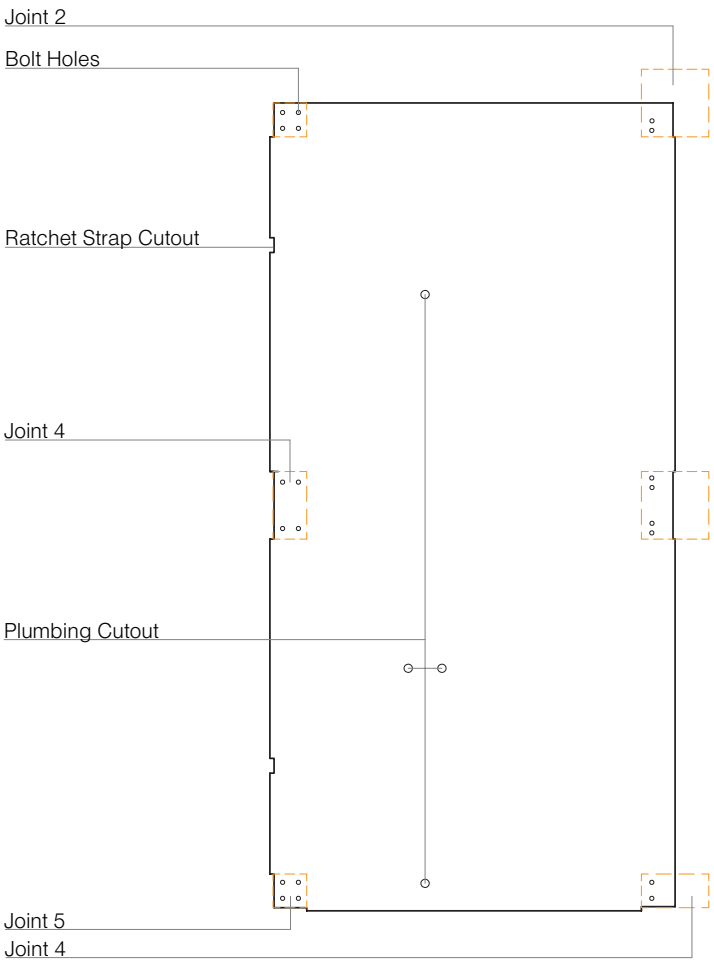
Height: 8’
Width: 2 1/2“
Length: 4’

Location: Interior walls, adjacent to shower unit

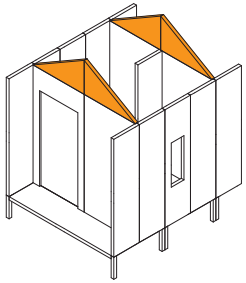
Joint Connections:
Joint 2, Joint 4, Joint 5

Insulation Connections:
Insul 9





[Figure 40]



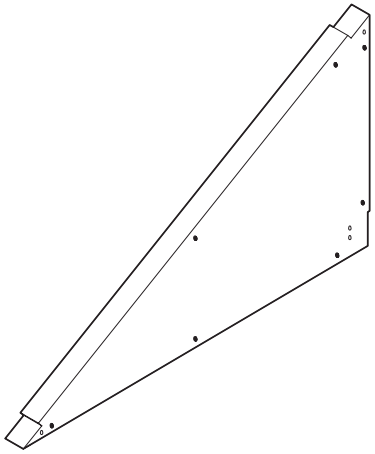
PANEL_09

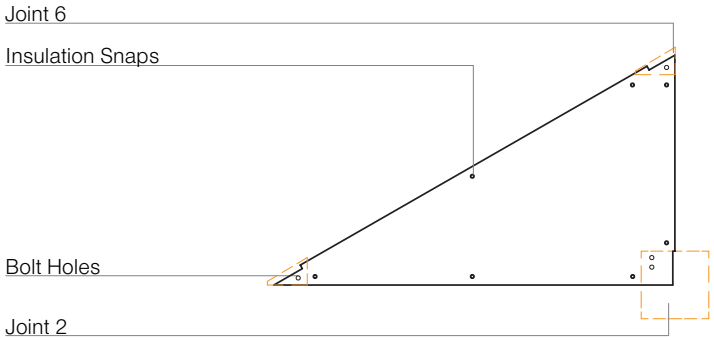
Height: 2’ 3 1/2”
Width: 2 1/2“
Length: 4’

Location: Above
Panels 5, 6, 7, and 8

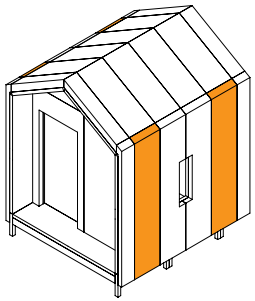
Joint Connections:
Joint 2, Joint 6

Insulation Connections:
Insul 10





[Figure 41]



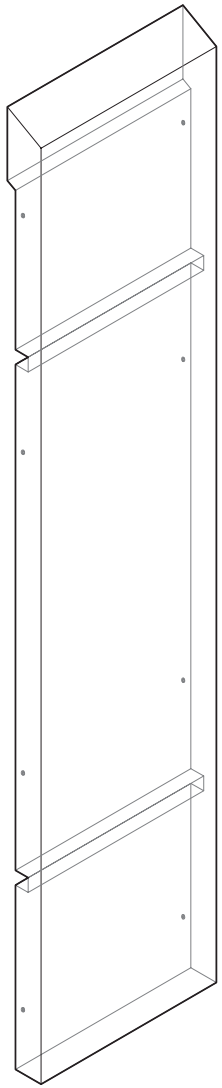
INSUL_01

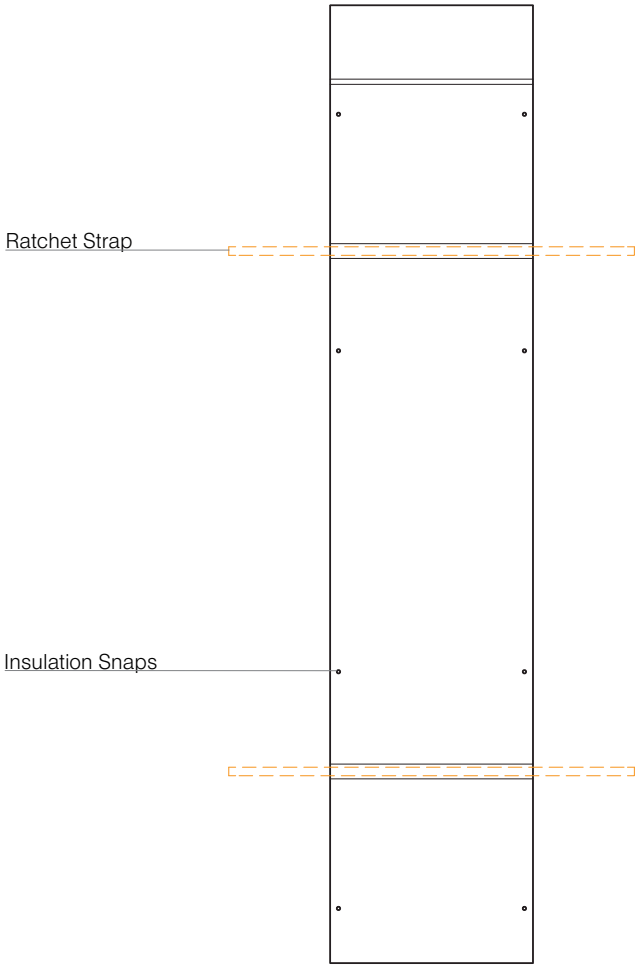
Height: 9’ 4 1/2”
Width: 3 1/2“
Length: 2’

Location: Exterior walls

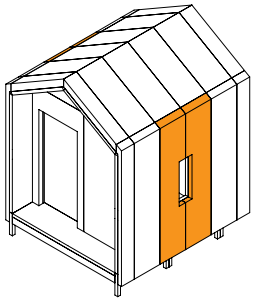
Panels Connections:
Panel 1

R-Value: 14





[Figure 42]



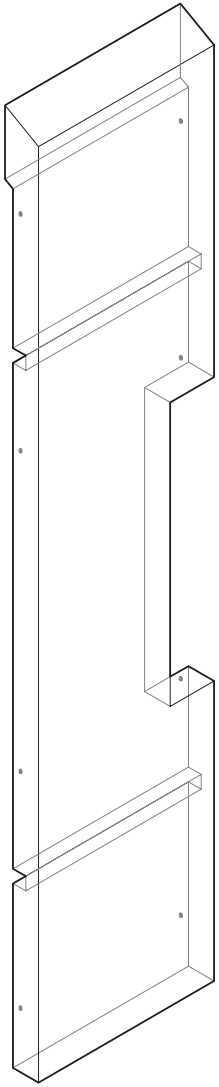
INSUL_02

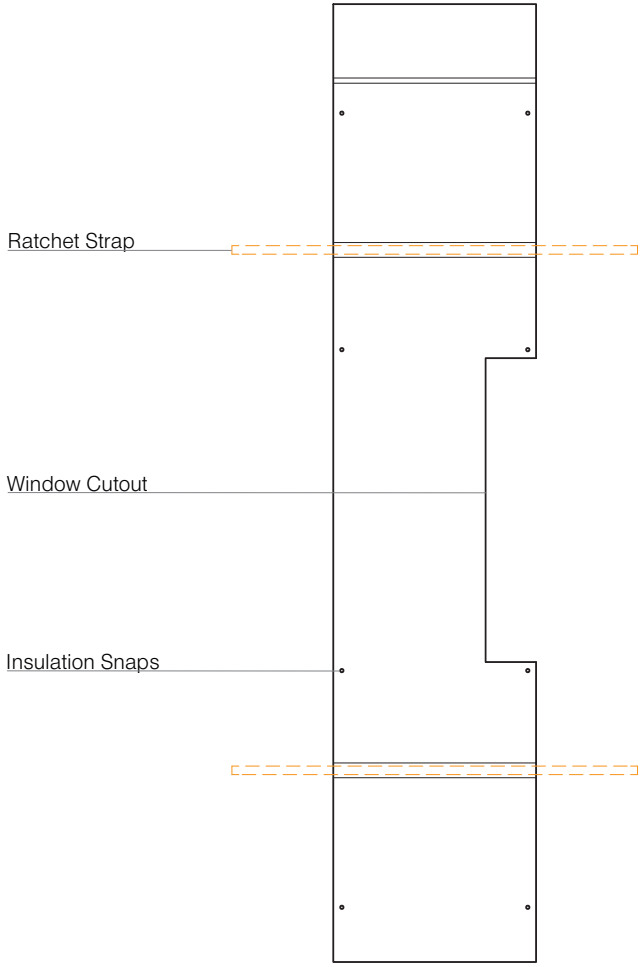
Height: 9 4 1/2”
Width: 3 1/2“
Length: 2’

Location: Exterior walls at window

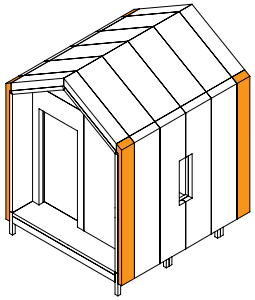
Panels Connections: Panel 2

R-Value: 14





[Figure 43]



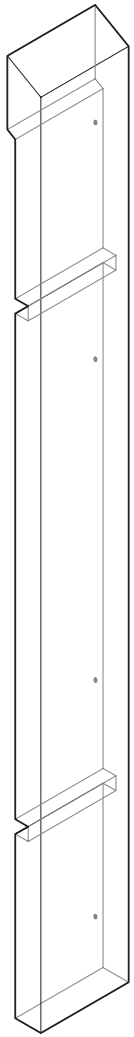
INSUL_03

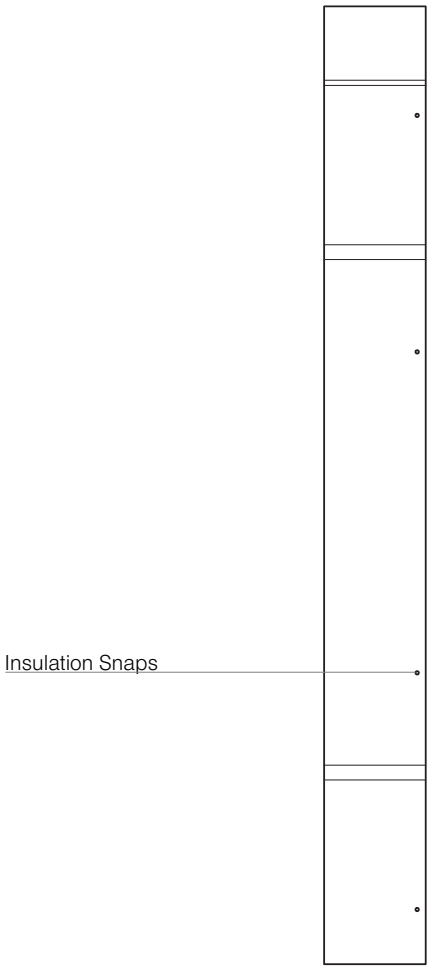
Height: 9 4 1/2”
Width: 3 1/2“
Length: 1’

Location: Exterior walls at edges

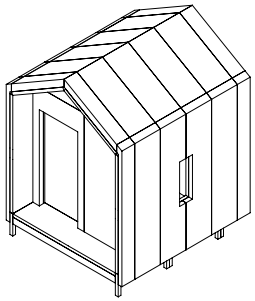
Panels Connections: Panel 1

R-Value: 14





[Figure 44]



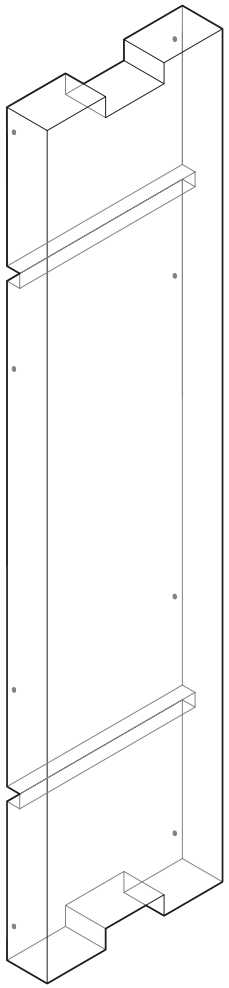
INSUL_04

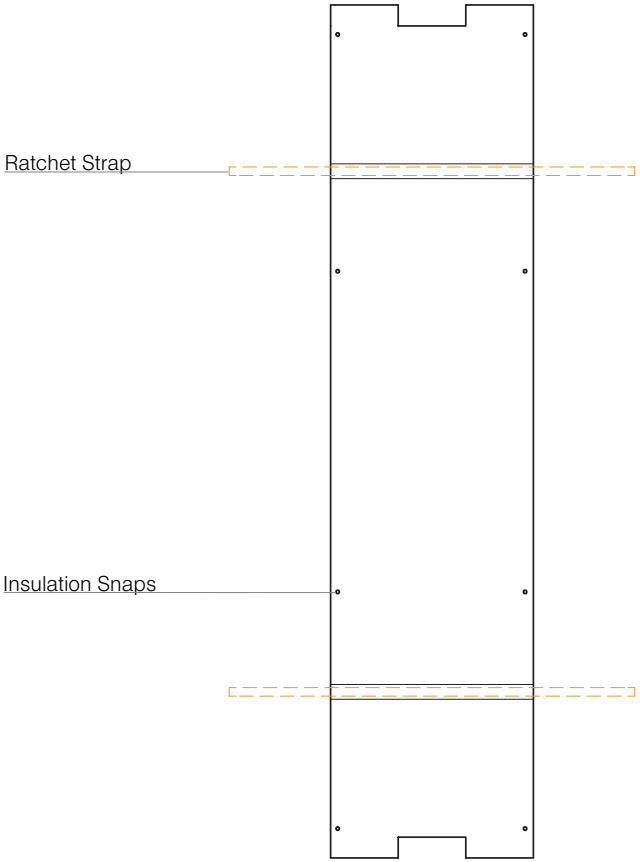
Height: 8’ 5 1/4”
Width: 5 1/2“
Length: 2’

Location: Exterior face of floors

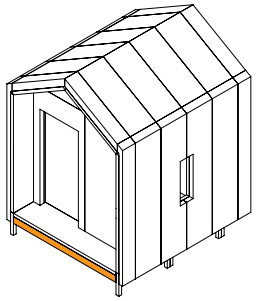
Panels Connections: Panel 1

R-Value: 22





[Figure 45]



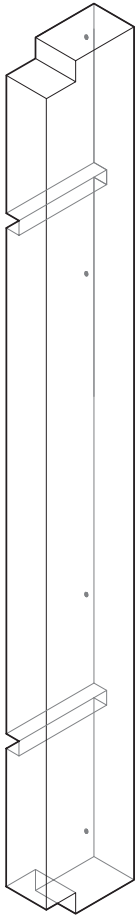
INSUL_05

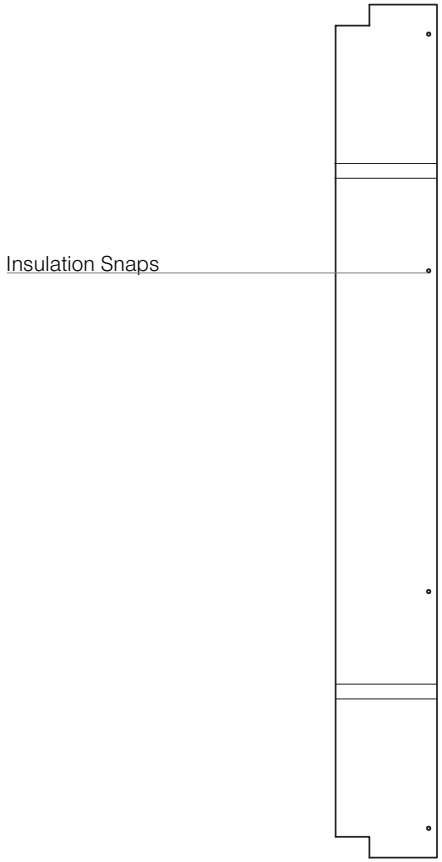
Height: 8’ 5 1/4”
Width: 5 1/2“
Length: 1’

Location: Exterior edge of floors

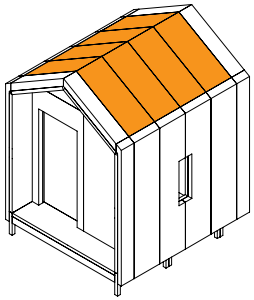
Panels Connections: Panel 1

R-Value: 22





[Figure 46]



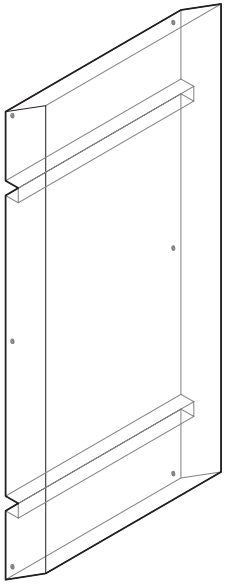
INSUL_06

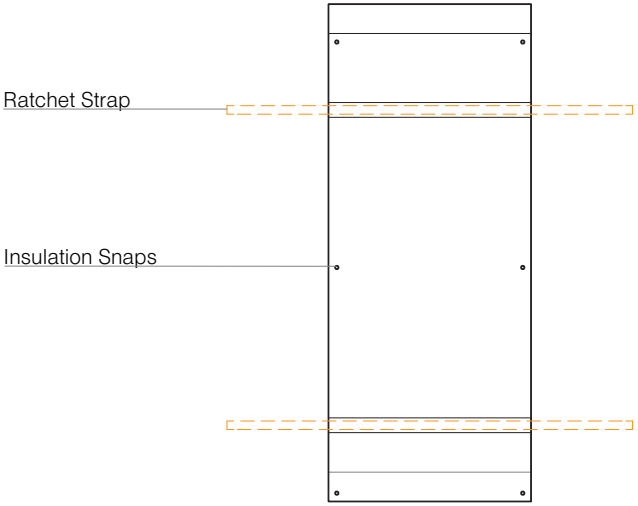
Height: 4’ 9”
Width: 5 1/5“
Length: 2’

Location: Exterior of ceiling

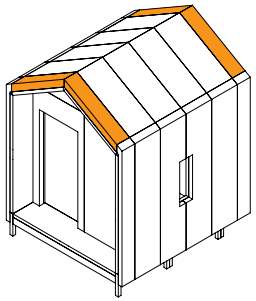
Panels Connections: Panel 4

R-Value: 22





[Figure 47]



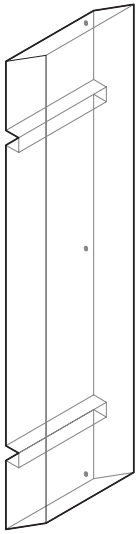
INSUL_07

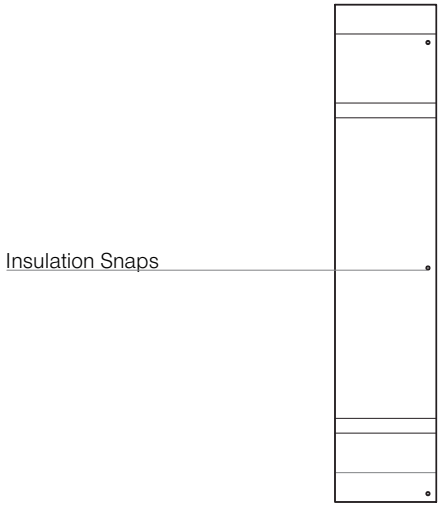
Height: 4’ 9”
Width: 5 1/5“
Length: 1’

Location: Exterior edges of ceiling

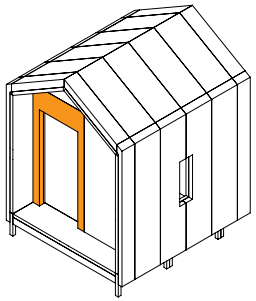
Panels Connections:
Panel 4

R-Value: 22





[Figure 48]



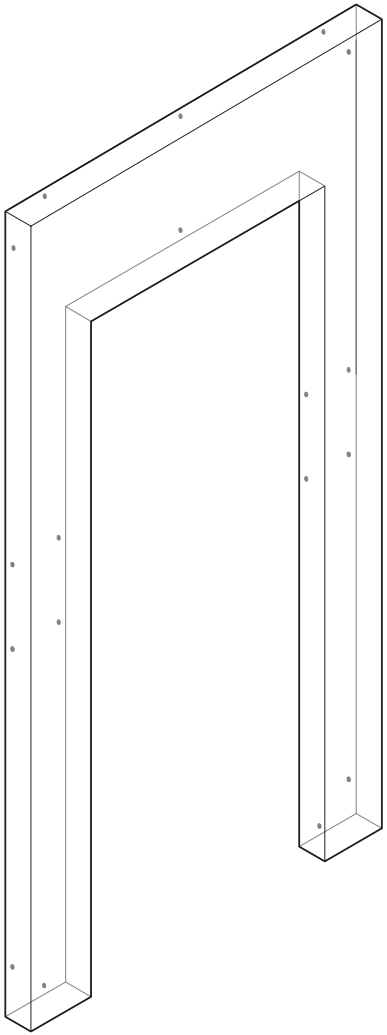
INSUL_08

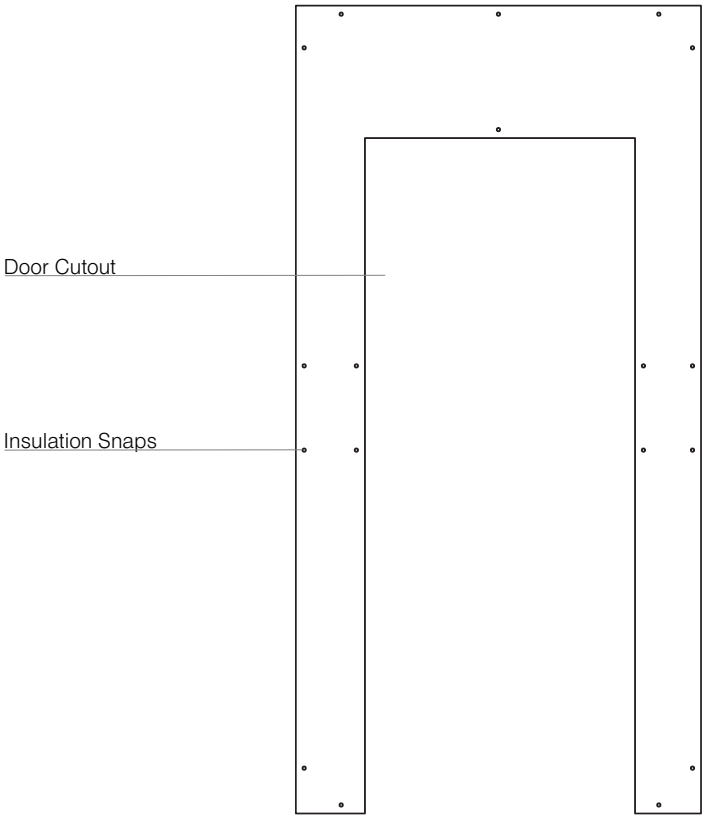
Height: 8’
Width: 3 1/2“
Length: 4”

Location: Exterior face of perpendicular walls

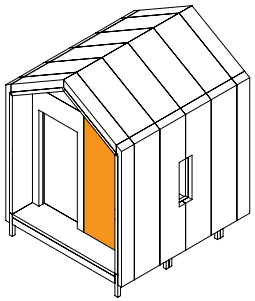
Panels Connections:
Panel 5

R-Value: 14





[Figure 49]



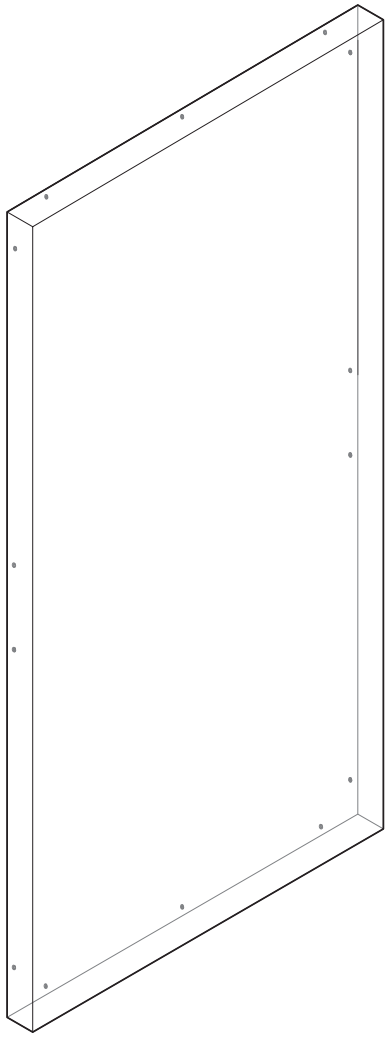
INSUL_09

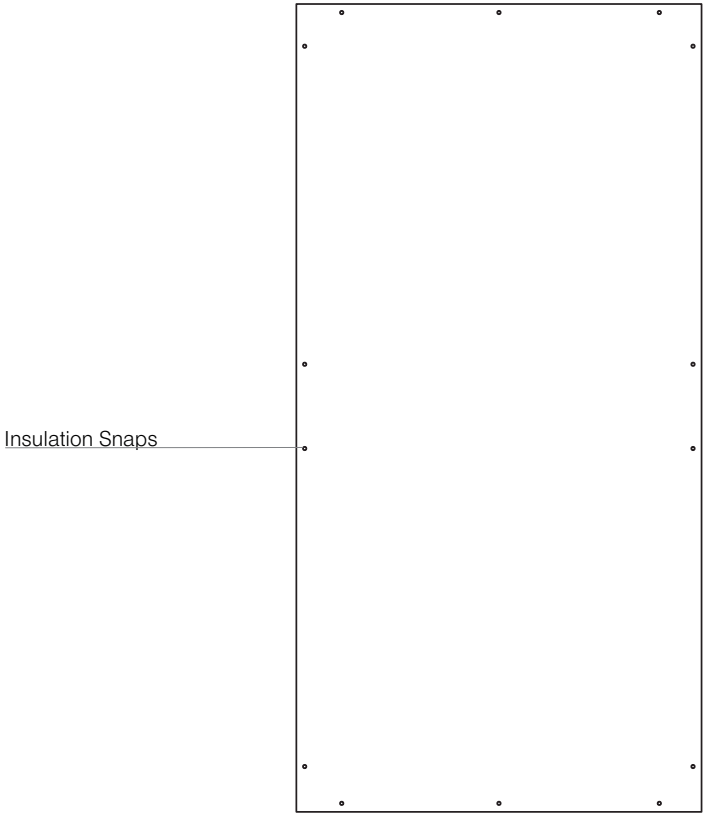
Height: 8’
Width: 3 1/2“
Length: 4’

Location: Exterior face of perpendicular walls

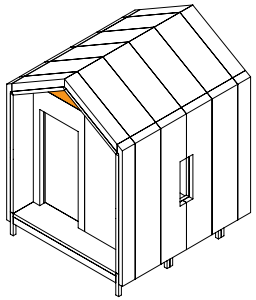
Panels Connections:
Panel 6, 7, 8

R-Value: 14





[Figure 50]



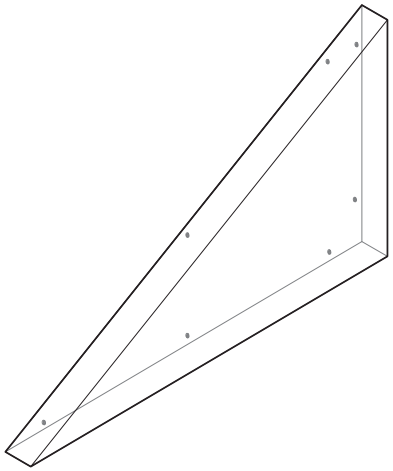
INSUL_10

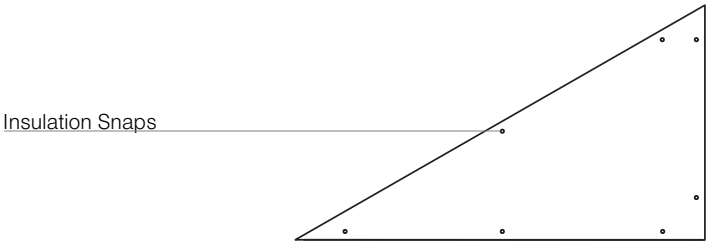
Height: 2’ 3 1/2”
Width: 3 1/2“
Length: 4’

Location: Exterior ceiling pitch

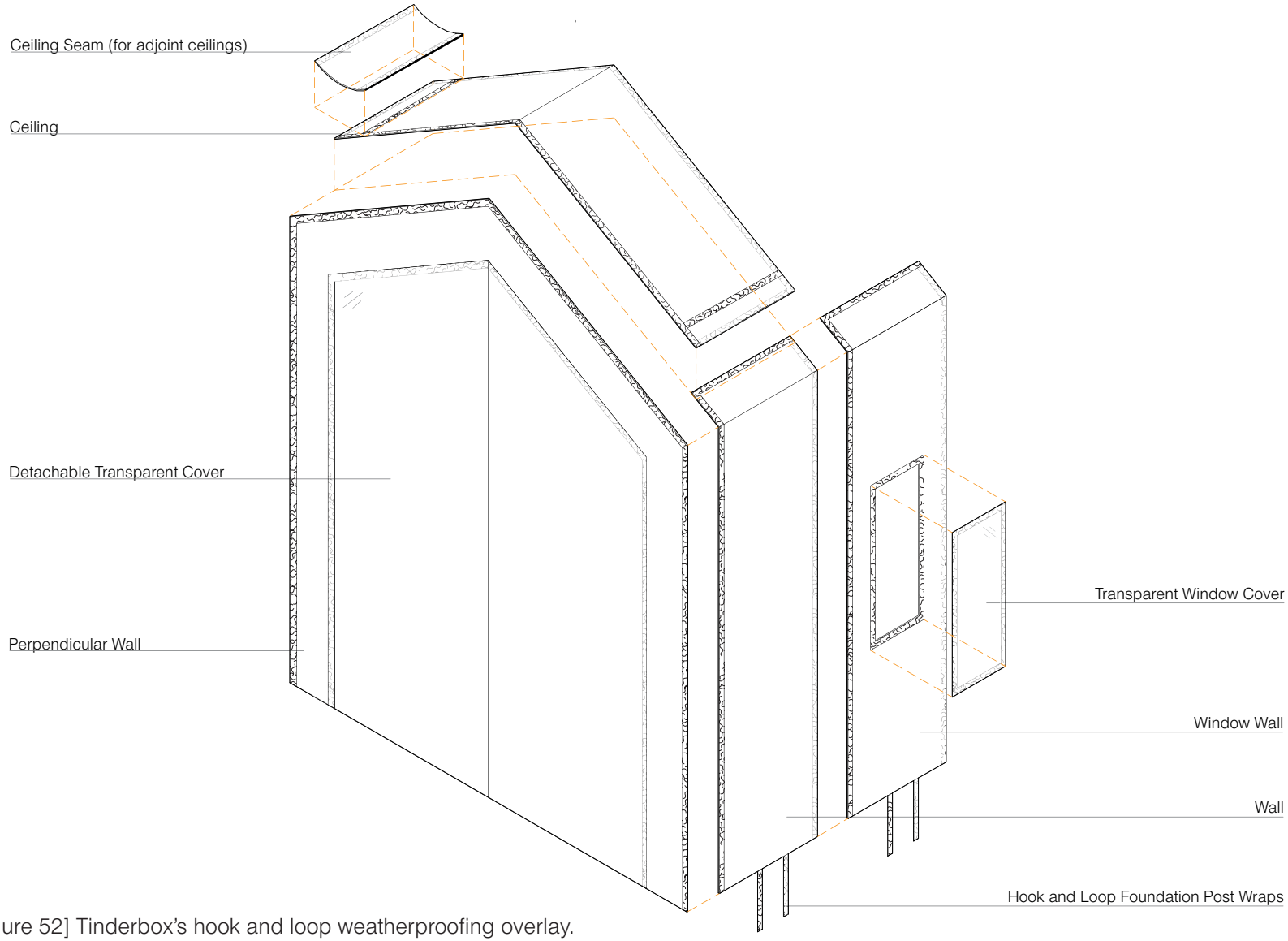
Panels Connections: Panel 9

R-Value: 14





[Figure 51]



[Figure 52] Tinderbox's hook and loop weatherproofing overlay.

5.6 INTEGRATING BUILDING SERVICES

The integration of building services into Tinderbox provides evacuees with the essential household facilities to live comfortably on both a short and long-term basis. These services connect sanitation and cooking facilities to the home, and have the capacity to be used off-grid for approximately three days. Over a longer time period they would be connected to municipal hydro and water systems. During a disaster, municipal services may suffer damages that require repair. By providing evacuees with a short-term off-grid option for water and electricity, they will be able to return to their daily routine without delay.

The electrical system operates using multiple 12-volt deep cycle RV batteries, where the number of batteries varies based on the size and electrical needs of the shelter. To allow the batteries to be used for appliances and household items, they are connected to a DC-AC converter and a circuit breaker. Once converted, three-prong cords transverse through the wall openings to provide connections for the kitchenette appliances, the electric composting toilet, the water pump and heater, and for small household items including floor lighting, laptops, and cell phones [Figure 53]. When used on a single charge, the batteries are capable of maintaining a sufficient power supply for approximately three days. For prolonged use, the batteries can be recharged, and if maintained can have a lifespan of up to five years. When a municipal power source available, an AC utility cord can connect directly to the circuit breaker to provide the shelter with an unrestricted supply of electricity [Figure 54].

The plumbing system provides each Tinderbox with sufficient clean water to supply a small shower and sinks. The system uses two large 250-litre water tanks, one for fresh water, and one for grey water storage. Using an electric water pump, fresh water is pressurized through one-way valves for cold water and hot water supply pipes. The hot water system consists of an electrical instant hot water heater. The two supply pipes lead to the kitchenette and bathroom sink faucets and the shower head [Figure 55]. All grey water from the sinks and shower travel through an output pipe to the grey water storage tank [Figure 56]. When used on a single fill, the plumbing system can operate independently for approximately three days. For prolonged use, the two tanks would need to be emptied and filled. When there is a municipal water source available, a one-way valve can be connected just past the water pump [Figure 57]. With mu

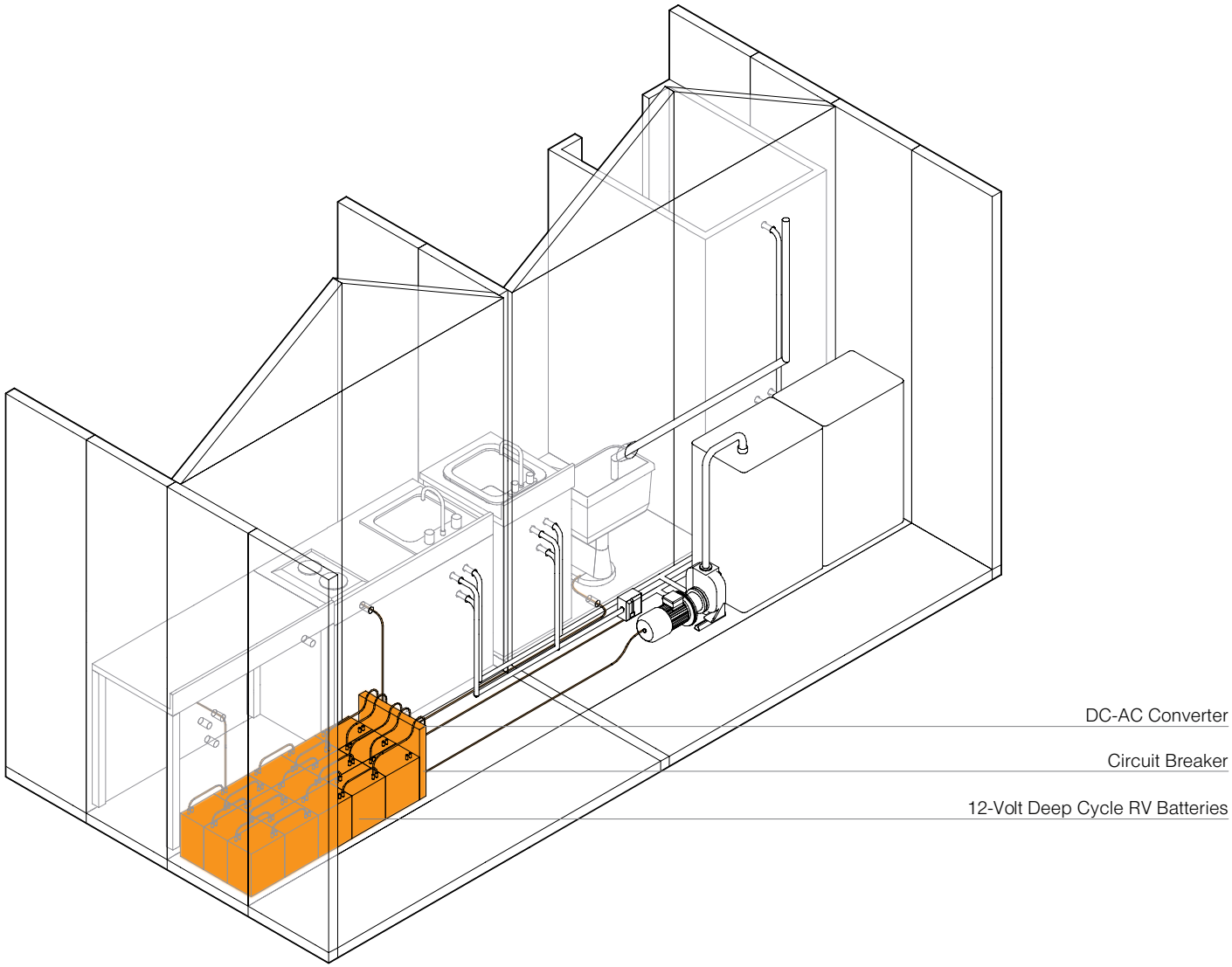
nicipal water, the grey water storage tank would need to be emptied more frequently.

In addition to plumbing and electrical systems, the electrical composting toilet requires adequate venting to prevent odor. This is achieved by providing a PVC vent stack that connects directly to the toilet and transverses through the wall panel at a 45-degree angle, extending out of the shelter and above the roof line [Figure 58]. The vent stack is protected from precipitation and snow with a rain cover.

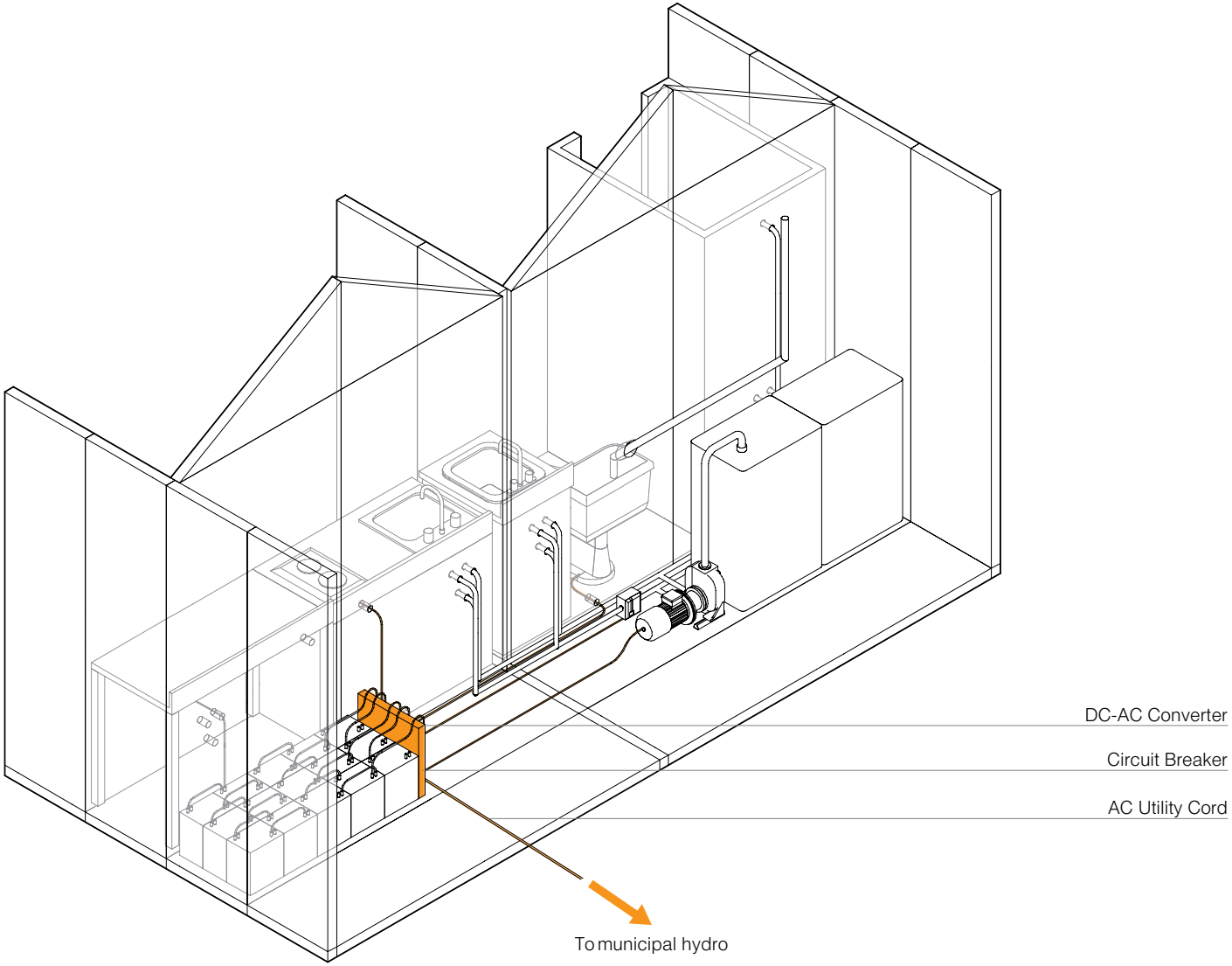
5.7 RESIDENTIAL KITS

Every household is different – in terms of size, needs, spatial requirements, and accessibility. Tinderbox has the capacity to address these differences through its modularity, with the ability to expand, and use flexible arrangements to adapt to the individual needs of the user. To simplify the assembly for the users, a series of standardized residential kits have been designed. Figures 59-71 illustrate the residential design variations for a one person, two-person, four-person, six-person, and accessible Tinderbox.

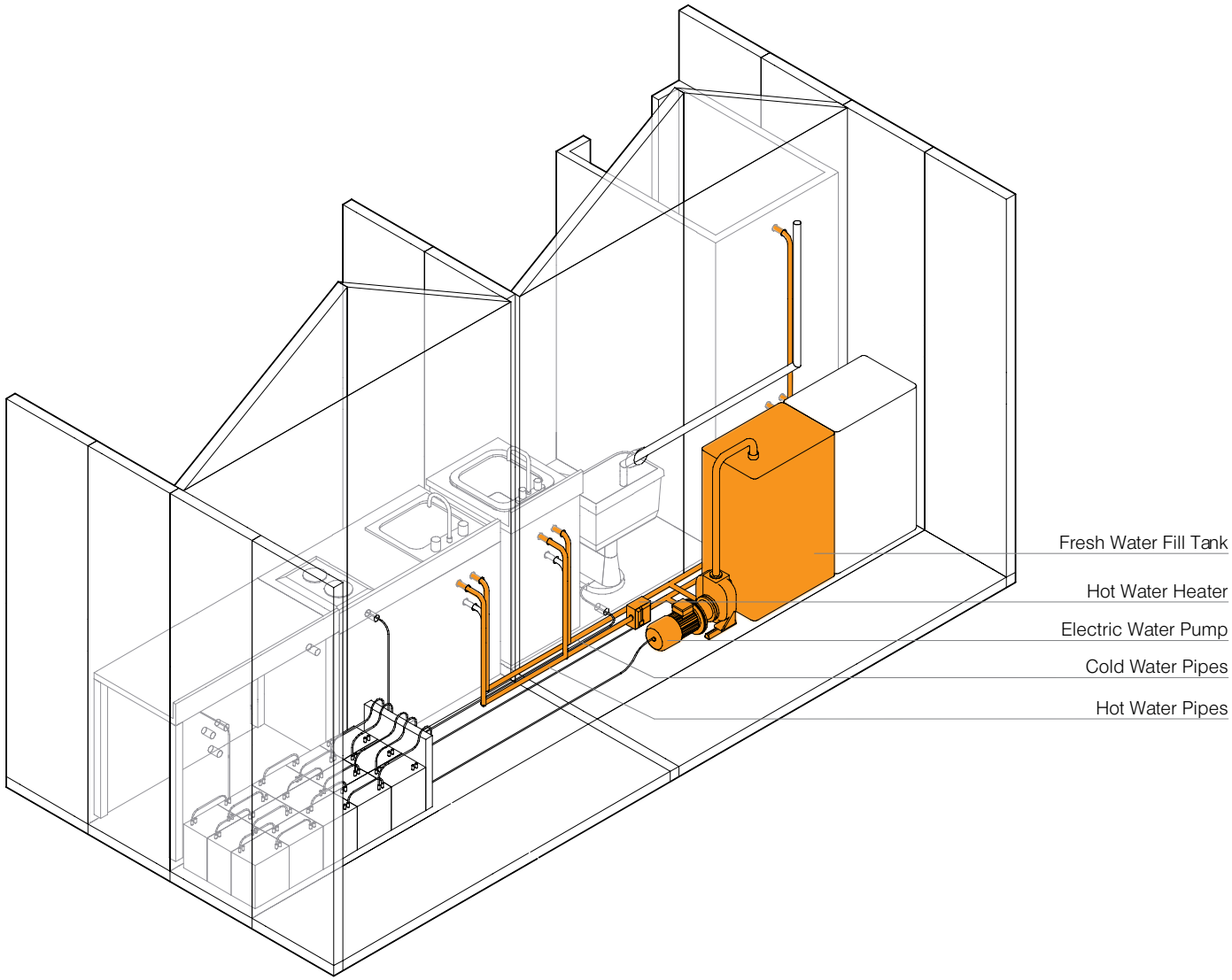
Each residential design includes a bathroom, kitchenette, sleeping area, living/dining area, building services, storage closets, and front porch. There are three types of bathrooms: half bathroom, standard, and accessible – where the half bathroom does not have a shower, and the accessible bathroom has an accessible shower but no sink fixture due to space limitations. All kitchenettes include a sink, a two-plate cooktop, a mini refrigerator, and dry storage. With the exception of the one-person and accessible units, all beds are twin sized bunk beds to maintain floor area. The living and dining areas are open spaces that provide sufficient seating and table space to accommodate the number of inhabitants.



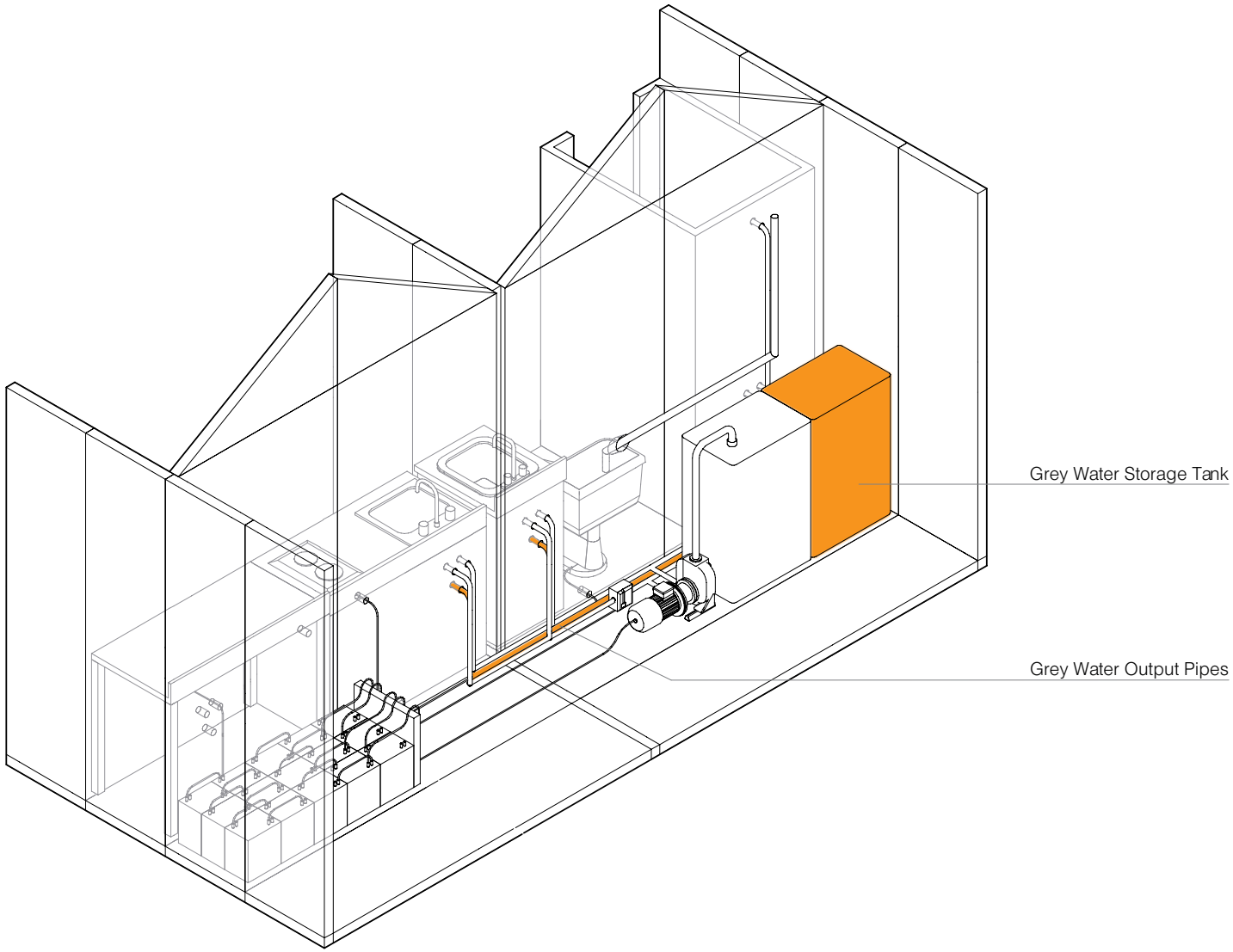
[Figure 53] Tinderbox's off-grid electricity system.



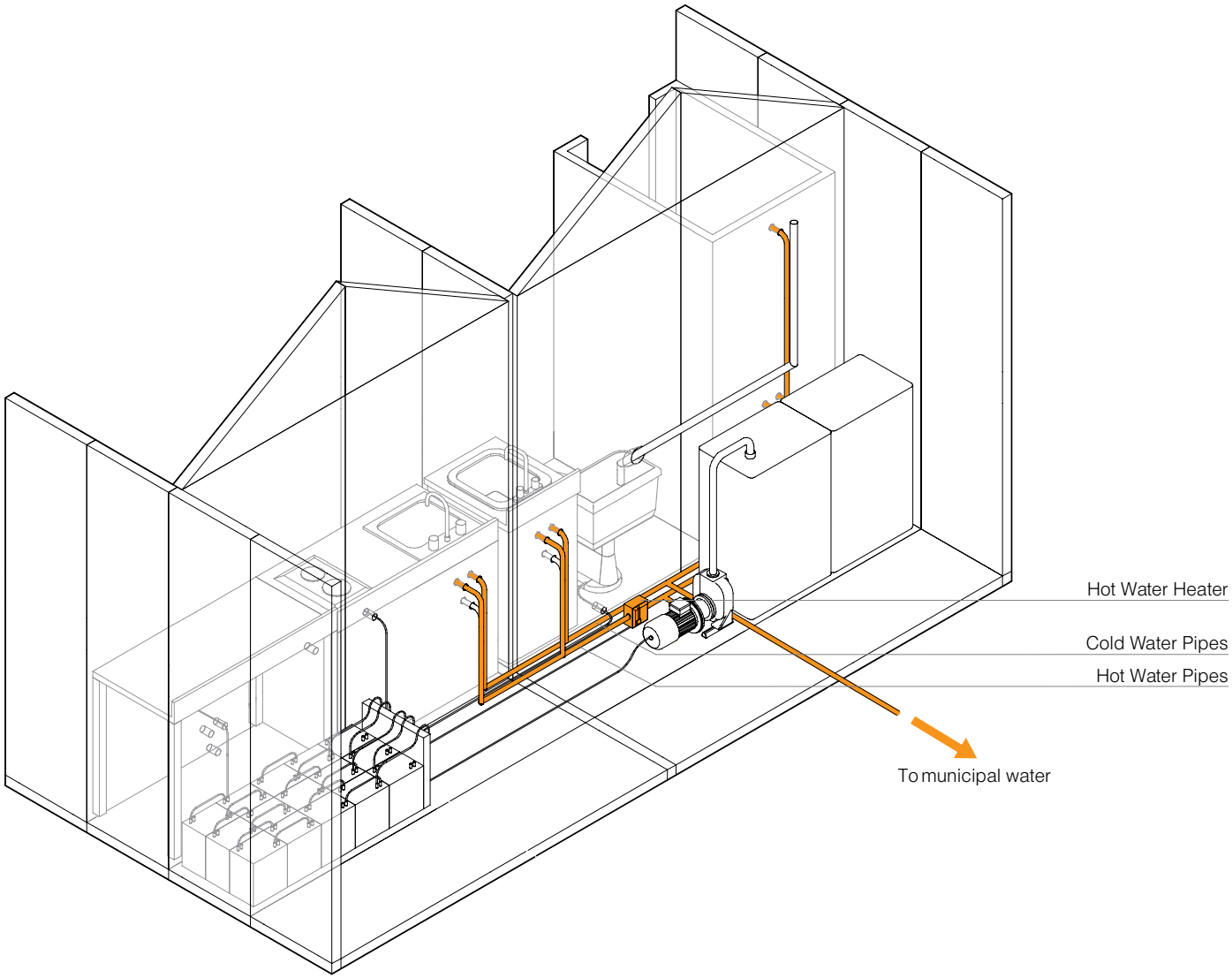
[Figure 54] Tinderbox's municipal electricity hookup.



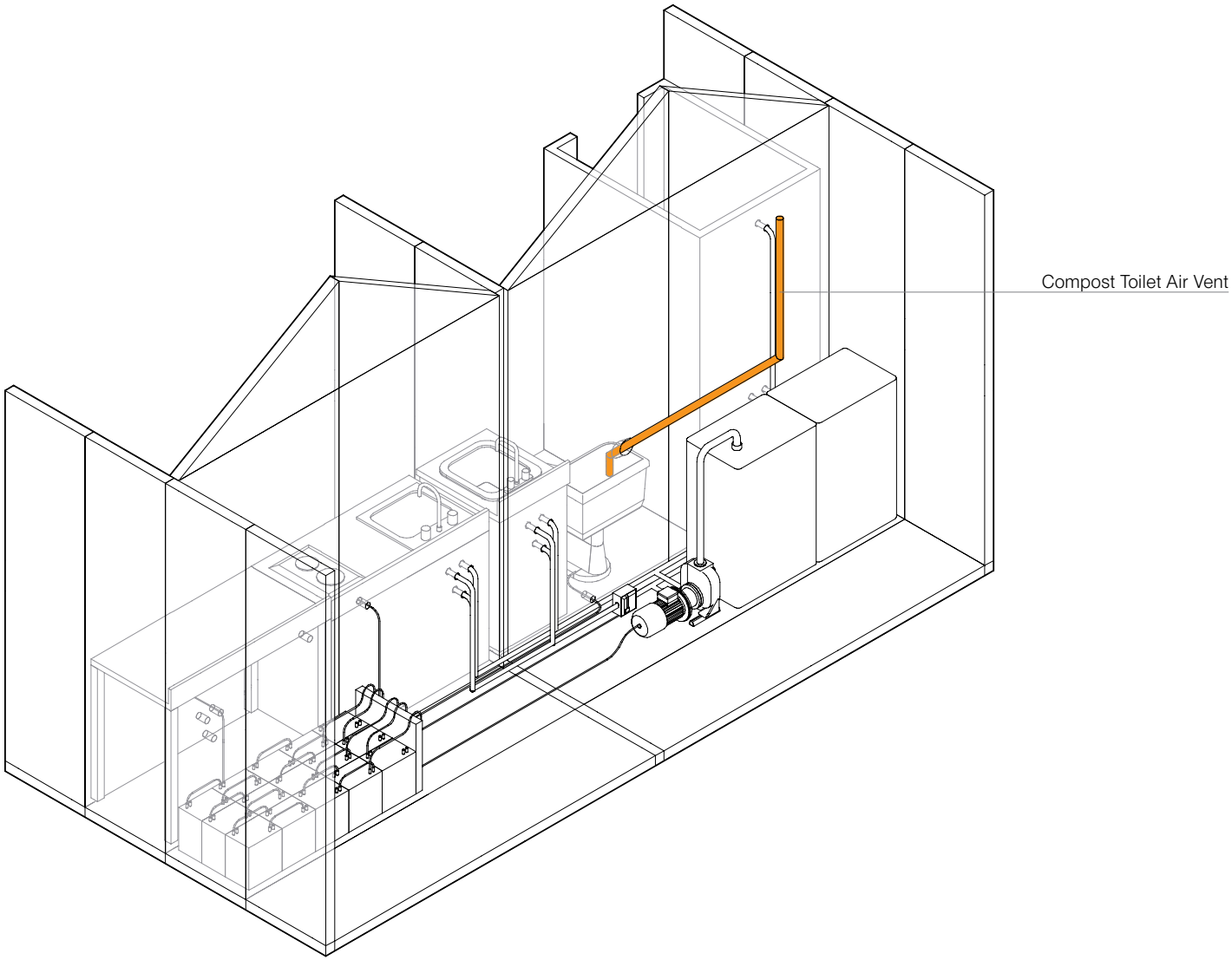
[Figure 55] Tinderbox's fresh water storage and pumping system.



[Figure 56] Tinderbox's grey water output system.



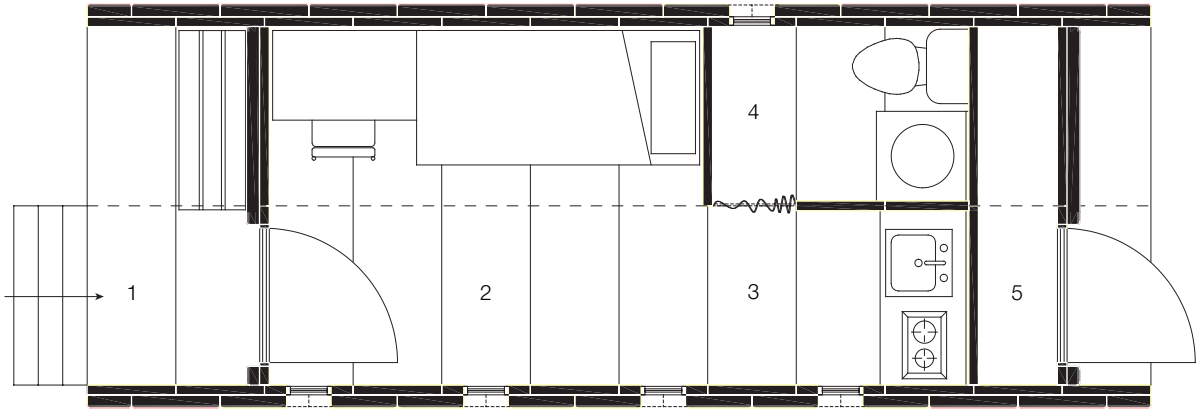
[Figure 57] Tinderbox's municipal water hookup.



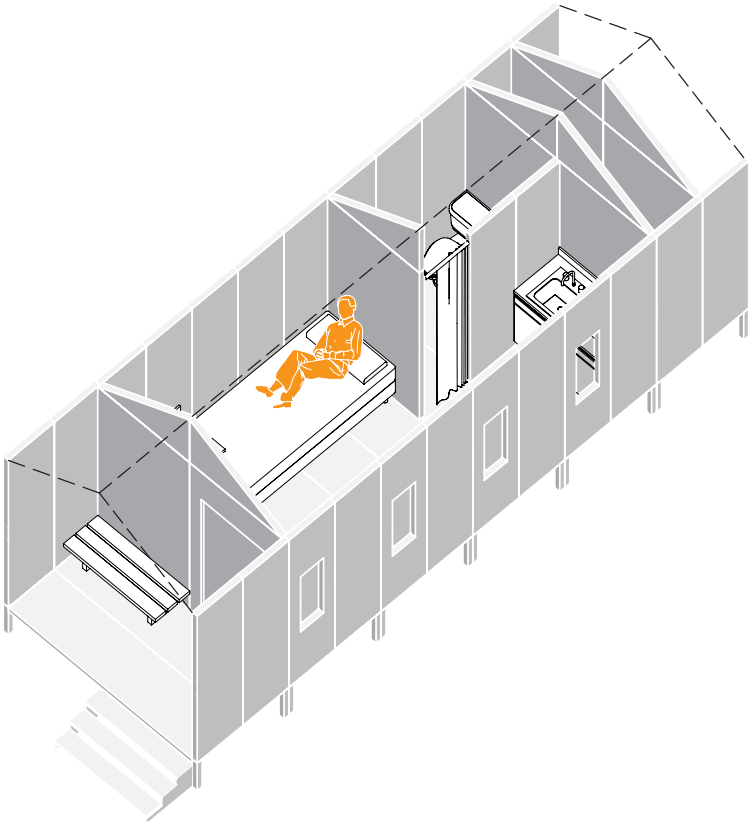
[Figure 58] Tinderbox's composting toilet air vent.

box mini

11.5 m² Home - 1 Person Capacity
1. Porch 2. Living / Sleeping Area 3. Kitchenette 4. Half Bathroom 5. Building Services



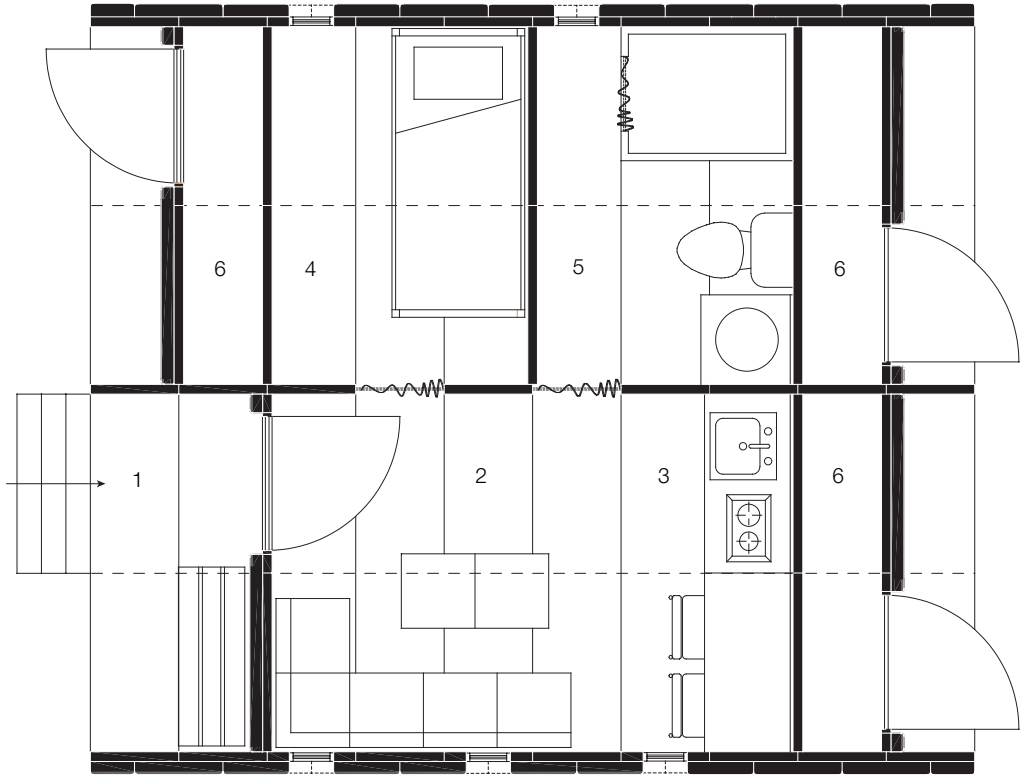
[Figure 59]



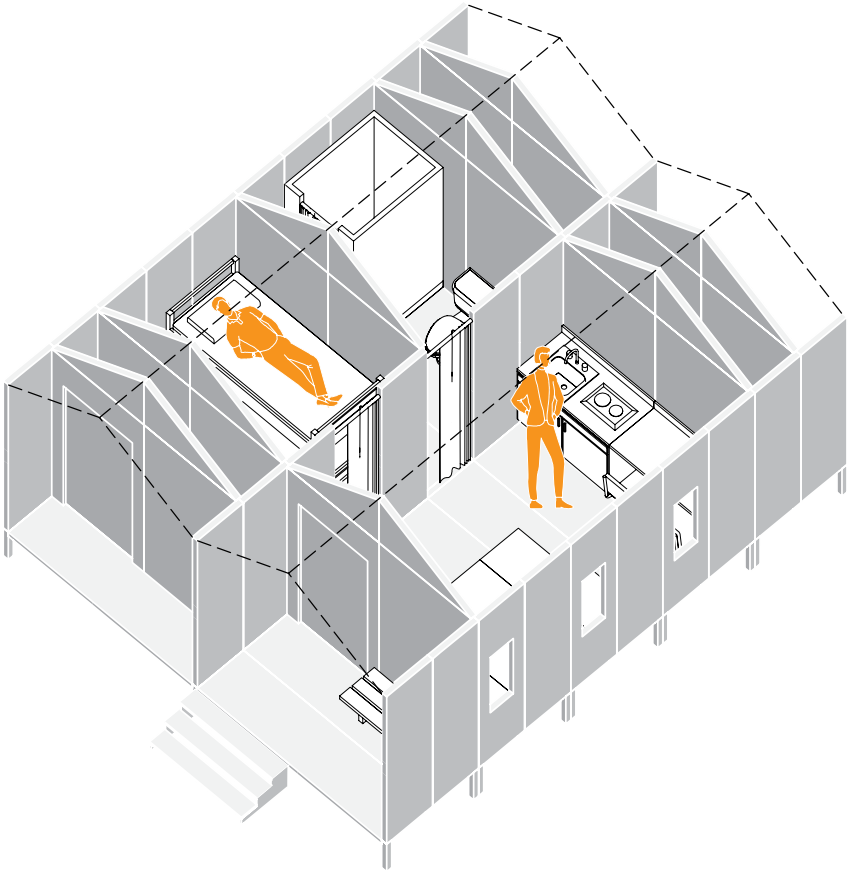
[Figure 60]

box²

17.8 m² Home - 2 Person Capacity
1. Porch 2. Living Area 3. Kitchenette / Dining Area 4. Sleeping Area 5. 3 Piece Bathroom 6. Building Services



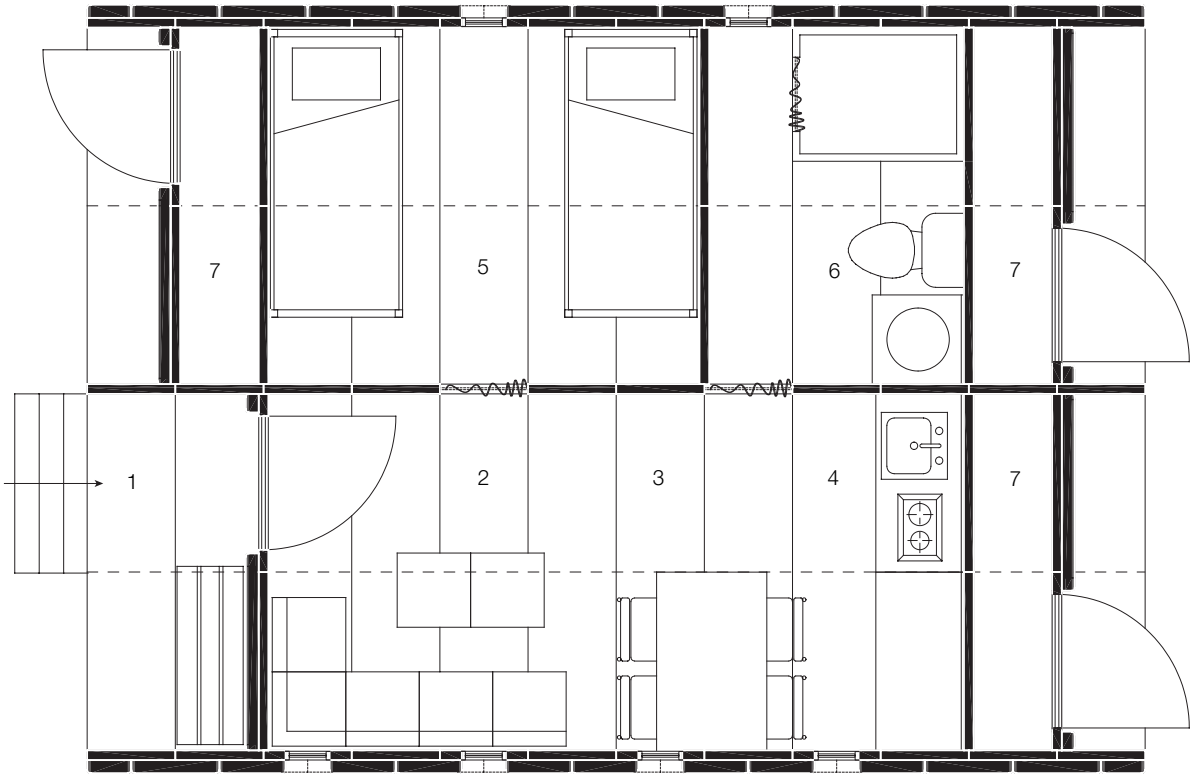
[Figure 61]



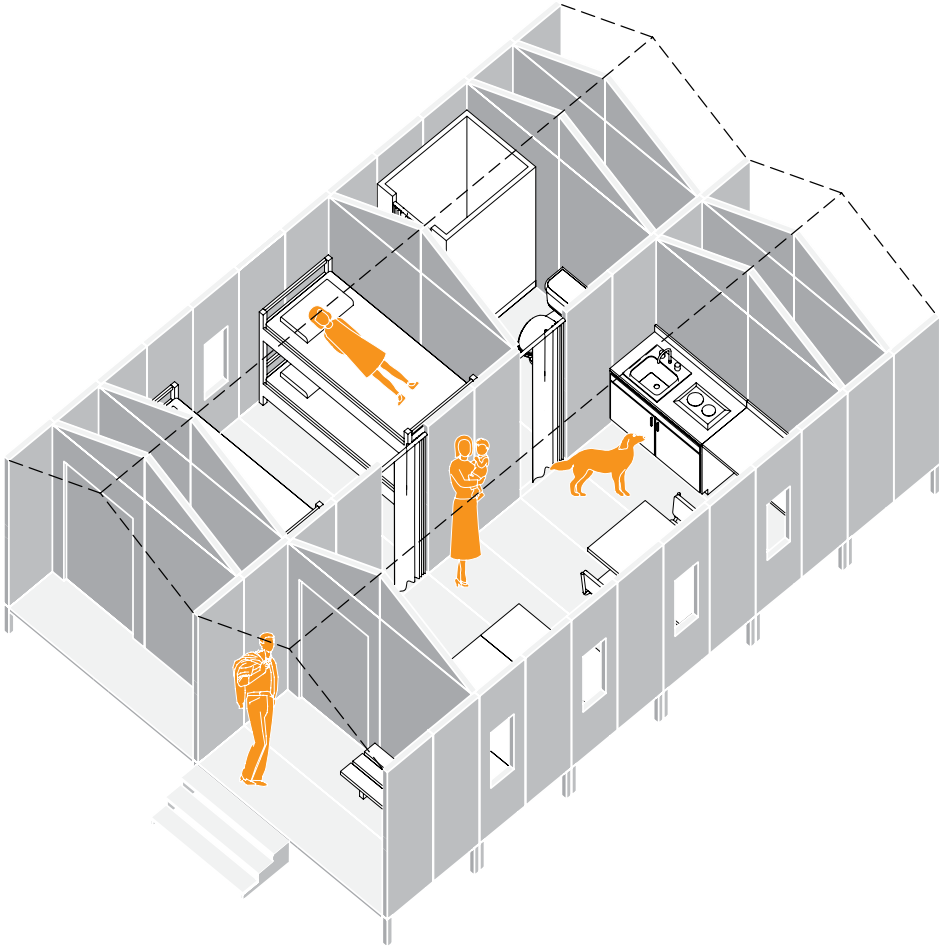
[Figure 62]

box4

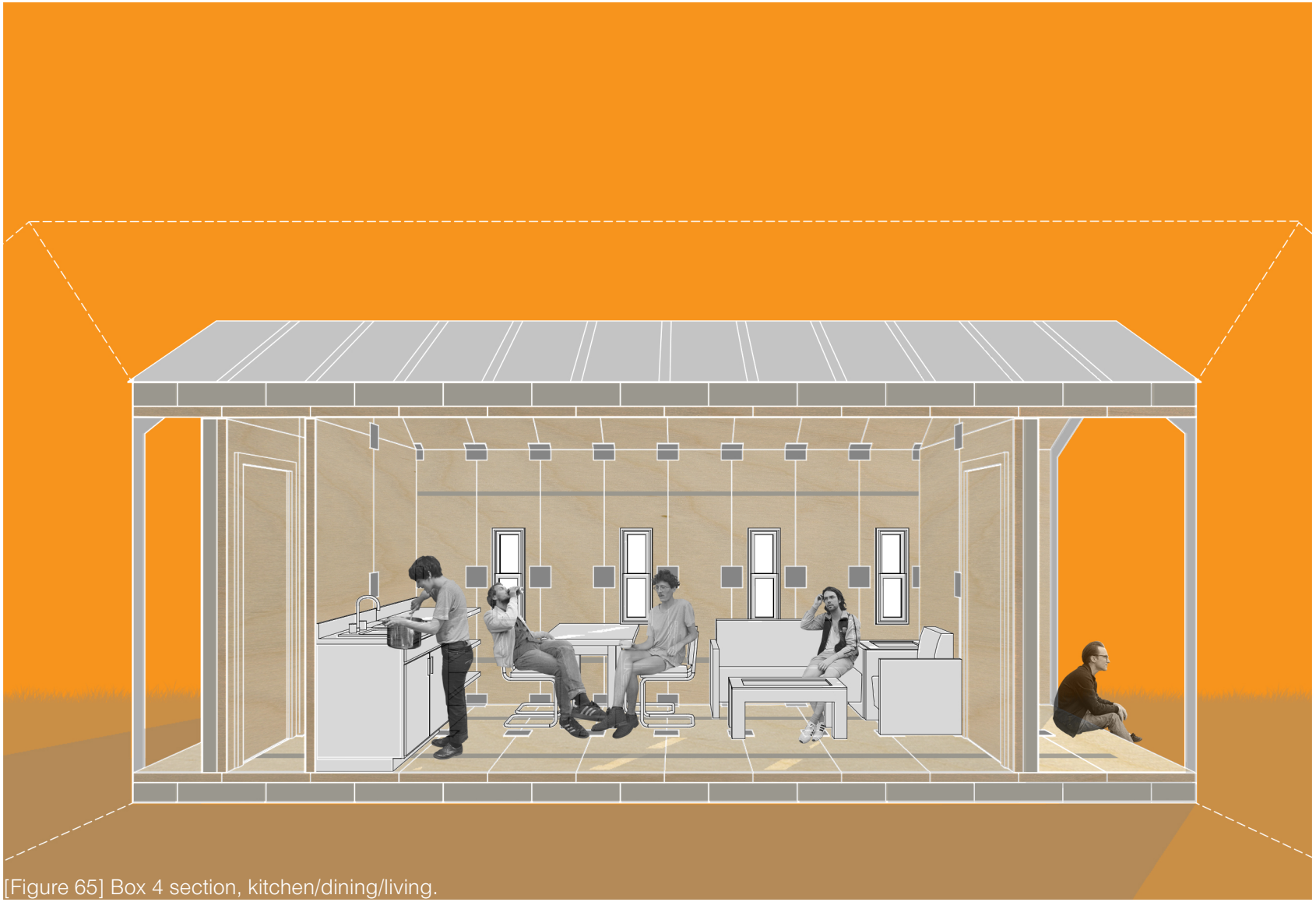
23.8 m² Home - 4 Person Capacity
1. Porch 2. Living Area 3. Dining Area 4. Kitchenette 5. Sleeping Area 6. 3 Piece Bathroom 7. Building Services



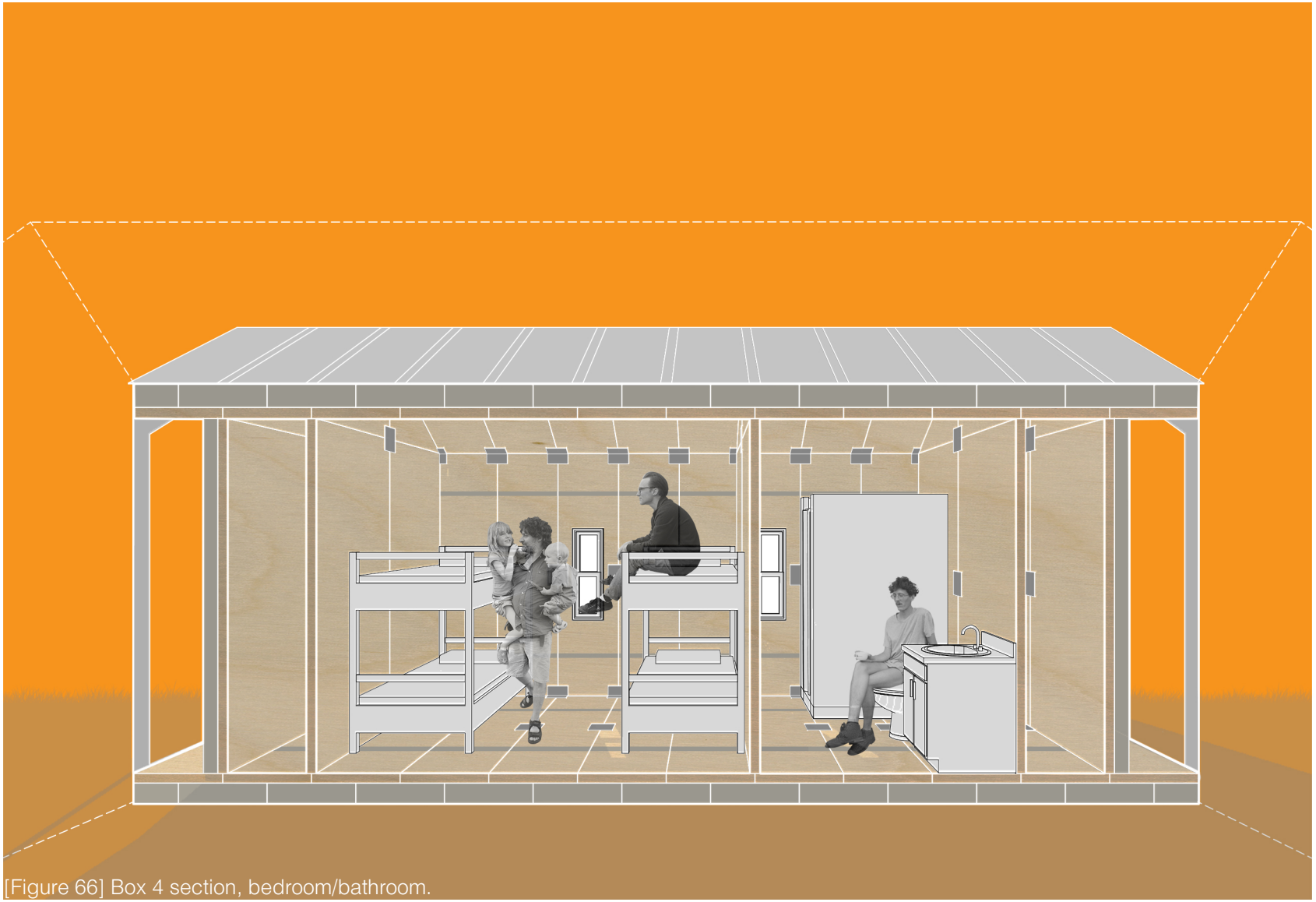
[Figure 63]



[Figure 64]



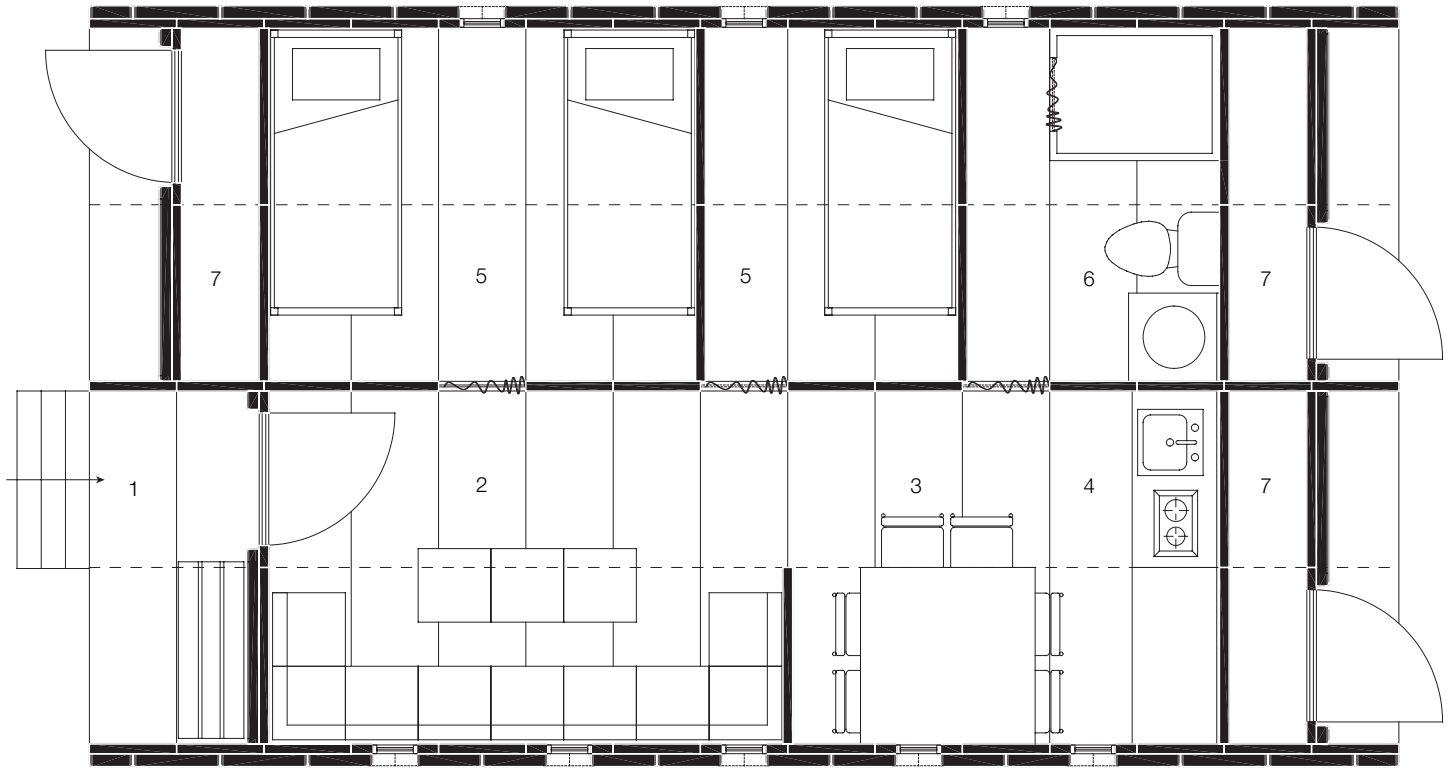
[Figure 65] Box 4 section, kitchen/dining/living.



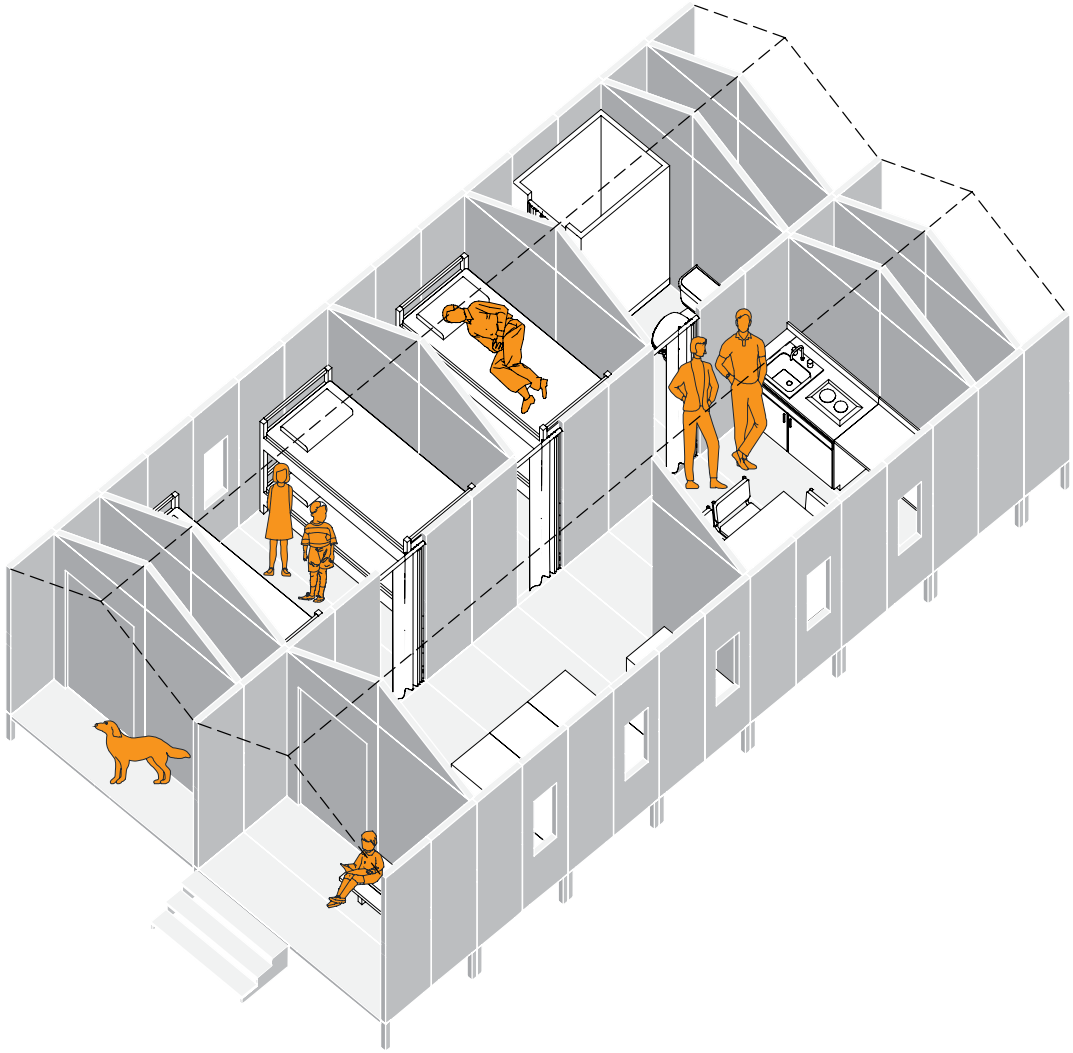
[Figure 66] Box 4 section, bedroom/bathroom.

box6

32.8 m² Home - 6 Person Capacity
1. Porch 2. Living Area 3. Dining Area 4. Kitchenette 5. Sleeping Area 6. 3 Piece Bathroom 7. Building Services



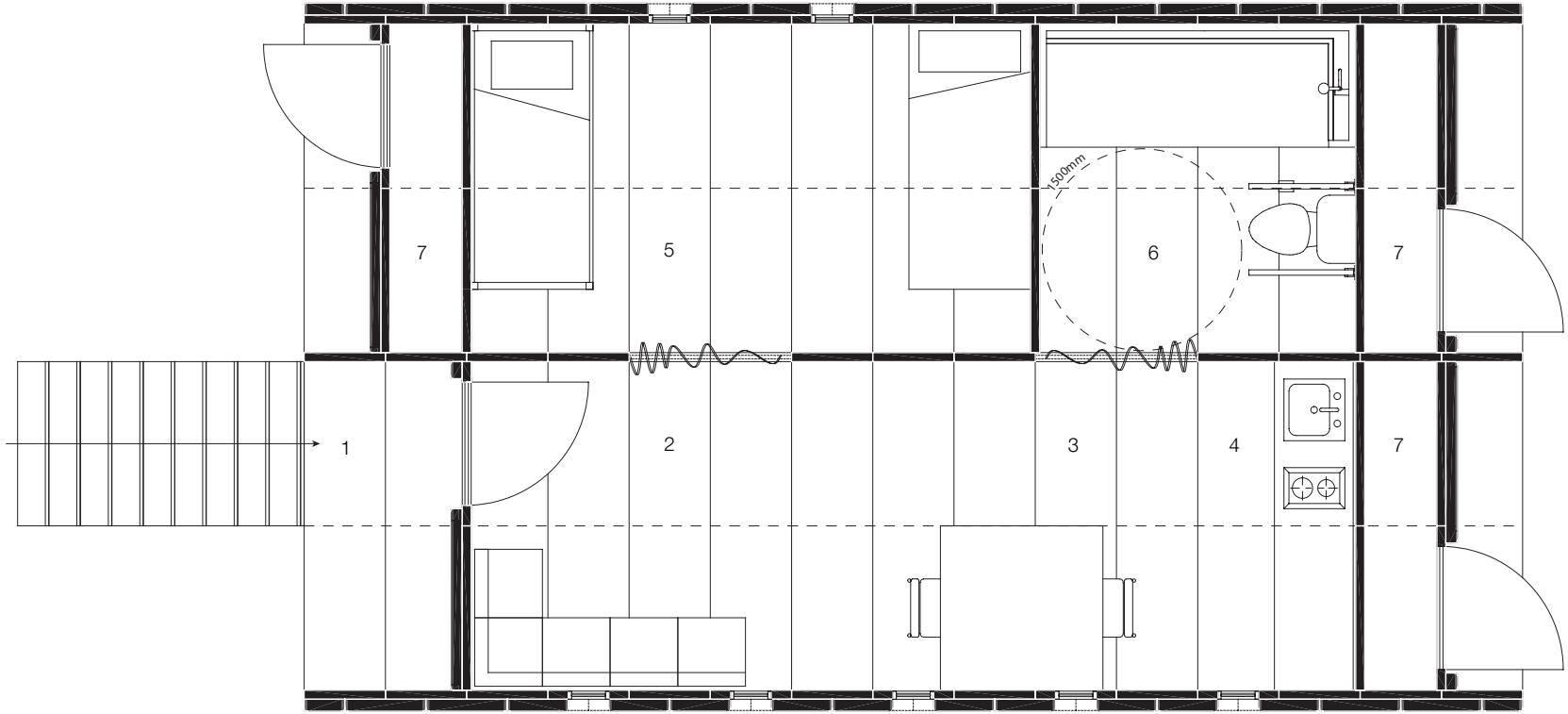
[Figure 67]



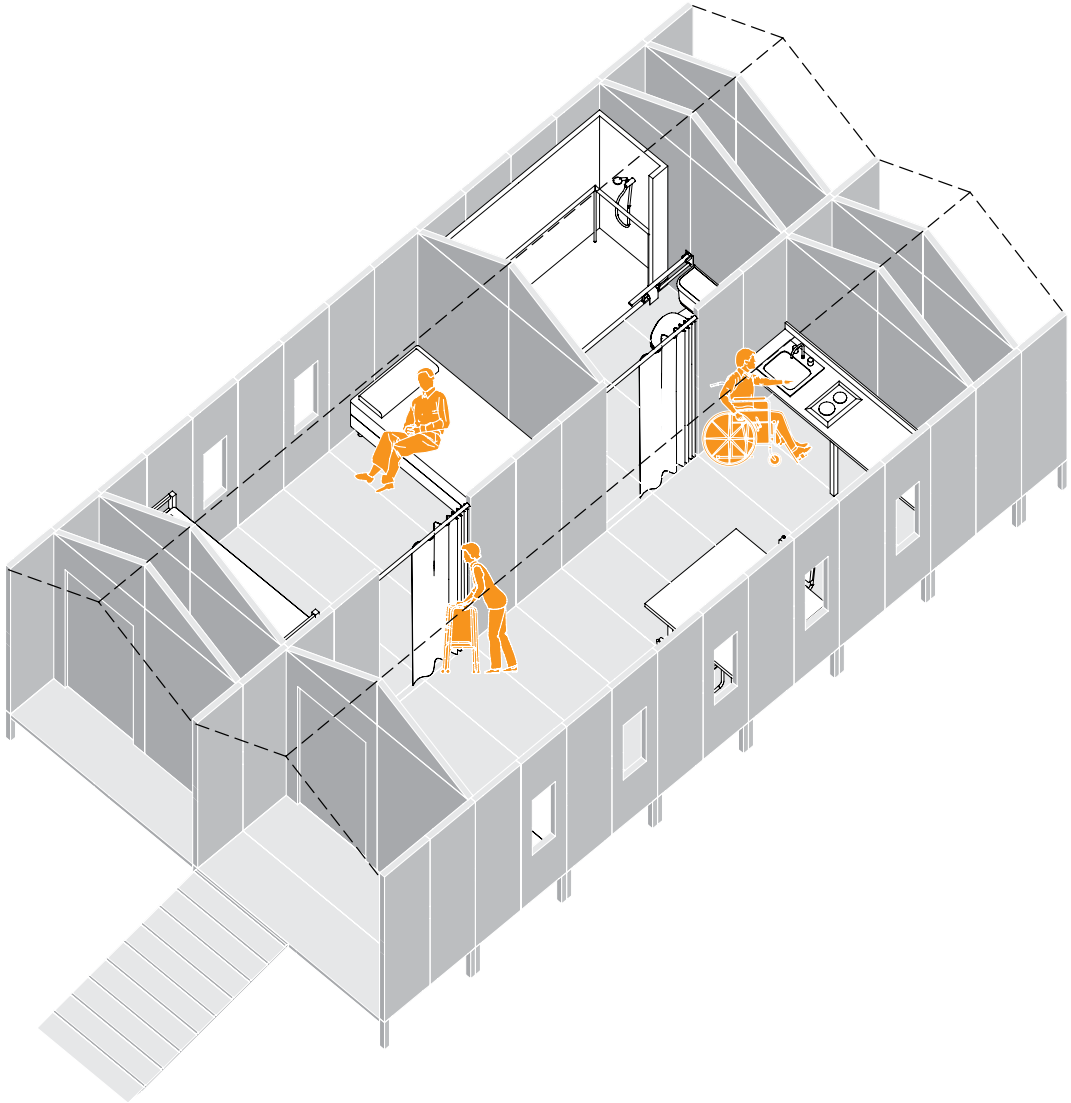
[Figure 68]

box

32.8 m² Accessible Home - 3 Person Capacity
1. Porch 2. Living Area 3. Dining Area 4. Kitchenette 5. Sleeping Area 6. 3 Piece Bathroom 7. Building Services



[Figure 69]



[Figure 70]

[Figure 71] Box 6 interior perspective

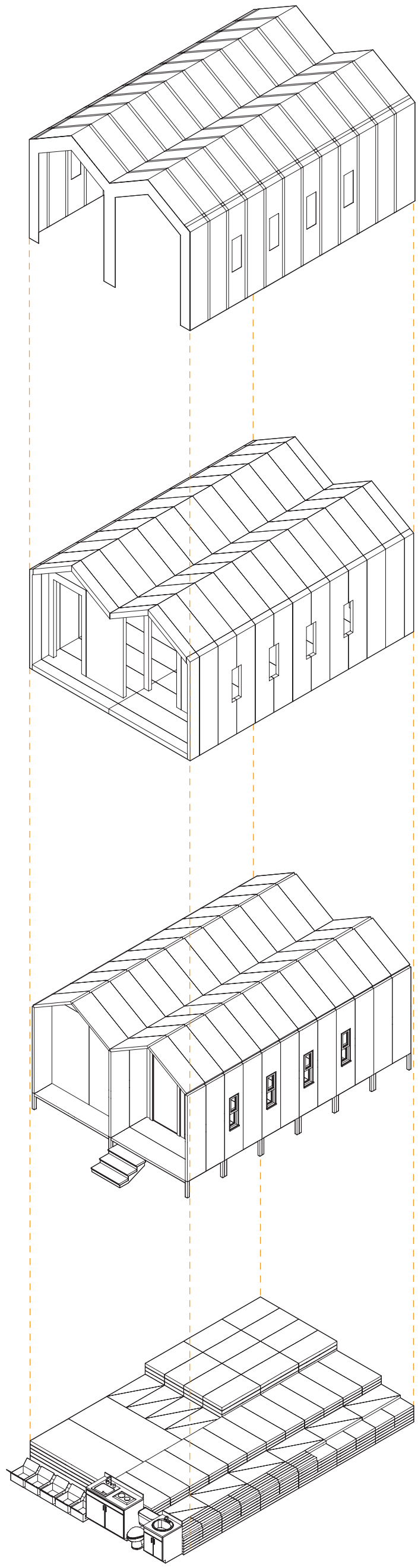
5.8 TRANSPORTATION & ASSEMBLY

Prior to, or just after an evacuation, Tinderbox kits can be transported in bulk using large freight vehicles [Figure #] and be compactly stored in distribution facilities or storage yards. To ensure that Tinderboxes are available, transporting the kits must be efficient and achievable by members of the community. Services may become interrupted during an evacuation, including the availability of commercial freight and delivery vehicles. To reduce the reliance on these services, Tinderbox's components are aptly sized so they can be transported via passenger vehicles, pickup trucks, or hitched trailers [Figure 72]. Community members can receive their Tinderbox kits from their local distribution centre, load their vehicles, and transport the components to their building site where they can begin assembling their shelter [Figure 73]. When the shelters are no longer needed, users can transport their disassembled kits back to the distribution centre, where they will either be moved into storage or deployed to the next community in need.

5.9 COST ANALYSIS

Affordability is an essential factor in determining the practicality of an evacuee shelter. Tinderbox's financial objective is to provide evacuees with adequate amenities and facilities at a mid-range cost of $25,000 - $40,000 for a multi-person residential unit. This cost range facilitates Tinderbox to have sufficient thermal resistance and weatherproofing, appropriate building services, and an acceptably sized living space. Table 4 analyses the cost breakdown for a Box 4 – a Tinderbox designed for residential use by four people.

[Figure 72] The panels for the sectional model are capable of being transported in the rear of a small hatchback car.



[Figure 73] Tinderbox arrives on site as a kit of parts. The kit assembles into three layers: the panels, the insulated panels, and the weather-proofing layer.

ITEM	QUANTITY	UNIT PRICE ($)	TOTAL PRICE ($)
BUILDING CONSTRUCTION			
Panel 1	52	41.32	2,148.64
Panel 2	6	232.32	1,393.92
Panel 3	0	41.32	0
Panel 4	48	28.10	1,348.80
Panel 5	4	132.64	530.56
Panel 6	8	82.64	661.12
Panel 7	1	82.64	82.64
Panel 8	1	82.64	82.64
Panel 9	16	10.66	170.56
Insul 1	10	84.51	845.10
Insul 2	12	84.51	1,014.12
Insul 3	4	42.26	169.04
Insul 4	22	90.88	1,999.36
Insul 5	4	45.44	181.76
Insul 6	44	59.06	2,598.64
Insul 7	8	29.53	236.24
Insul 8	4	84.51	338.04
Insul 9	4	169.02	676.08
Insul 10	8	21.12	168.96
Fabric 1	18	36.38	654.84
Fabric 2	6	36.38	218.28
Fabric 3	6	6.49	38.94
Fabric 4	4	155.94	623.76
Fabric 5	24	72.77	1,746.48
Fabric 6	12	6.49	77.78
Foundation Post	36	3.00	108.00
Joint Post	96	3.00	288.00

Ratchet Strap	102	5.99	610.98
Joint 1	39	5.00	195.00
Joint 2	67	5.00	335.00
Joint 3	65	5.00	325.00
Joint 4	188	5.00	940.00
Joint 5	32	5.00	160.00
Joint 6	32	5.00	160.00
Bolts & Nuts	1,448	0.60	766.70
TOTAL			21,894.98

BUILDING SERVICES			
Kitchenette	1	2,799.99	2,799.99
Toilet	1	1,662.00	1,662.00
Shower	1	309.00	309.00
Vanity	1	162.98	162.98
12V Deep Cycle Batteries	15	139.99	2,099.85
Circuit Breaker	1	178.00	178.00
AC-DC Converter	1	26.24	26.24
Water Tank	2	175.65	351.30
Water Pump	1	176.59	176.59
Water Heater	1	647.00	647.00
TOTAL			8,412.95

TOTAL	30,307.93

[Table 4] A four-person Tinderbox unit would cost approximately $30,307.93, falling within the expected budget of $35,000 for a family sized unit.

5.10 SECTIONAL MODEL

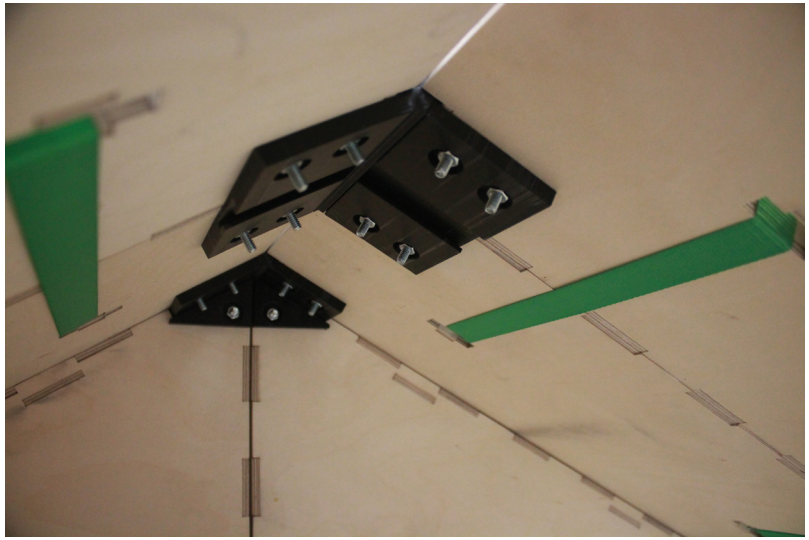
A 1:2 scale sectional model of Tinderbox was constructed and assembled to evaluate the cohesiveness and feasibility of the design [Figures 74-79]. The single-width model, measuring three panels deep, consists of 3D-printed ASA plastic joinery, ratchet straps, insulated plywood panels, and insulated canvas fabric panels. The model measures 4' wide, by 3' deep, by 6' tall.

The model demonstrates how the joinery attaches to the panels, and when used in combination, allows for multiple panel connections. The combination joints allow for uniform connection between wall, floor, ceiling, and perpendicular panels. The model also demonstrates one setback in regards to the panels, which is the inability to have a dividing wall that reaches the height of the roofline. The spatial gap has the potential to cause minor disruptions such as sound travel and reduced privacy.

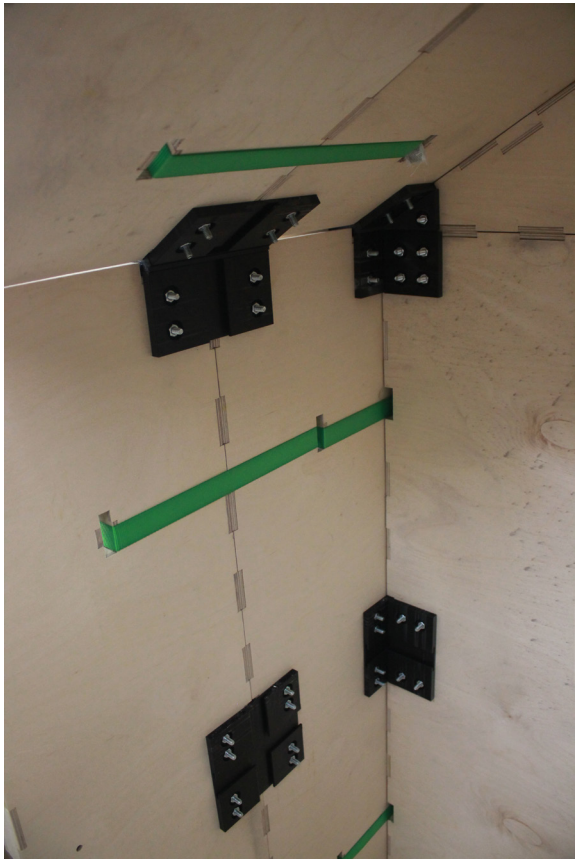
Throughout the development of the model, various difficulties and faults were discovered. One issue that arose was that the foundation design needs improvement. The current foundation design uses small posts that connect to the edges of the floor panels with joinery – however, due to the weight of the structure and the expected load of the inhabitants, a stronger, more robust construction is required. To prevent the floor panels from buckling, the foundation design will require centralized floor posts and cross-bracing.

The assembly process brought forth some challenges that could be an obstacle to the user and hinder the expected two-day assembly time. Since the joints slot into grooves in the panels, all panels must be connected in a specific order. If the assembly does not follow a specific order, there will be missed connections and gaps in the panels and joinery. To avoid this, the users would require a very thorough, illustrated assembly instruction booklet.

[Figures 74 & 75] The 1:2 scale sectional model of Tinderbox includes panels, insulation panels, and joints.



[Figures 76 & 77] Joinery details on the 1:2 scale sectional model.



[Figures 78 & 79] Joinery details on the 1:2 scale sectional model.

5.11 RESPONSE

Tinderbox's design proposal uses non-traditional building methods and materials to facilitate an easy-assembly shelter with sufficient facilities and amenities. Tinderbox's design decisions propagate numerous questions in regards to material choice, aesthetic qualities, and cost.

Why does Tinderbox have three separate layers? Each layer addresses a different factor in the building assembly: structure, insulation, and weatherproofing. These layers remain independent of each other to allow for efficient packing, small vehicle transportation, and to be lifted and carried with minimal strain. These layers use high quality, higher cost materials to ensure that Tinderbox is durable; able to withstand the rigors of weathering and daily use.

Why does Tinderbox adopt the gable roof shape, despite the increased material usage and higher cost? The gable roof gives the shelters an aesthetic quality that existing temporary structures lack. The pitched shape mimics that of a traditional home, as opposed to a trailer, which may bring users comfort. Evacuees may spend up to a year in transitional housing; it is important to design a shelter that makes them feel at home.

Why does Tinderbox opt against solar power harnessing for its electricity needs? Photovoltaic panels are commonly used to power tiny homes, recreational vehicles, and existing emergency shelters. Tinderbox does not use photovoltaic panels because it uses light, flexible materials on the exterior membrane. Photovoltaic panels would create a heavy load along the roof-line, which has the potential to damage the insulative and weatherproofing layers. Integrating photovoltaic panels into the design also increases the cost and complexity, challenging Tinderbox's objective of being inexpensive and easy assembly.

Part 6

COMMUNITY PLANNING

“Thoughtful, integrative, and transdisciplinary planning and intervention could strengthen a community and facilitate recovery following disasters, whereas separate and nonintersecting efforts to design transitional communities and to restore social and behavioral health following disasters could exacerbate problems and illness trajectories in the short and long term.” – Arnold R. Spokane et al., Housing Arrays Following Disasters: Social Vulnerability Considerations in Designing Transitional Communities [75]

6.1 INTRODUCTION

This section discusses how Tinderbox can be implemented into community planning for interim disaster housing. Through an investigation of Tinderbox's modularity, specialized community structures for services such as medical care and child care are proposed. To understand Tinderbox at a community scale, a larger study site was established as an analogue to determine if Tinderbox is feasible at larger community scale interventions and programs. This larger site considers key factors such as material accessibility and transportation routes. Within this study site, small and large scale interim housing sites are proposed to explore how Tinderbox could be implemented into a community. These interim sites will analyze and explore methods of arrangement that facilitate accessibility, efficiency, and comfort.

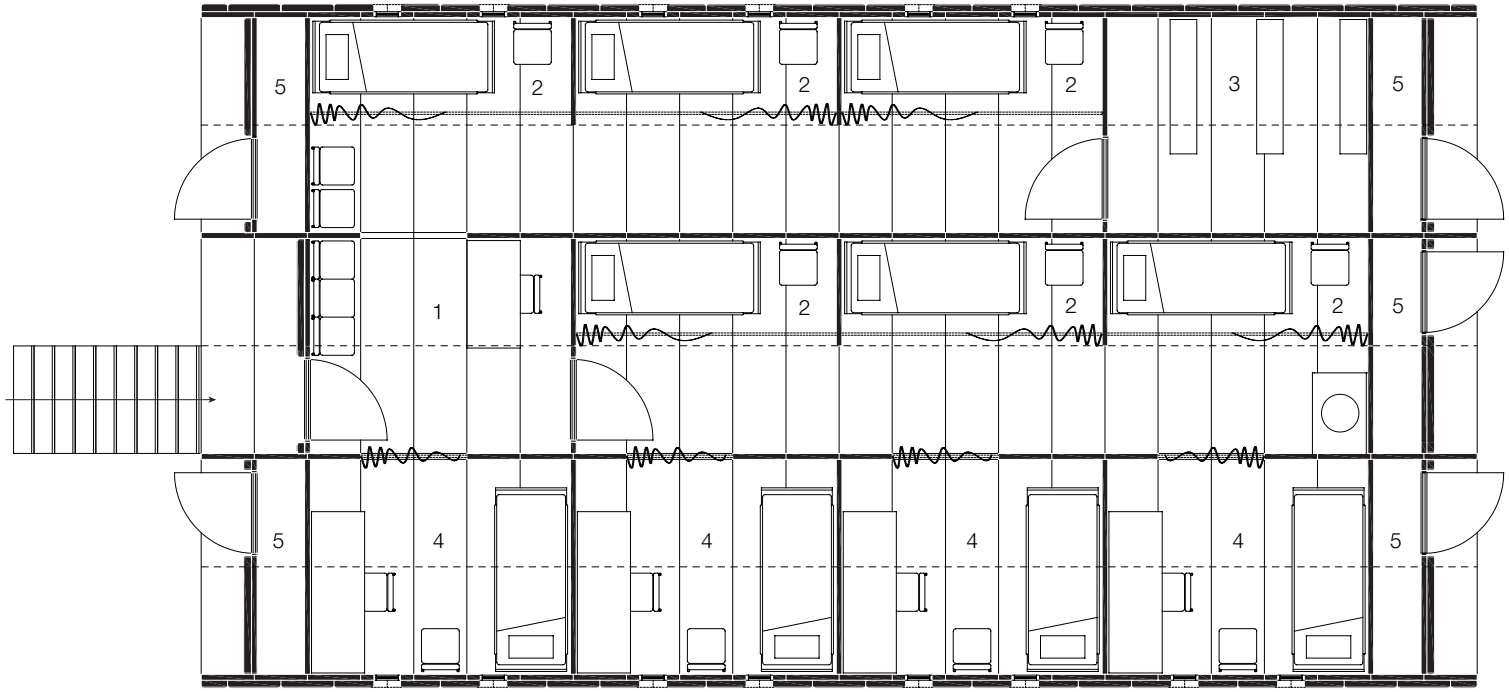
Determining interim housing sites prior to disaster can be challenging, as there is no way to predict the path of a wildfire or the level of destruction. After the Slave Lake fire of 2011, the town prepared a document that reflects on the recovery process and recommendations for future events. In preparing for post-disaster transition housing, they suggest that communities at risk of a fire should, "Identify possible sites for interim housing in the emergency plan, including those slated for future development."[76] Since the evacuation sites are also at risk for destruction, communities should identify multiple potential sites, both locally and remotely, for accommodating the displaced population.

6.2 DESIGNING FOR THE COMMUNITY

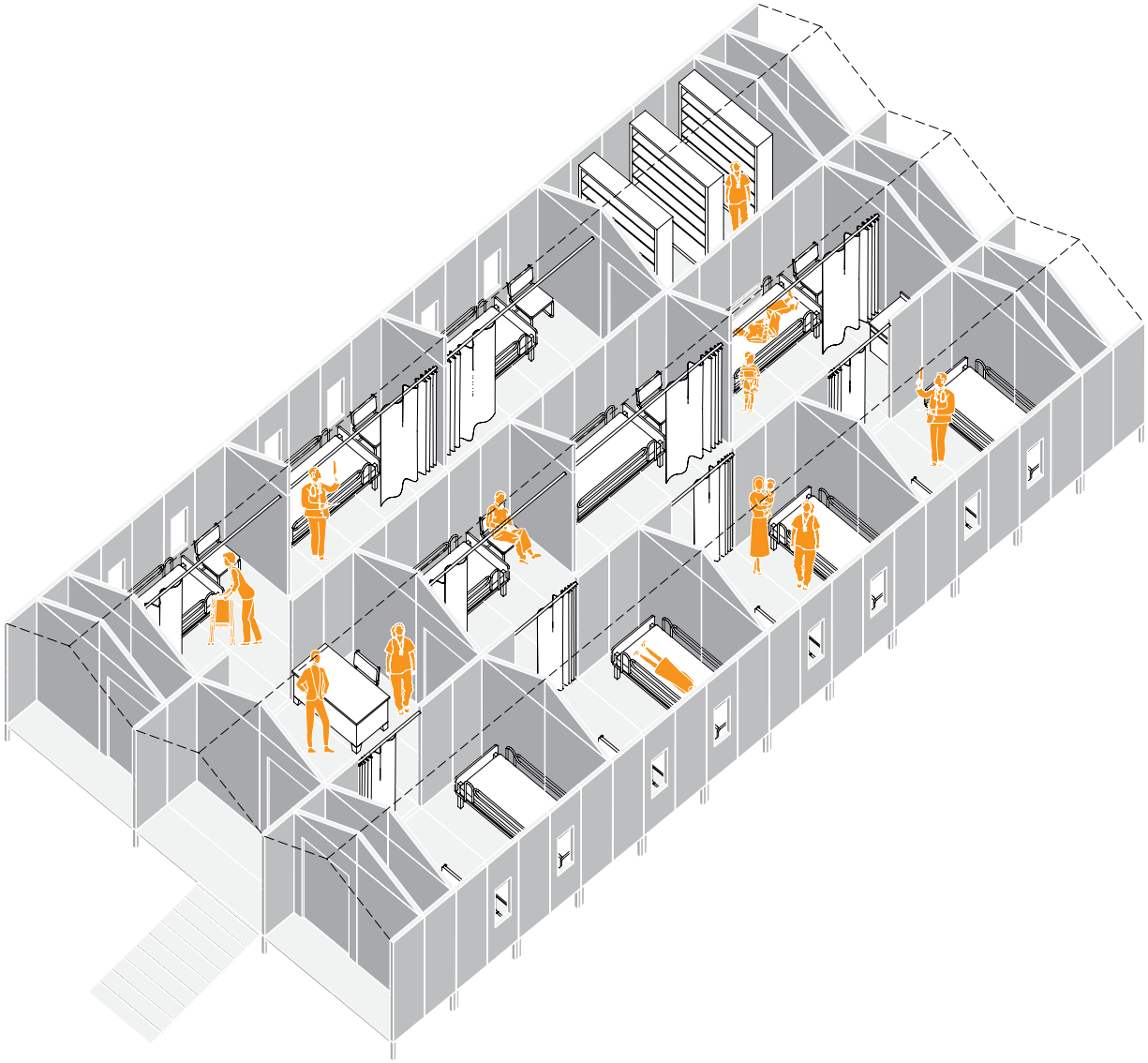
In addition to providing wildfire-stricken communities with temporary residential shelters, Tinderbox can also provide larger structures for municipal services. The kits provide an insulated shell with optional room divisions, allowing communities to configure the shelter to meet their programmatic needs. Figures 74-81 illustrate how Tinderbox's modular components can be arranged to create a medical facility, child care facility, donation distribution centre, and municipal office. Similar to the residential units, these community units have the capacity to provide users with electricity, bathrooms, and kitchenettes. These larger structures face more frequent and rigorous use and will require larger inputs of electricity and water. Respectively, these arrangements require more space dedicated to building services and are significantly more expensive to operate.

box⊕

90 m² infirmary - 10 Examination Rooms
1. Waiting room / Reception 2. Examination Bed 3. Supplies Closet 4. Private Examination Room 5. Building Services



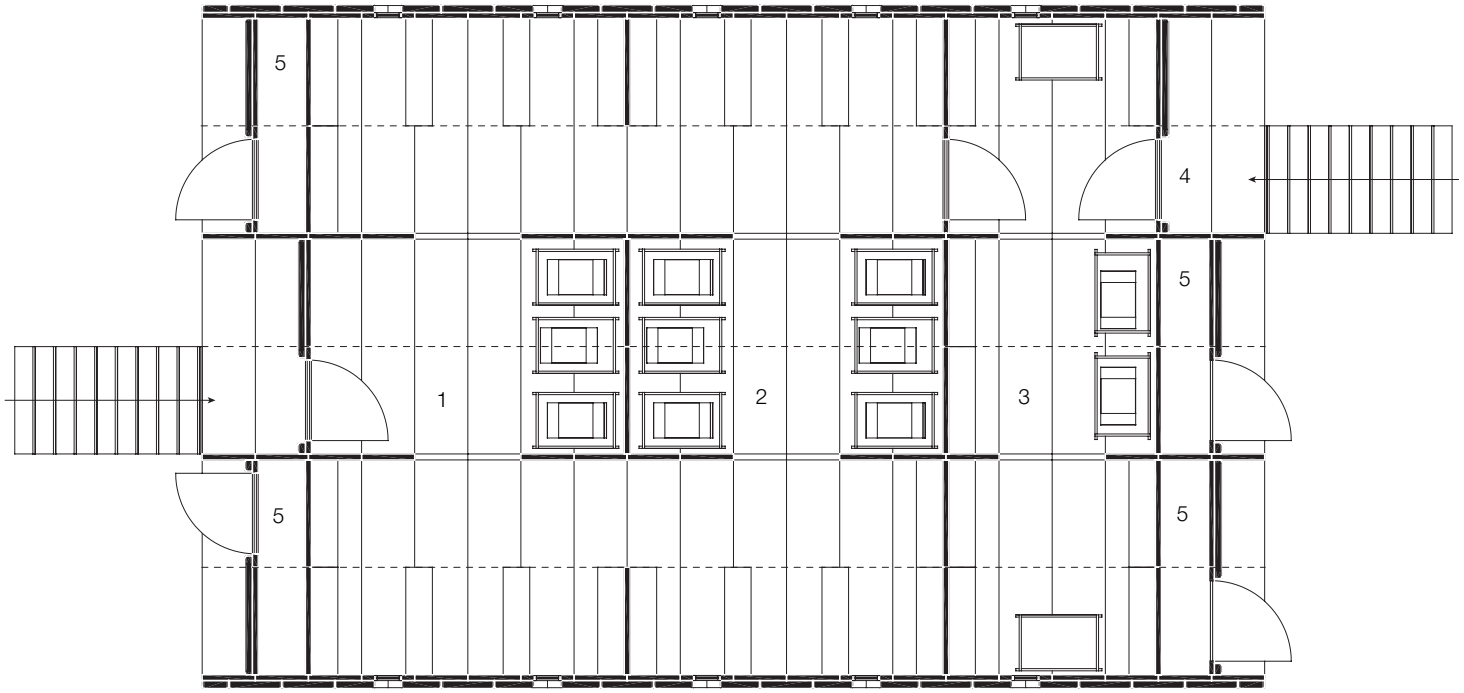
[Figure 80]



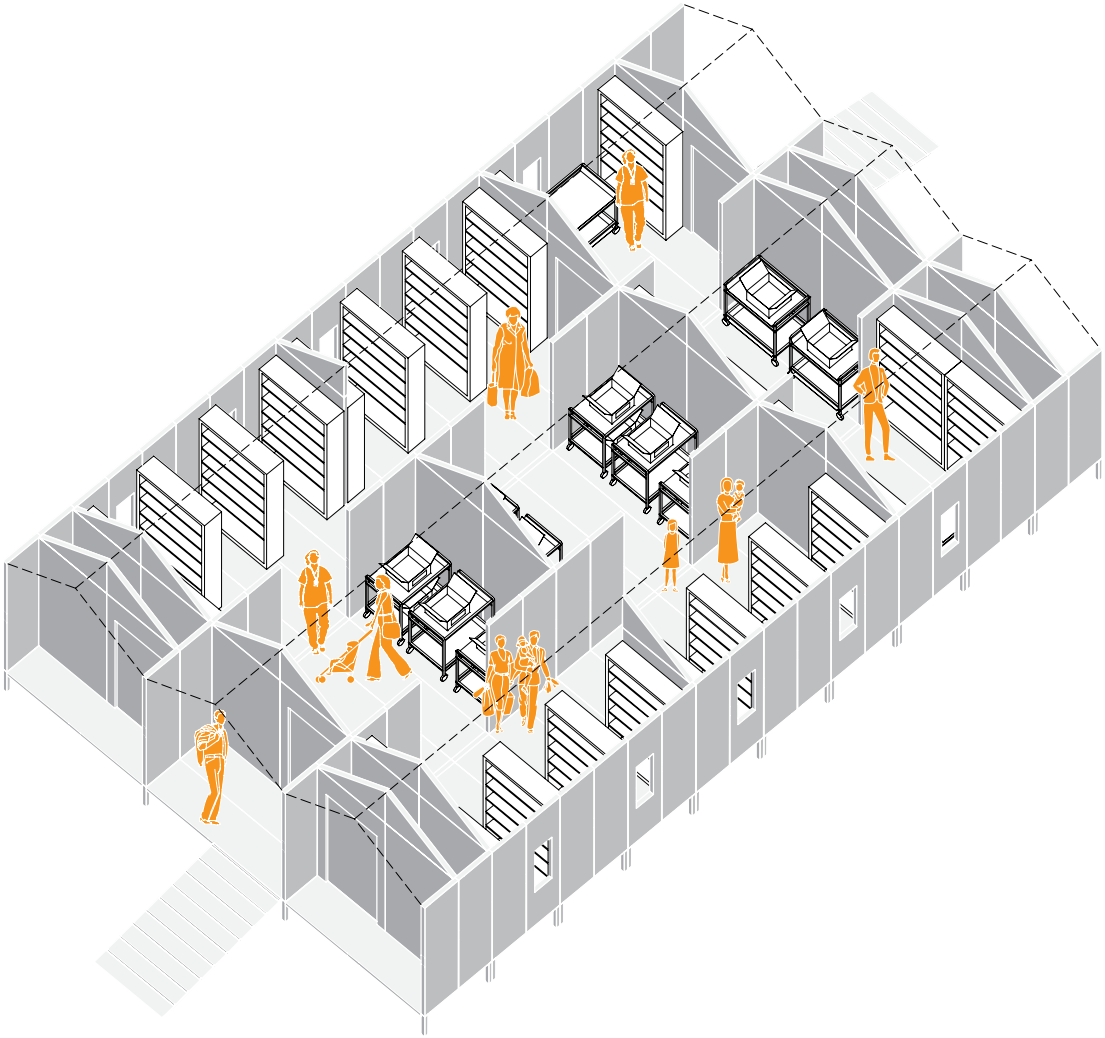
[Figure 81]

box

72 m² Donation and Grocery Distribution Facility
1. Entry 2. Public Donation Access 3. Sorting and Storage 4. Loading Dock 5. Building Services



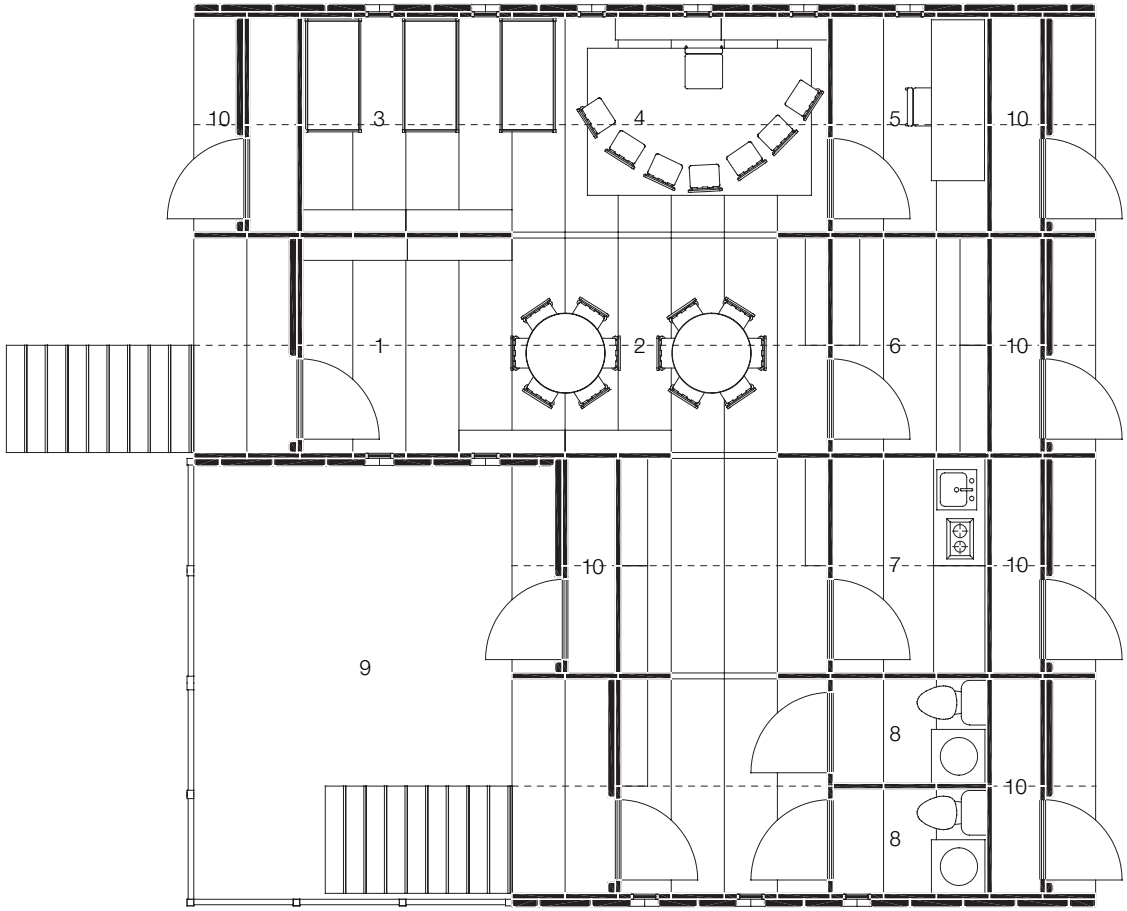
[Figure 82]



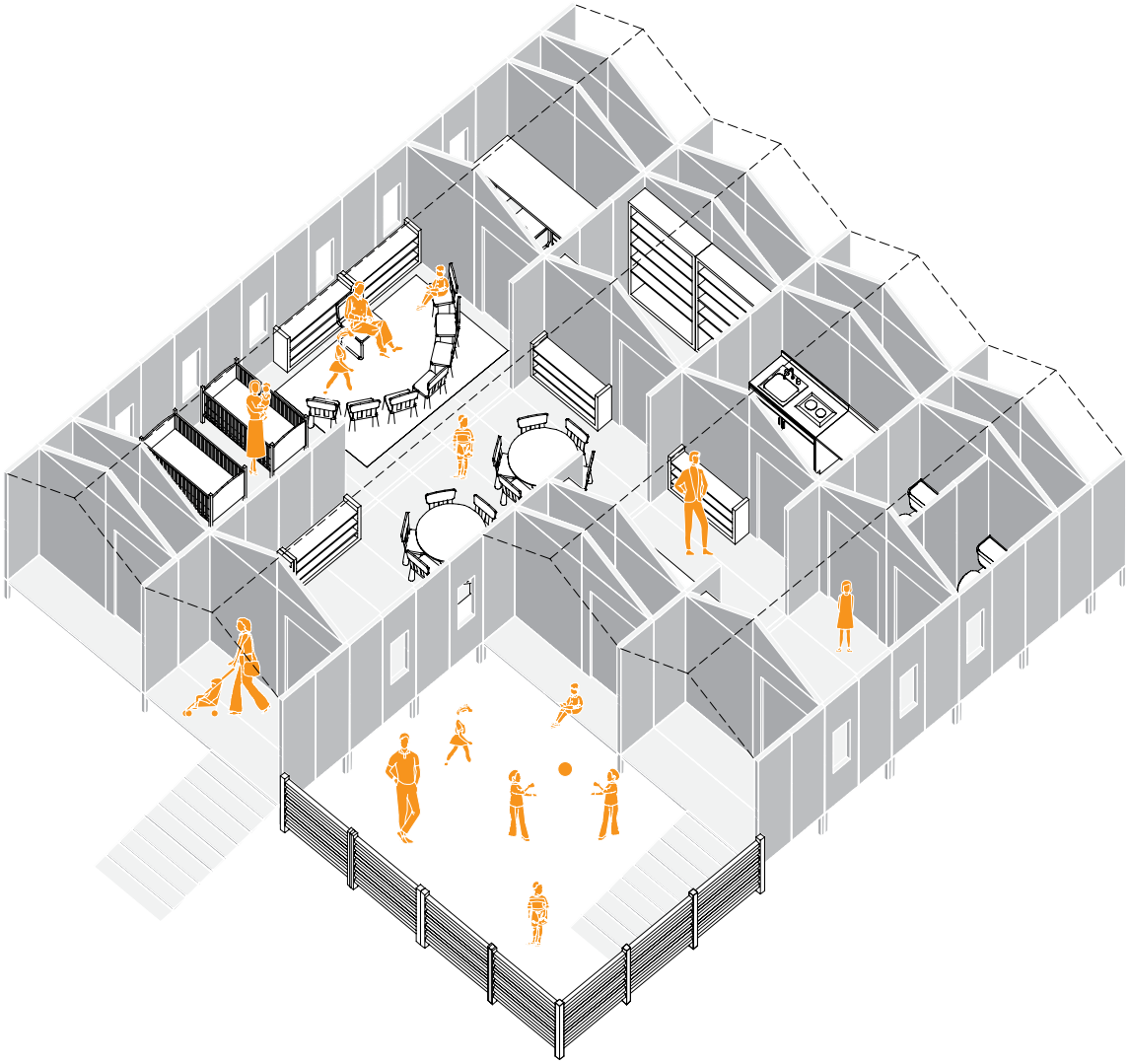
[Figure 83]

box jr.

58.5 m² Child Care Facility
1. Foyer 2. Desks 3. Nursery 4. Carpet 5. Office 6. Storage 7. Kitchen 8. Bathroom 9. Playground 10. Building Services



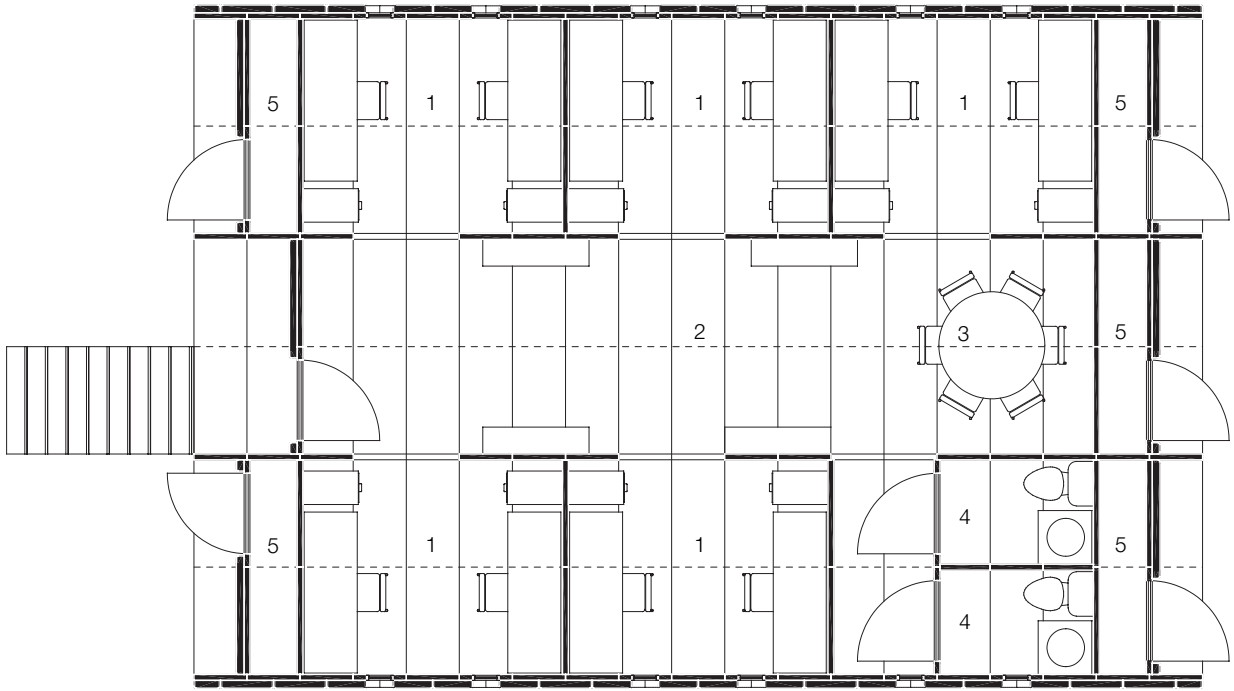
[Figure 84]



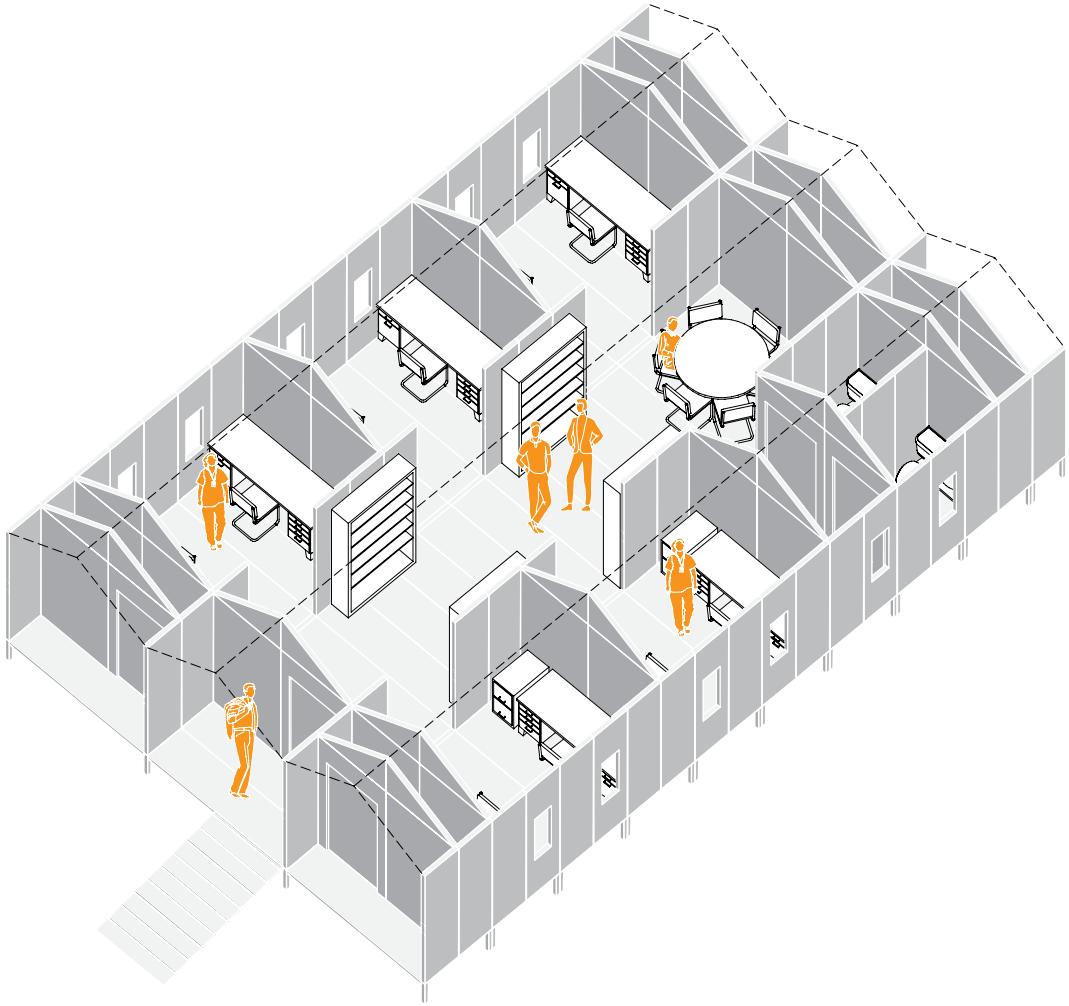
[Figure 85]

box office

65.0 m² Municipal Office
1. Work Space 2. File Storage 3. Meeting Room 4. Bathroom 5. Building Services



[Figure 86]



[Figure 87]

6.3 IDENTIFYING SITES

Wildfires occur across the entire span of Canada, affecting various regions, populations, and demographics. When configuring interim housing sites, the infrastructure, material availability, and population densities must be considered. To establish a baseline for community planning, a 750km diameter study site has been determined [Figure 82]. The site stretches across northeastern Alberta and northwestern Saskatchewan – an area that has faced some of the largest wildfires evacuations, including the 2011 Slake Lake fire and the 2016 Fort McMurray fire [Figure 83]. The site includes the major communities of Edmonton, Slave Lake, and Fort McMurray, as well as dozens of smaller townships.

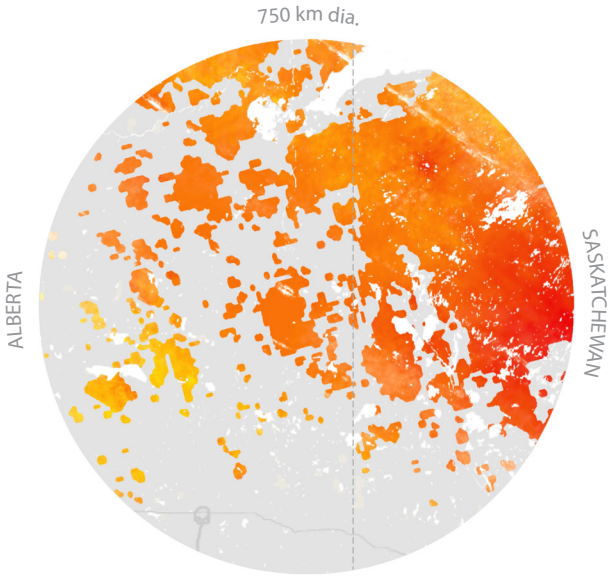
The study site analyzes the existing conditions of wildfire-prone communities. Many northern communities have singular transportation routes [Figure 84]. With minimal access, deploying Tinderbox kits to these locations becomes difficult and costly. To reduce delay, Tinderbox kits are constructed and stored at facilities across the study site. The kits are fabricated at local building material centres such as Home Depot, Rona, or Lowes; businesses with ample building supplies, the capacity for large-scale construction, and storage grounds. Within the study site, there are 48 building material facilities, including locations in the remote northern communities [Figure 85].

6.4 COMMUNITY ARRANGEMENTS

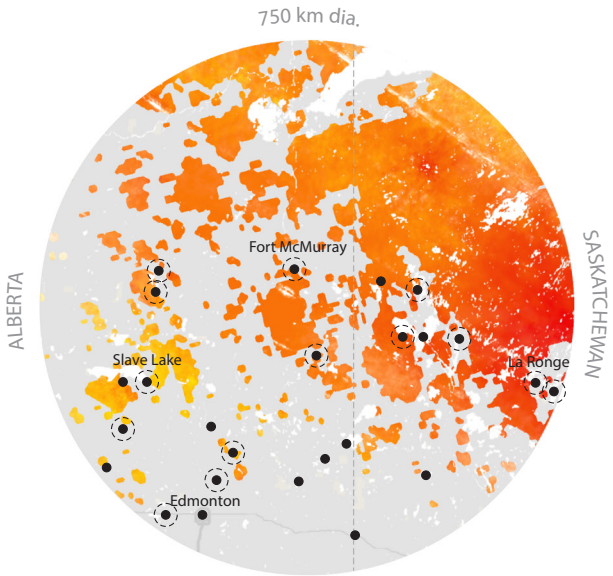
Communities that are vulnerable to wildfires should prepare accommodation strategies for population displacement. This planning should include appropriate sites to facilitate interim housing such as Tinderbox. These sites, which may be used during an evacuation or following an evacuation, must be capable of providing sufficient amenities and facilities to the evacuees. This includes adequate road access, electricity and water hookup, and close proximity to a Tinderbox distribution centre.

When a community suffers small-scale damage from a wildfire, community-sized interim housing sites may not be necessary. Rather, Tinderboxes can be placed on, or just outside of damaged residential properties [Figure 86]. With a small, non-destructive footprint, the shelters can be assembled on yards or driveways, while allowing construction of the original home [Figure 87 & 88]. This configuration allows the residents to remain on their property, which may reduce the consequential stress of relocation. Residents also have the opportunity to oversee the construction and repairs on their home, which may provide comfort and peace of mind.

When a wildfire destroys a large percentage of a community, a communal interim housing site may be necessary. This site would need to have the capacity to house and service hundreds of evacuees. In addition to having ample space, these sites should also have abundant municipal services and community resources. Figures 89-92 illustrate a community planning proposal for MacDonald Island in Fort McMurray, demonstrating how Tinderboxes can be arranged to meet the needs of a large displaced population. MacDonald Island is a 291-acre site that consists of a golf course, a municipal library, a community leisure centre, a sports complex, and paved parking for over 400 cars. The large open parking lot provides 13 acres of flat, hard surface where the transitional housing and other temporary structures can be assembled. The planning proposal accommodates 190 many residential Tinderbox units – enough to provide housing for approximately 760 evacuees. Additionally, the site includes a specific area for community structures, including two medical centres, two child care centres, two donation distribution centres, and two municipal buildings. The plan includes designated areas for parking, pedestrian pathways, and community gathering points.

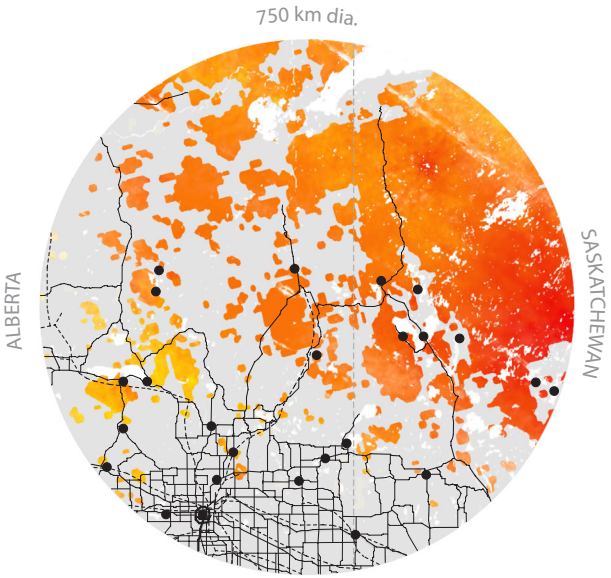


Burn Perimeter 1986-2015

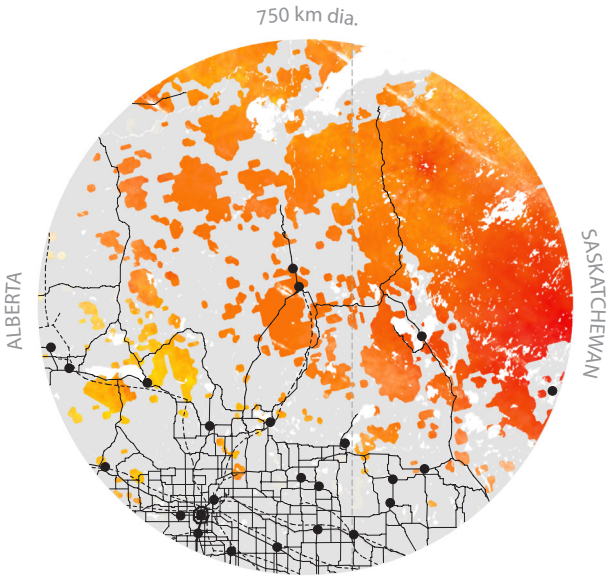


• Population Densities ◌ Previously Evacuated

[Figure 88 & 89] The 750km study site encompasses an area with a history of wildfires, notably, the 2011 Slave Lake fire and 2016 Fort McMurray fire.

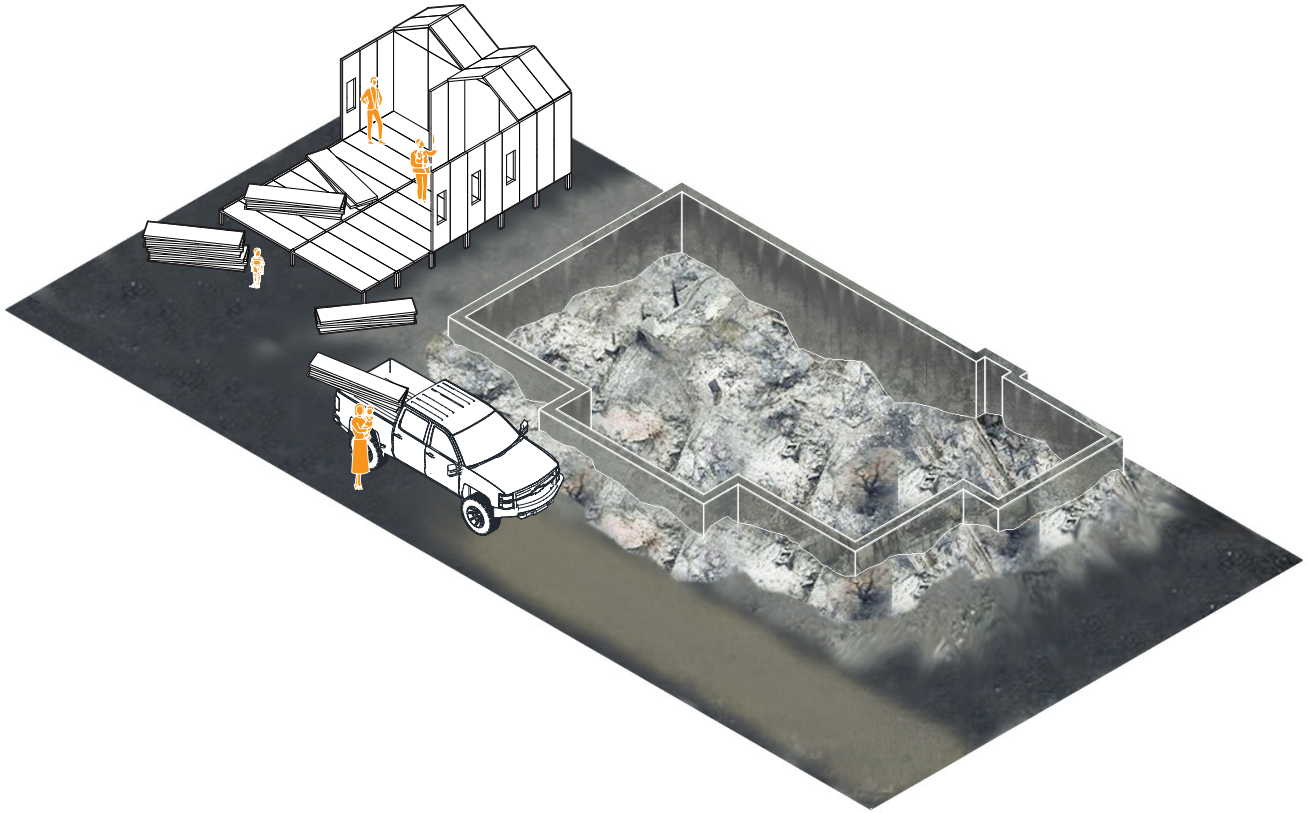


Major Roadways Railways

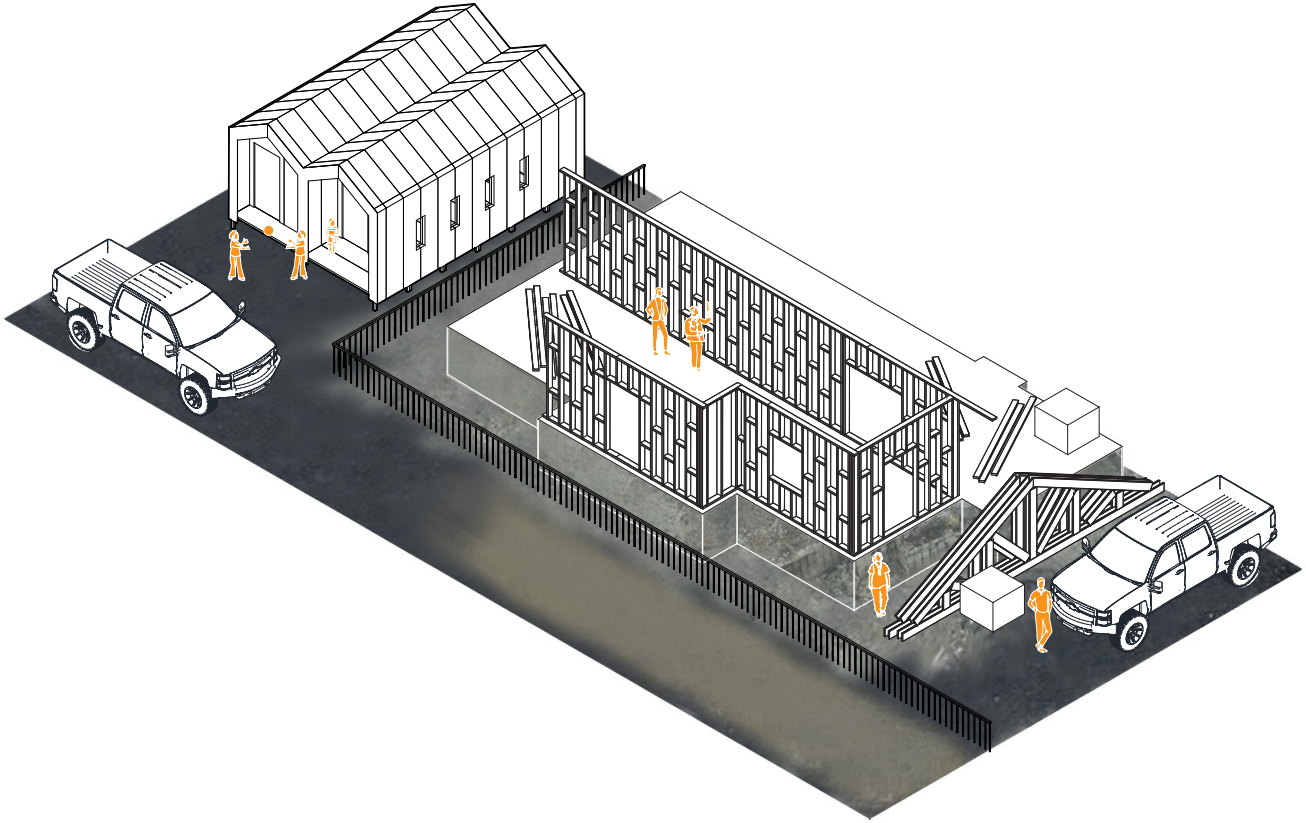


Building Material Facilities

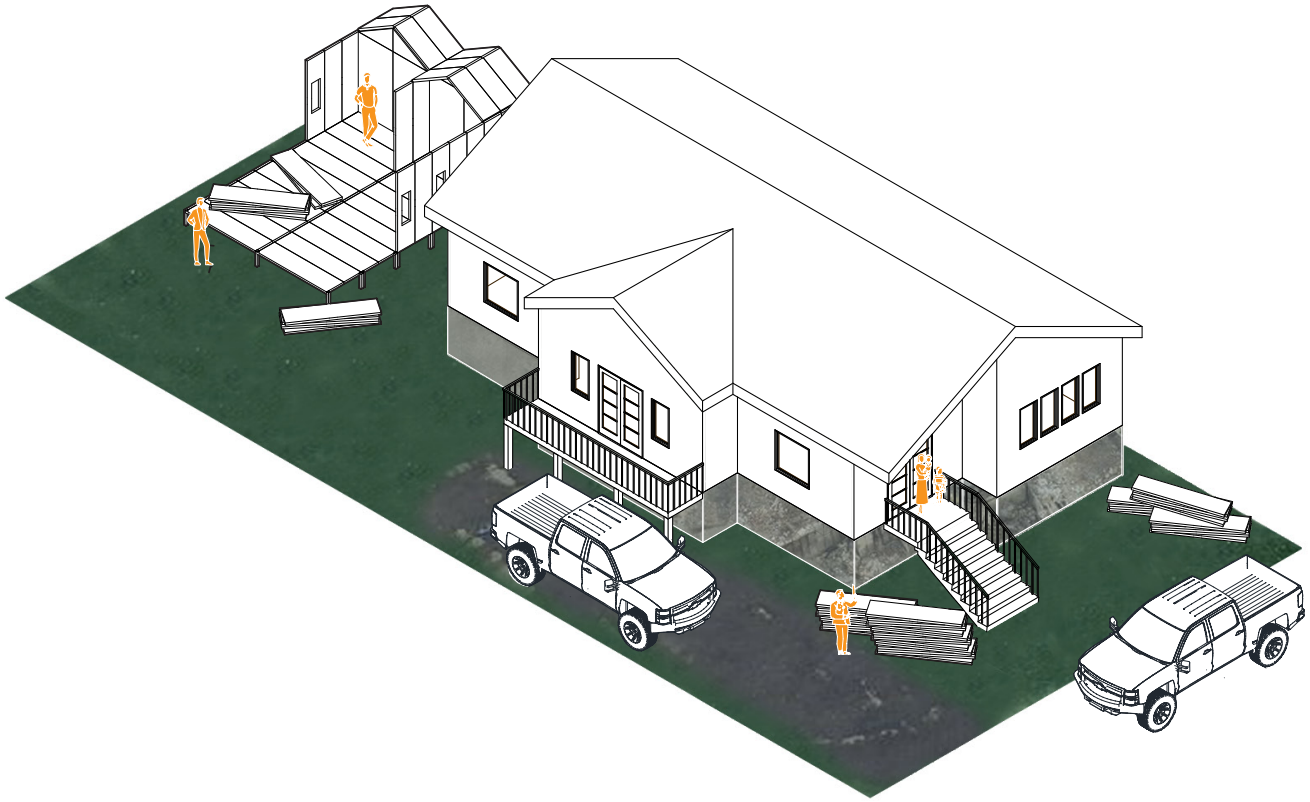
[Figure 90 & 91] Communities in the northern region of the study site are remote and have few access points. Local building material facilities have the capacity to produce and store Tinderboxes, reducing reliance on delivery systems.



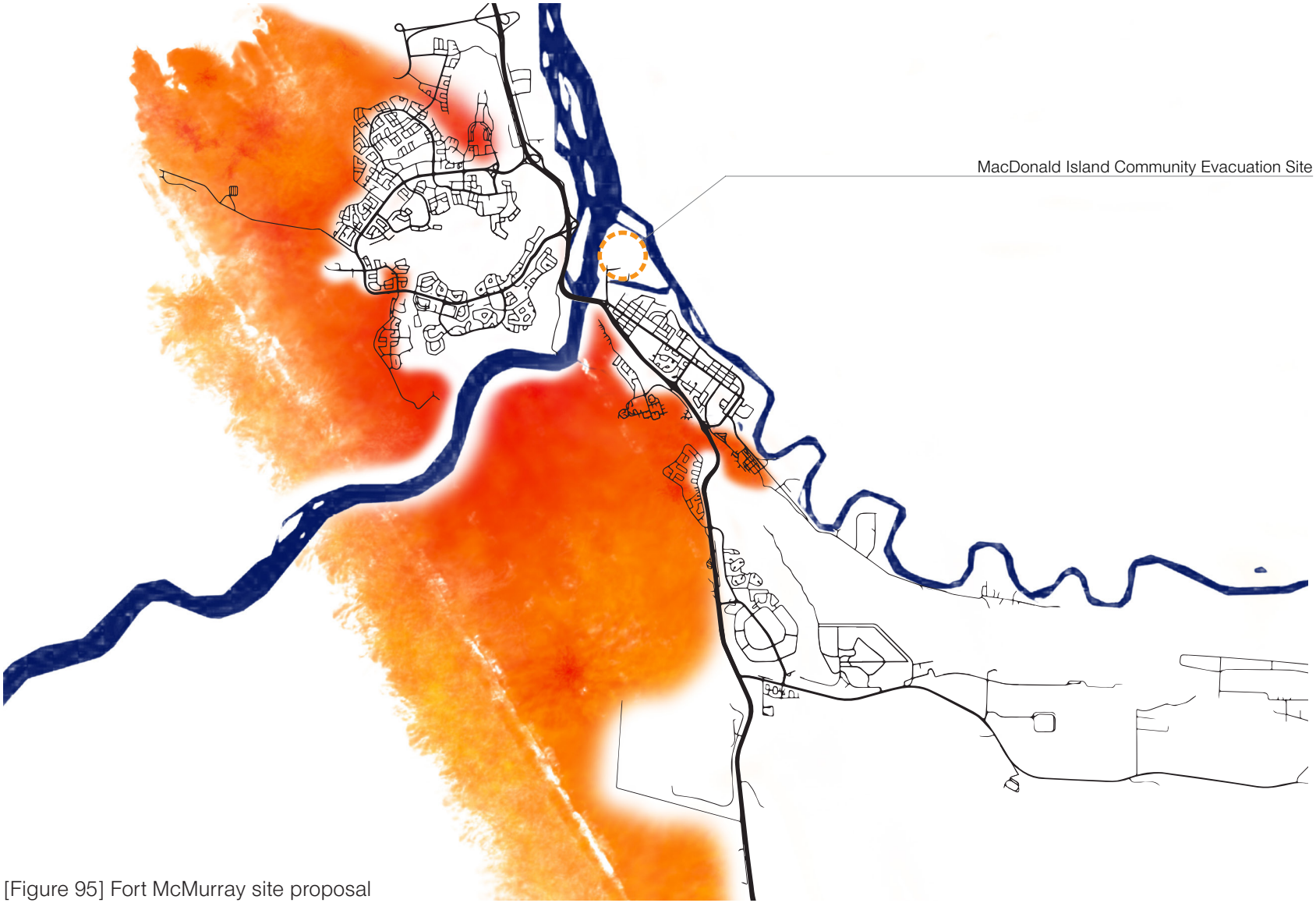
[Figure 92] Residents can begin assembling their Tinderbox on their property once the evacuation notice is lifted.



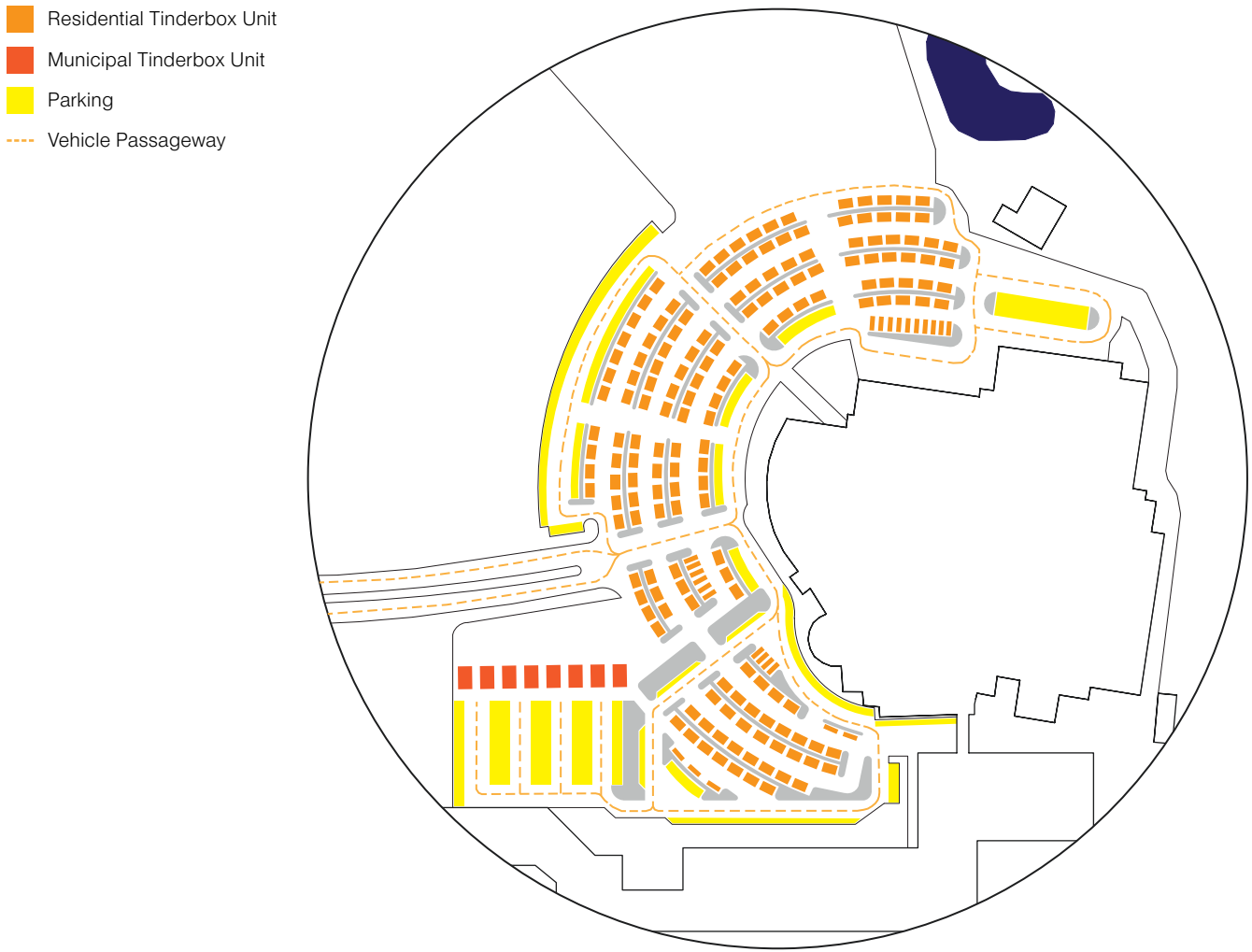
[Figure 93] Residents can remain living in their Tinderbox while their home is under construction.



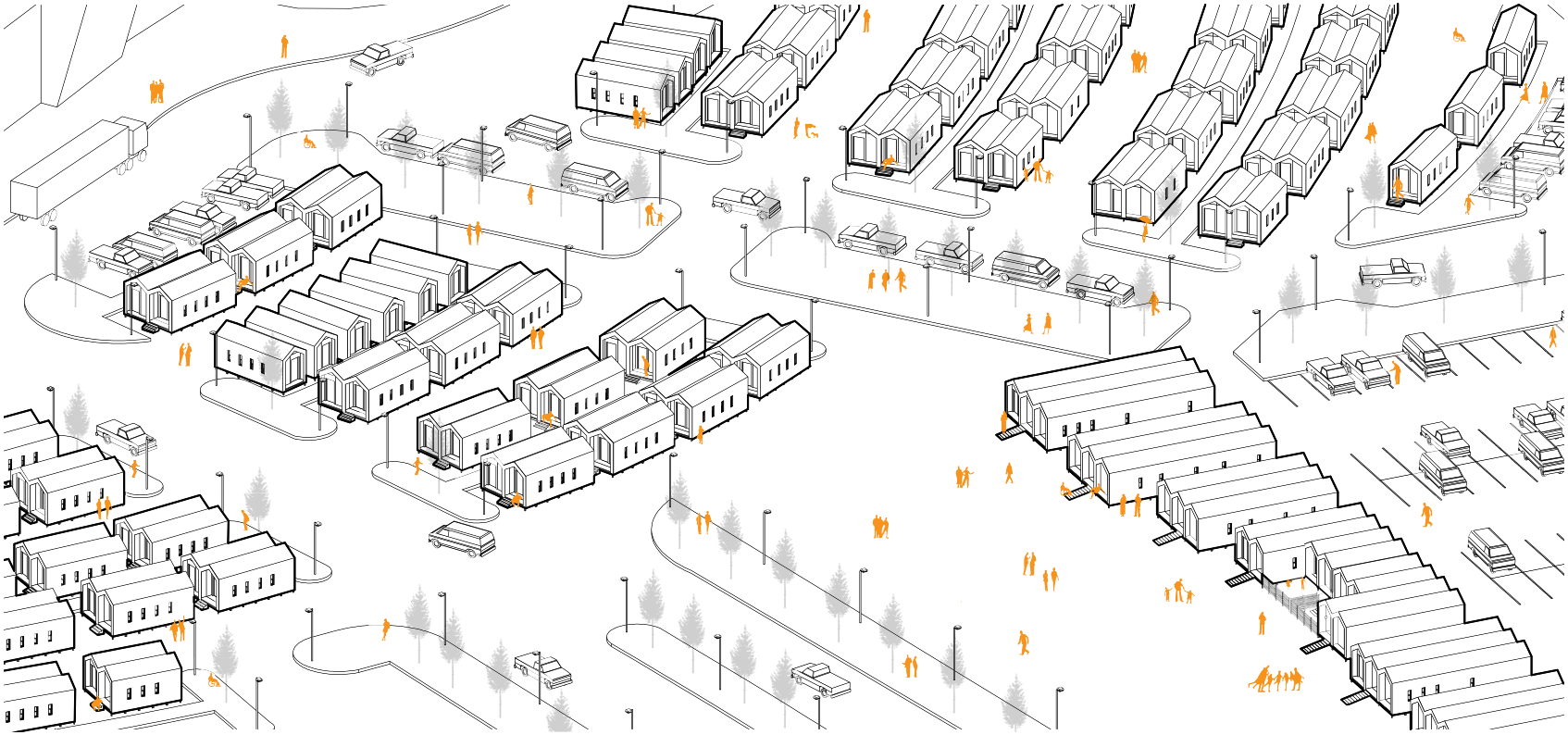
[Figure 94] Once the home construction is complete, residents can begin disassembling their Tinderbox to return to the distribution centre.



[Figure 95] Fort McMurray site proposal



[Figure 96] Proposed site plan at MacDonald Island in Fort McMurray. The proposal includes designated space for residential Tinderboxes, municipal Tinderboxes, parking, and vehicle passageways. Extra space is available on the north side for overflow. Parking lot medians create an opportunity for municipal electricity and water connections.



[Figure 97] Proposed site arrangement at MacDonald Island in Fort McMurray.

[Figure 98] Tinderboxes being assembled at MacDonald Island in Fort McMurray.

CONCLUSION

The objective of this study was to identify current evacuation accommodation for Canadian wildfire evacuees, and how post-disaster living arrangements can cause consequential stresses leading to mental health issues. Using a research by design method, this thesis proposed a temporary transitional shelter entitled Tinderbox. The primary objective of the design was to provide evacuees with appropriate post-disaster accommodation that would be low-cost and require minimal resources such as skilled labor and commercial freight transportation.

The budget for this project was to have a four-person shelter costing no more than $35,000 in material costs, or the equivalent cost of a new car. This budget was based on the prices of existing temporary shelters, including the Ikea Better Shelter, trailers, and tiny homes. Tinderbox was compared against these systems for its durability, facilities, and climate control. In comparison, the Ikea Better Shelter costs approximately $1,500, while trailers and tiny homes are upwards of approximately $80,000. To design a shelter within the $35,000 budget, decisions had to be balanced in regards to material quality, amenities, and facilities.

All insulation is stone wool, a more expensive cost compared to an extruded polystyrene insulation. The decision to use a costlier material was made due to environmental considerations, thermal resistance, and fire retardance. For some aspects of the kit, low-cost options were not available. For both the kitchenette and vented electric composting toilet, there are few models on the market. As a result, these systems consume a large percentage of the overall budget. It is hoped that with a systemic program such as Tinderbox, economies of scale could reduce the cost of such items and improve the overall financial viability of the project.

The design hypothesized that assembling a four-person Tinderbox would be achievable within two days by two adults. Without a 1:1 scale model of the system, the accuracy of this statement remains difficult to test and verify. There are many factors that could affect this intent, including physical limitations of those assembling the shelter, limited assembly knowledge, inaccessible transportation, and adverse site, or environmental conditions.

Despite Tinderbox's objective to be assembled by the users, there remains sections of the assembly that require

highly skilled labor. Certified electricians and plumbers are required for all electrical and plumbing work. This means that professionals will be required to be at site to complete these services, which may increase costs and delay assembly time. Users may have to wait before having full use over their Tinderbox's facilities.

Instead of using existing joinery methods, Tinderbox uses custom combination joints. These joints are designed quick and efficient assembly, and facilitates different shelter arrangements. The custom combination joints can facilitate a connection of up to 12 panels simultaneously, which gives occupants a range of designs. What makes this joinery system promising is its potential beyond Tinderbox, and its application to a wider range of functions, including simplifying the assembly of other existing systems such as sheds and furniture.

Tinderbox achieves its goal of providing wildfire evacuees with adequate shelter for short and long-term use. Tinderbox has the capacity to provide essential accommodation and resources to evacuees, reducing the amount of time spent in emergency reception centres. By reducing evacuees exposure to unfit living conditions, the risk of heightened stress, anxiety, and mental health issues may be minimized.

EPILOGUE

The final thesis defense, which occurred on April 18th, 2018, brought forth some important points and questions regarding Tinderbox. The discussion included concerns with the logistics of Tinderbox, specifically the construction labor, the deployment process, and the assembly and organization of the community. Tinderbox's temperance also offered thoughts towards the opportunity for customized housing configurations and collective community planning.

For Tinderbox to remain a low-cost shelter, the construction labor must be carried out without additional cost, which can be achieved through volunteer work or as a means of education. One option is to have Tinderbox's construction carried out by a humanitarian organization such as the Red Cross or Habitat for Humanity. These organizations offer volunteer services and have the capacity to fulfill Tinderbox's labor needs at no cost. Another option is to integrate the construction of Tinderbox into an institutional environment. Tinderbox can provide students from secondary, vocational,

and technical schools with the opportunity to gain hands-on experience in the trades, learning various skills in woodworking, milling, carpentry, and textiles.

The deployment process and community organization are two factors that would need to be predetermined in a community's emergency plan. The plan would be arranged in consultation with stakeholders prior to a disaster and would outline the specific tasks and responsibilities should a disaster occur. This includes sourcing companies and individuals who would have the capacity to transport Tinderbox kits in large quantities. The plan would also include appropriate interim housing sites for the assembly of Tinderbox communities.

Tinderbox's modularity allows for customization of the shelters based off of the needs of the users. Evacuees have the opportunity to grow their Tinderbox, starting off with a small shelter and adding additional rooms to it as their stay lengthens and spatial needs increase. This freedom of design allows for individuality and self-expression, eliminating the conformity that is associated with a 'one-size-fits-all' shelter. Customization also allows the community members to become involved with community planning. People have the opportunity to join their homes together and create communal spaces for gathering and play. The resulting emergency community creates an opportunity to explore new types of urbanism, temporality, and experience as it disregards the conformity of a traditional city. The direct involvement in the planning process provides evacuees with the freedom to make cooperative decisions, which can strengthen the relationships of community members during a time of difficulty.

POST-SCRIPT

This project has been incredibly overwhelming in the best of ways. At the beginning of the year, my research traveled along a consistent, predictable path. It wasn't until Colloquium 1 that I began to see Tinderbox through a new lens. During my Colloquium 1 presentation, it was suggested to me that because Tinderbox is a small-scale building I should construct a fully functional 1:1 scale model. I admit, a 1:1 scale Tinderbox model sounded incredibly enticing – but where was I supposed to get $35,000?

To find that much money, I had to think outside the (Tinder) box. I promptly put together a sales pitch, created a social media platform for my thesis project, and began a crowdfunding campaign using Carleton's FutureFunder. Within one day of launching my platform and campaign, I received an award from CUSA, was interviewed about my project on CBC Radio Edmonton, and had an article published by CBC News. Donations were coming in as I watched my project gain exposure by the thousands – it was surreal.

There was a moment around Colloquium 2 when I realized that it would be impossible to build a full Tinderbox in just a few short months, so I revised my goal. Instead, I aimed for a 1:2 scale sectional model. Through a grant opportunity organized by MadeMill in Ottawa and Prof. Sheryl Boyle, I was able to explore new technologies and construction methods, including 3D printing and waterjet cutting. By Colloquium 3, I had 3D printed two prototype sets of joints and refined my joinery design. With Mademill's facilities, I was able to produce a comprehensive model to illustrate the joint and panel connections.

In March I entered my thesis into Carleton's annual 3 Minute Thesis public speaking competition. The concept of the presentation is simple, but the execution is incredibly challenging. With only 180 seconds, every word counts. This forced me to refine my thesis argument into a quick, powerful statement that could convince an audience on the importance of my research and the relevance of Tinderbox.

Going forward, I hope that my research and design proposal offers a little into wildfire evacuee accommodation, and contributes to the research of evacuation shelters and their potential, mitigating functions to improve evacuee well-being and mental health.

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