DURABILITY AND RESILIENCE

D8 SUBMISSION

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I. Resilience & Durability

Resilience and durability relate to the capacity for a structure to maintain habitability and resist damage in a disruptive event. This is a primary concern in the age of climate change. Resilience may be characterized by the 4 Rs[1]:

- Robustness
- Resourcefulness
- Rapid recovery
- Redundancy

The resilience of the Wind River home stems from the following design elements:

a) Airtight and well-insulated envelope
b) Passive solar heating and thermal mass
c) Solar power and battery storage
d) Redundancy of electrical heating
e) Flood-resistant site design

a. Envelope

The Wind River house features an impressive envelope (Figure 1), with R-20 floors, R-30 walls, and an R-50 roof. Rigid, insulative *ZIP* sheathing wraps the entire structure, effectively preventing thermal bridging and moisture infiltration. In addition, closed-cell spray foam seals the envelope to create an airtight barrier. In most homes, windows are the largest source of heat loss. However, the Wind River home employs Alpen triple pane windows that not only have an R-value of 6.7 but are also tightly sealed. Overall, this envelope makes the Wind River home the tightest house in Wyoming, with only 0.25 ACH. Having an airtight envelope improves the building's performance year-round, but the benefits are realized most during the long, cold winters in Lander. Heating loads can be greatly reduced, which puts less

Figure 1: Spray foam insulation and Zip sheathing

[1] *Architectural Graphic Standards, 12th Ed.*

strain on the mechanical equipment, and the elimination of drafts increases occupant comfort and stabilizes the interior environment.

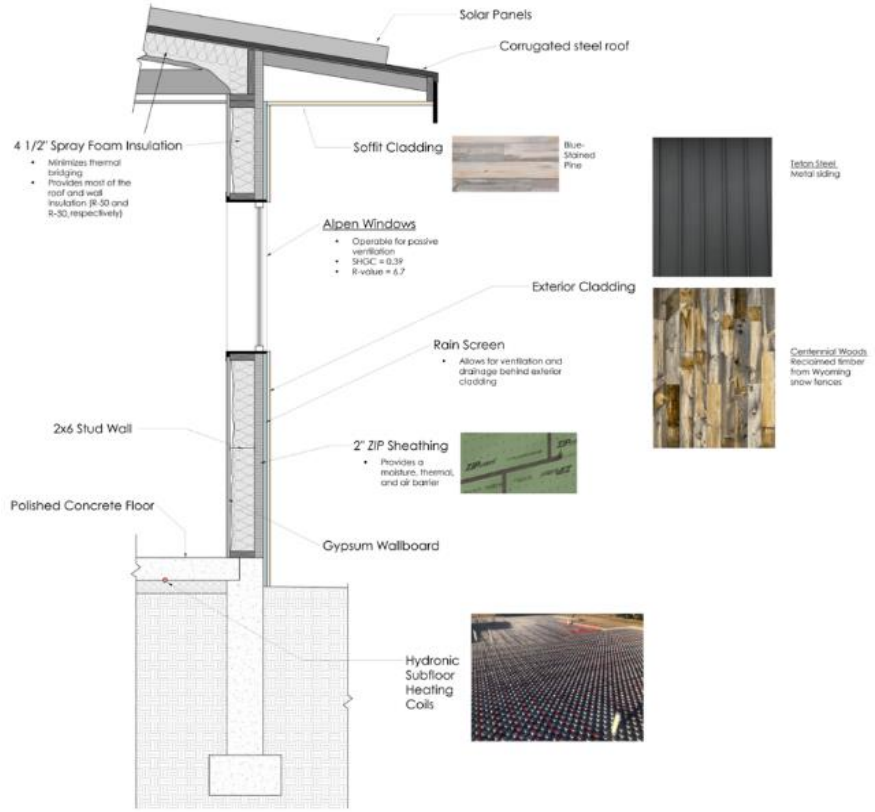

Figure 3: Wall Section

Issues such as mold and condensation are also minimized. While Lander does have a relatively dry climate, condensation can occur within exterior walls due to the temperature gradient between the inside and outside during the winter. Having an airtight envelope limits the transfer of moisture into the building fabric, and it also allows for the close regulation of interior air psychometrics, which is accomplished by the CERV unit in the Wind River home. These properties control condensation in the envelope, reducing the risk of mold and water damage. This means that the house can maintain a high level of thermal performance during extreme weather conditions with minimal impact on the home's long-term performance.

b. Passive Solar Heating and Thermal Mass

The orientation and architectural design of the house creates passive solar opportunities, which means the house can stay warm for extended periods of time in the winter without needing help from mechanical systems. This performance is furthered by the concrete slab floor, which collects heat during the day and releases it at night.

Figure 2: Wind River house, solar array—32 panels @ 480W each

c. Solar Power and Battery Storage

The solar panel array, which provides over 100% of the home's energy consumption on and off the grid, allows the home can be fully operational on and off grid in the event of an emergency (Figure 3).

In the event of full electrical failure, including the solar panels, the home would be able to function for nearly half a day with the KiloVault battery system being used to perform necessary tasks (Figure 4). The battery power allows time for the solar array to be fixed or maintained, which is especially important during the winter months when the solar panels could be covered with snow. Even without any electricity, the home was designed such that living conditions could be maintained under extreme conditions. The oversized solar array also accounts for damage to individual modules: with the loss of one or two panels, the home can still be fully net-zero and fully operational.

d. Redundancy of Electrical Heating

For mechanical system resilience, the home incorporates a backup electric boiler (Figure 4) that can be used in conjunction with the heat pump. Generally, the heat pump provides 90% of all heating and cooling loads for the home. However, during particularly cold periods, the electric boiler will supplement the heat pump. While the boiler is less efficient, the electricity is derived from the solar array, maintaining net-zero energy. Beyond practical supplementation for extreme conditions, the electric boiler can also operate in case the heat pump is damaged.

Figure 4: Electric Back-up Boiler System (Hydro Shark)

The glycol buffer tank holds and distributes heat throughout the house in both the water and the radiant in-floor heating system. This buffer could be useful in the event of equipment failure or other heating issues. There is also a hot-water recirculation loop to help distribute hot water throughout the house quickly on demand.

e. Flood and Wind Resistant Design

As the climate begins to produce larger and more frequent storms, the Wind River home was designed to mitigate flood hazards. The house is situated mid slope on a shallow ridge, meaning that water will flow away from the structure in all directions except for the West side. Here, the building pad cuts into the hillside slightly. However, a simple retaining wall can be erected to direct water away from the home (Figure 5)

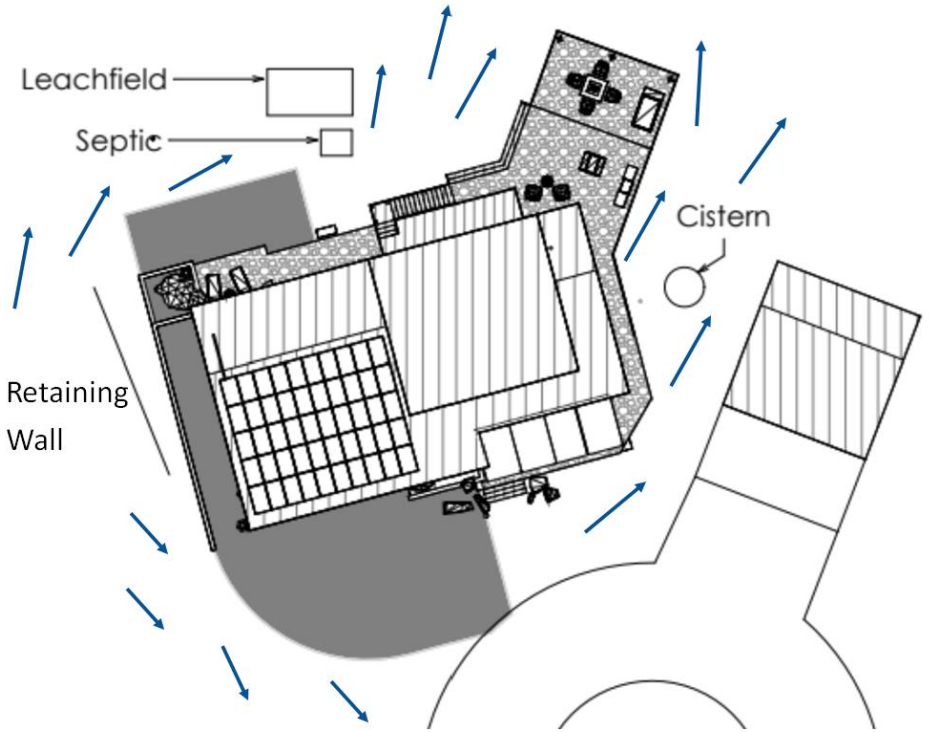

Figure 5: Water Direction away from home

Located at the top of Red Canyon, the Wind River home experiences daily breezes that are harnessed for passive ventilation in the home. However, they can quickly morph into wind storms with gust frequenting 60-70 mph, especially during afternoon summer rain-showers. During more violent storms, the Red Canyon valley often reaches gusts of 100 mph. The Wind River home was structurally designed to resist a 115mph basic wind speed, and other elements such as the solar panels are tightly secured to prevent damage.

II. Resource Management and Performance

Situated 11 miles from Lander and with the intent to remain independent from the grid, resource management and efficient home performance is a critical part of the Wind River home's function. The Wind River excels in three main categories:

a) Water Management
b) Electrical Performance
c) Construction Resource Management

a. Water Management

Potable water must be transported to the site, which highlights the need to conserve water usage. This is evident in many design aspects of the home, even landscaping; native shrubs and grasses are planted throughout the property, eliminating the need for irrigation. Low-flow faucets and a water-efficient dishwasher and washing machine help with this goal. A recirculation line is also utilized to maintain on-demand hot water. The water is constantly circulated through the hot water heater, meaning that hot water is available with almost no wait time. Beyond the convenience of this system, it also reduces hot water heat loss and reduces water waste while hot water makes its way to the faucet.

b. Electrical Performance

To achieve net-zero energy, the entire house was designed around conserving electricity. This is evident in the high insulation walls and roof which limit the loss of thermal energy to the environment. In addition, the heat pump operates at a COP of 3.1 to 4.0 during non-extreme conditions. Compared to a traditional electric heater, this is three to four times as efficient.

Between the insulative and airtight envelope, concrete slab, and the passive heating and cooling strategies, the home can function without any mechanical assistance, especially during the long shoulder seasons Lander experiences. During these shoulder seasons, daily temperatures can fluctuate between 30°F to 75°. In traditional homes, this can lead to mechanically heating and cooling the home multiple times a week which wastes large amounts of energy. The Wind River home passively regulates its temperature, leading to a better occupant experience and less demand on mechanical equipment.

The solar panel array also allows for off-grid charging of an electric vehicle (Figure 6). This is important to avoid the frequent and often expensive variations in gas prices, and it also provides a reliable location to charge the vehicle. Though Wyoming has slowly expanded its EV charging infrastructure, current legislation within the state seeks to further hinder such development. This uncertainty is avoided by installing a clean-energy charging option for the homeowner.

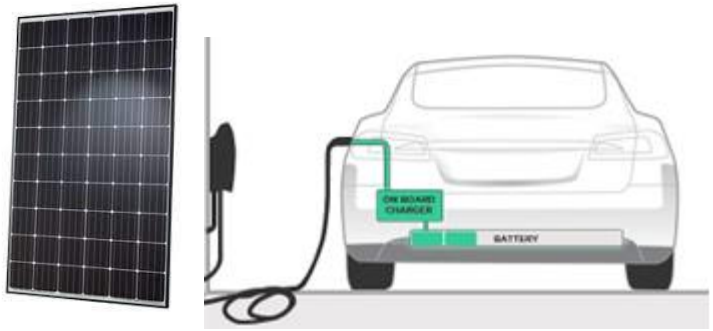

Figure 6: Solar Energy is directly utilized for EV charging

c. Construction Resource Management

Resource management for the house includes not only the resources needed to run the house but those needed to build it. Timber was chosen as the sustainable construction material, and the façade incorporates reclaimed timber from Wyoming snow fences, as well as wood from the 2020 Mullen fire which occurred near Laramie, Wyoming (Figure 7).

Figure 7: Reclaimed snow fence siding

III. Innovation

The Wind River home is a leading example of spec-home construction in Wyoming by using innovative design strategies and equipment. These include the implementation of an oversized solar array, as well as passive thermal regulation strategies. The heat pump heating and cooling system is an extremely innovative product that is significantly cheaper and more efficient than traditional forced-air HVAC systems, saving homeowners on electrical bills. The subfloor glycol tubing which is used to heat and cool the home is also an innovative product. Originally thought of as a luxury factor, properly designed heated flooring is one of the most efficient and comfortable techniques to provide consistent heating.

The most innovative factor about the Wind River home, however, is that these features are included in a spec home. Many of the features the house includes are only seen on small houses or on experimental home designs. The Wind River home incorporates them into a home that can be used as a future template to accommodate the lifestyle of an average Wyoming resident.

Figure 8: The Wind River home demonstrates the potential for net-zero spec home construction