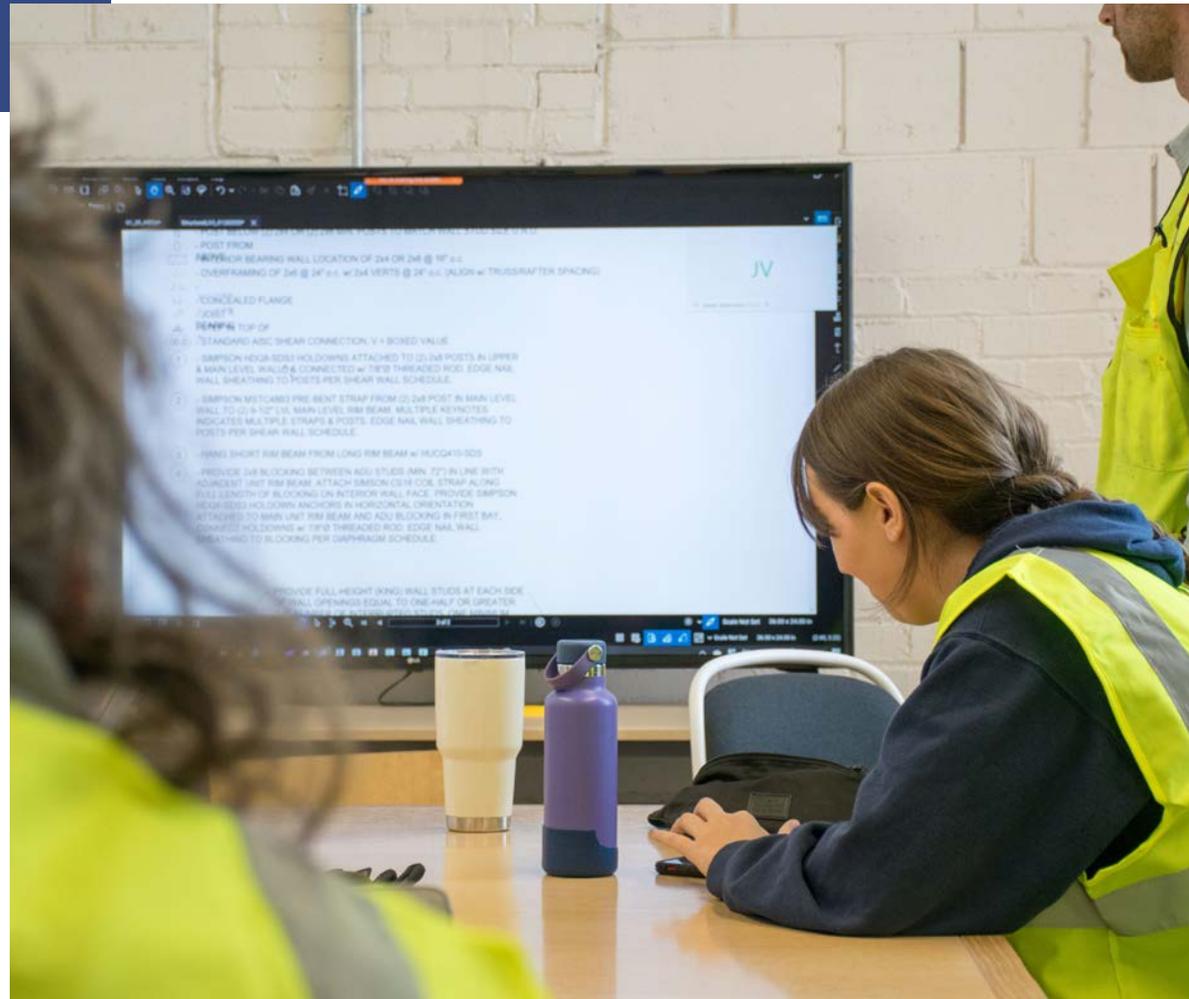


MARKET POTENTIAL



U.S. Department of Energy
Solar Decathlon 2021

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A design meeting at Simple Homes



THE MOUNTAIN TOWN HOUSING CRISIS

Mountain communities are in need of sustainable ways to increase density in low-density areas. Often misunderstood as existing purely for ski vacations, mountain towns are composed of multifaceted and lively local communities with real and complex economies much like the towns that people often visit from. In recent years, however, an influx of challenges are raising housing costs beyond the reach of both low- and middle-income residents. These are teachers, small business owners, restaurant staff, even seasonal resort employees, etc. who are being displaced by these issues. Without them, businesses suffer, and as a result, economies are weakened. The middle class is often considered the backbone of these mountain town economies and makes up a vital portion of the population during town development.

Currently, property and construction costs are high and on the rise.

Pairing this factor with cold climates that are accompanied by short build seasons explains why developers are choosing to build luxury homes with high return. In addition to a universal skilled labor

shortage, builders and developers are understandably selecting the most lucrative projects. Meanwhile, these second-homes often sit unused for the vast majority of the year, while the towns struggle to accommodate the heart of their community, middle-income residents and families.¹

CLIMATE CHANGE & SUSTAINABILITY

The climate change crisis is already here. The consequences of the world's level of inaction are making headlines consistently, highlighting both direct and indirect impacts around the globe. Among the direct include the record-breaking wildfires that destroyed 700,000 acres of land in Colorado alone just months ago, causing thousands to evacuate and entire properties to be burned to the ground. For mountain communities, this all happened in their backyard. An indirect consequence, the smoke from these fires extended far beyond the 700,000 acres, creating unhealthy air quality, causing respiratory issues and other dangerous health conditions for both people and animals throughout the West.²

Climate change has severe economic and social implications.

Many fail to realize that the world's climate is deeply intertwined in various divisions of society (energy, agriculture, infrastructure, tourism, etc.). Unfortunately, if the world does not take appropriate action, time still progresses and people will need to continue to adapt to new and harsher norms whether they want to or not. The CU Boulder Team maintains a central focus to promote true sustainability. Often oversimplified, the comprehensive interpretation extends beyond environmental protection and includes two additional components: economic prosperity and social equity.³

Environmental decisions at home hold an understated degree of influence in the big picture. Moreover, they can end up being the more economical path in the long run. There's a common misconception among hesitant homeowners that buying energy efficient features is expensive. Although these kinds of upgrades can cost more money up front, they function more as an investment and often pay for themselves with the amount of energy they save over time. In 2015, the organization Energy Efficiency For All found that integrating energy efficiency strategies in a range of affordable housing types can yield energy savings between 15-30%.⁴

Aside from reduced operating costs and return on investment, homeowners are attracted to these aspects of eco homes:

- Reduced maintenance required
- Comfort (e.g. When it's cold outside, the house can be heated faster and can stay warm longer)
- Home automation (smart home appliances)
- Support of a healthier planet and mitigation of climate change

Today, 89% of homebuyers nationwide want energy efficiencies incorporated into their



Figure 1: Smoke from nearby wildfires in Fraser, Colorado 2020. Source: Lizzy Sommer

home, whether through appliances or a highly effective envelope.⁵

A CLOSER LOOK

In order to establish practical and effective housing solutions, the CU Boulder Team believes it's necessary to not just investigate local issues at arm's length but to dive deeper and explore the community experiences and struggles more intimately. The reality is that housing is not one size fits all.

The SPARC House is the product of the team's globally-minded design goals applied in a specific setting with real people and real issues.

The team's story is based in Fraser, a charming town tucked away in the Rocky Mountains of Colorado, at an elevation of 8,574 feet and with a population of just 1,378 people.⁶ By working with a client from before starting the design process, the CU Boulder Team was able to conduct close market research to better understand the unique experiences and struggles of Fraser locals.

With Winter Park just minutes away, Fraser attracts those who lead an active lifestyle, enjoy wildlife, and thrive on nearby ski resorts. Residents appreciate

the quirky, small-town feel where faces are familiar and everyone is seen as a valuable member of the community. In Fraser, there exists a mutual enthusiasm for live music and eccentric art in the form of public murals throughout the town, all of which further affirms a popular saying in the area to "Keep Fraser Funky."

Residents are proud of the town's historical connection to the 1905 railroad that traversed the nearby Continental Divide (visible from the area), connecting Denver to Salt Lake City with Fraser situated along the way.⁷ Today, an Amtrak train station located in the center of town connects Fraser to the rest of the country. While local residents appreciate the network and access that the commuter train provides, the blasting horns of the coal trains that frequently pass through are a nuisance, particularly at night. This is especially true for lower-income residents who often live in sub-par housing with thin walls and little to no noise insulation.

As a former competitor for the trademark "Icebox of the Nation," Fraser possesses unique climate challenges that make it a notable location to use as precedent for designing net-zero, all-electric homes. Average seasonal temperatures in the US hover far above those in Fraser (see

Figure 2). Conversations with local contractors and town officials informed the team that Fraser experiences approximately three months of reliable construction conditions per year. With home and property costs rising, Fraser is experiencing the growing mountain town housing crisis firsthand, causing many to relocate and businesses to struggle to stay afloat. Those who can afford to live there are surrounded by a high and increasing number of luxury rentals that sit unoccupied for the majority of the year. Fraser is at risk of slowly losing its livelihood as a result.

The SPARC House's build site is representative of many other properties in the area, constricted and awkwardly shaped. The rise of property prices means lower-

and middle-income families are seeking out smaller plots of land. Examining the inner workings of the town of Fraser serves as a tool for designing a house that can seamlessly integrate into the community and confront relevant and important large-scale issues affecting all mountain towns but through the unique lens of one. By speaking closely with locals and attending town hall meetings, the CU Boulder Team intentionally incorporated residents into the solution process.

TARGET MARKET

The SPARC House addresses the needs of both middle class home buyers and lower-income long-term renters in mountain towns by providing a sustainable and gradual way for communities to

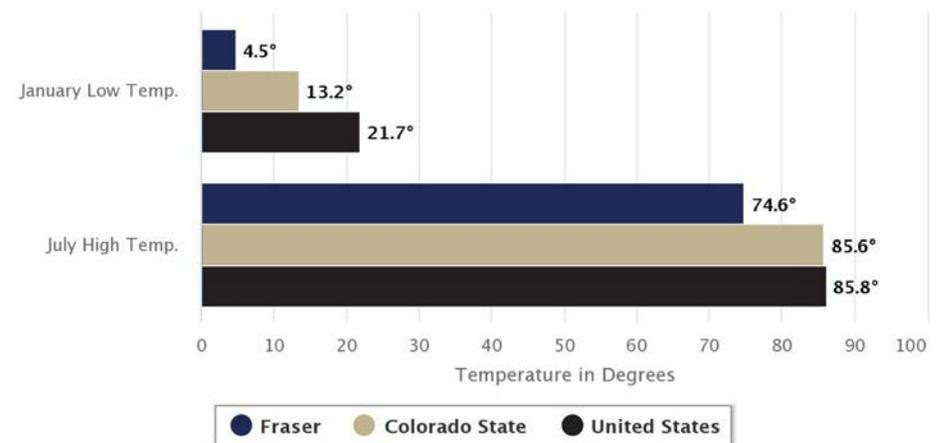


Figure 2: Fraser, Colorado, average annual low and high temperature as compared to Colorado State and in the US⁶

increase their density. The CU Boulder Team's target market consists of young couples, ages 25-40, who are looking to purchase a home in a mountain town. In 2021, this age range embodies generation Y, also referred to as millennials. As a whole, the most prevalent shared characteristic of this generation is their level of utilization of advanced technology.⁸ Millennials are more inclined than previous generations to welcome progressive and efficient systems that not only decrease energy use and therefore save them money, but also evolve user integration within the framework of their homes.

The team's target clients are young professionals who live active lifestyles, are involved in the community, and are experiencing various phases of life. The ideal household income for clients is just over \$60k in order to maintain a minimum of 2/3 of earnings for unrelated expenses. For reference, the median household income in Colorado is currently \$77k.⁹ The CU Boulder Team created client personas named Antonio and Laura to demonstrate the possibility that the SPARC House affords residents. Antonio and Laura (35 and 31 years old, respectively) have been married for three years and have been living in a 400

square foot apartment in Denver. Their companies have both gone completely remote during the pandemic and have no intent to require people to come back into the office full time after the pandemic is over, so they want to take this opportunity to move to the mountains. They have always loved to spend time outdoors, whether that is skiing, mountain biking, or hiking, and they've they've finally found their opportunity to focus on their passions. Though they prefer a small living space, they also want to be able to store all their gear and the opportunity to host friends and family in their own home. This makes Antonio and Laura ideal occupants for the SPARC House. Understanding that the pandemic has intensified the existing affordability issues in the community, the couple is eager to help alleviate the strain by renting out the ADU and simultaneously offsetting their mortgage payments.

The average American household has decreased in size from 3.33 people in 1960 to just 2.53 people in 2020.¹⁰ At the same time, the average home size in the US has spiked from 1,660 square feet in 1973 to a peak of 2,700 square feet in 2015. With fewer people living in larger spaces, this trend is problematic in a number of ways, including increased

environmental impact. However, a DataTrek analysis has found that since 2015, the trend has started to reverse itself and is expected to continue this trajectory.¹¹ With Americans starting to look for smaller homes, the CU Boulder Team has joined the conversation and is further challenging public perception about house size and livability.

The CU Boulder Team has worked alongside real clients who will ultimately reside in the SPARC House post-construction. A millennial couple that currently reside in a 275 square feet Fraser condo, Kristen and Joe are passionate about their community and environmental issues. They are both involved in the clean energy industry in Fraser and are eager to progress current standards of living both locally and beyond in order to promote a more

sustainable lifestyle. When they're not working, Kristen and Joe enjoy mountain biking, rock climbing, skiing, and travelling in their self-made solar powered camper van. They're eager to move in and showcase the SPARC House to the community.

LIVABILITY & DESIGN

The SPARC House creates a space for occupants to live both comfortably and efficiently. With three identical modules and a multi-story approach, the 1,176 square foot structure can fit on small or constrained plots of land without limiting the quality of the home experience.

With the average US house size's new downward trend, the SPARC House proves that small, multi-story homes provide a number of benefits to home buyers that often go unnoticed, including:

- Multi-story = smaller footprint = lower cost of foundation and roofing
- Less space to heat and light = lower energy bills
- Ideal for 1st home buyers who want to gradually grow into their home
- Less time spent maintaining, more time spent living



Figure 3: The three elements of sustainability

Higher roofs can clear tree and neighbor shadows, allowing for more solar access and higher PV production

Increased access to views of mountain peaks

Innovative, multi-functional uses of indoor space allow smaller homes to reap the benefits of larger homes (feelings of space, openness, and privacy) without having to endure the troubles commonly associated with them (higher heating bills, costly maintenance, more to clean, buildup of clutter, wasted space, etc.). Research even suggests that size is the most significant factor of a house's environmental impact, making the case for downsizing all the more important.¹² Especially in mountain communities where construction is limited and expensive, the CU Boulder Team recognizes the power in building smarter, not bigger.

Two of the three modules are vertically stacked and referred to as the main unit. The bottom floor of the main unit houses the open kitchen/living space and powder room, while the office space, master bathroom, and master bedroom are all located on the second floor in addition to laundry access. With access beneath the stairs, a conditioned crawl

space beneath the house provides homeowners with ample storage for outdoor equipment and non-daily-essentials. The two floors within the SPARC House provide a clear separation of space and a distinction between shared space (bottom floor) and private quarters (upper floor).

Rise of the ADU

Likely the most distinguishing element of the SPARC House is the third module, designed to serve as an attached accessory dwelling unit (ADU) situated directly adjacent to the main unit, with its own exterior entry and lockoff access from the main house. The ADU functions as a separate, rentable unit with a studio layout including a sleeping area, full bathroom, living area, and kitchenette. This not only provides the homeowners with a source of income that can offset the cost of the home, but also sustainably addresses the need for more affordable housing options for lower-income residents and workers who are otherwise unable to live in mountain communities.

The demising wall separating the ADU from the adjacent module is also a double wall, which enhances privacy by reducing sound transmission between units. This also allows the possibility for the main house to be constructed and the ADU module added at

a later date if desired. At the discretion of the homeowners, the ADU enables potential future expansion of their space. The third module can be transformed into a second bedroom, larger living space, etc. sparing homeowners from requiring costly expansions to upsize their home. The SPARC House aims to not only meet current needs, but also hold space for a variety of needs in every phase of life because young couples, especially, benefit from a home that can grow along with them.

The ADU arrangement promotes stronger communities by allowing homeowners to recognize and meet the needs of other locals. It provides opportunity for interaction and formation of new relationships, fostering the development of more unified neighborhoods and sustainable density growth. According to the United Nations, along with creating healthier economies and an increased sense of safety, integrated communities have the potential to improve the overall well-being of their people.¹³ The SPARC House allows mountain towns the ability to showcase the power of not just sustainable housing but also sustainable communities.

Historically, ADUs have had a wavering track record. In the



1940s and '50s, having an accessory dwelling unit was popular across the US as a way to help manage mortgage payments and other common expenses. They were successful because the demand was there. Over time, however, increased zoning regulations began to heavily restrict - if not eliminate - ADUs in an effort to protect suburban single-family neighborhoods throughout the nation. In recent years, as demand for affordable housing reaches crisis level throughout much of the country, communities are being forced to reexamine these laws.¹⁴

Unfortunately, progress has been slow to meet the demand. The complicated and outdated regulation continues to deter homeowners in the meantime. Some metropolitan cities like Austin, Texas, have recognized the potential of ADUs for mitigating affordability issues and have reversed previous legislation to the extent of now proactively organizing ways in which residents are encouraged to build and rent them out.

The Family Housing Fund, reports that the three best ways for a city to promote ADU development are as follows:

- Remove complicated legal obstacles
- Scale back design restrictions and permitting requirements.
- Find ways to incentivize financially
- Lower certain associated costs; provide ADU loan programs, waivers, or discounts to homeowners.
- Actively advocate and educate
- Assemble accessible and updated information regarding ADUs and how to pursue their development.¹⁵

The CU Boulder Team recognizes that ADUs wouldn't only be successful in metropolitan cities, but also in mountain towns where the cost of land and living is also becoming unattainably high for many residents who play major roles in their local economies. ADUs can help these communities increase density gradually and sustainably. The mountain town of Durango, Colorado, has already been working to

implement several strategies to offset local housing affordability issues, including updating policy regarding accessory dwelling units, which has gained the city special recognition.¹⁶

In 2018, the Fraser Municipal Code adopted ordinance number 452, which in Section 19-2-470, eases restrictions associated with ADU development, including reducing the minimum floor area to 200 square feet, thereby enabling more homeowners living on space-constrained plots of land to consider adopting an ADU.¹⁷ Still, scaling back restrictions doesn't necessarily excite more homeowners to build ADUs if they're not yet informed about the concept or its potential advantages. With this, the CU Boulder Team responds to a gap between administration and community. The SPARC House implements an attached ADU in its design to showcase to the local community and surrounding mountain towns that they are effective investments that can not only help alleviate local housing issues, but also can provide homeowners an additional source of income in order to grow their wealth sustainably.

As an indirect consequence of the coronavirus pandemic, demand for ADUs has escalated nationwide. Now in 2021, it offers

much more than a rentable space or a conveniently existing future addition. It allows for a completely separate work-from-home space with the privacy and silence most normal home offices simply can't provide. It can function as a flex space: an artist studio for creatives or designated exercise space while gyms are temporarily shut down. It also enables temporary detached living situations in order to quarantine safely or care for immuno-compromised family members.¹⁸ Throughout the current global health crisis, ADUs have proven to be an unexpected champion for many American families, and their

popularity is only continuing to increase.

The Envelope

The SPARC House's exterior walls contribute to an optimal indoor experience for residents. The east, south, and west facades all include doors and windows for exterior access, daylighting, and passive heating. Only two windows are located on the north facade in order to allow residents to enjoy panoramic views and cross ventilation in the summer months while also minimizing thermal losses in the winter. On the second floor, high set windows provide more passive heating



Figure 4: High set windows in the SPARC House allow mountain peak views

Table 1: Insulation Value Comparison

	Wall R-Value	Roof R-Value
Climate Zone 7 Residential Home Code Standard Insulation Values	R-20+5	R-49 (R-38 acceptable at truss heel)
SPARC House Insulation Values	R-42	R-59

in the space during the winter months when the sun's rays are angled lower in the sky, meaning they are less obstructed by the roof's overhang.¹⁹ Additionally, the high set windows allow for an added sense of privacy for occupants, concealing the tops of neighborhood homes while still perfectly capturing the beauty of the mountain ranges in the distance. This provides homeowners with a unique impression of serene seclusion without actually needing to live in an isolated area.

By outperforming the code requirements for insulation values in climate zone 7 residential homes, the SPARC House retains heat both effectively and efficiently (see Table 1). Havelock wool, a sustainably-sourced insulation material used throughout the envelope of the house, provides additional latent services to the occupant such as absorbing harmful chemicals from the air

as well as absorbing sound. Not only does this provide an extra measure of privacy between the main unit and the ADU, but it also provides an increased buffer to the frequent noise attributed to the train transit through town.

Lighting

In addition to intentionally oriented windows that allow daylighting, the hardwired electric lighting scheme consists of an ambient layer of warm but efficacious light at the living and working areas of the house. Recessed downlights in the lower main area and ADU are used to provide ambient lighting for movement through the space, and near the main kitchen and ADU kitchenette. Additional under cabinet lighting at the kitchens will reduce shadows on working surfaces. Sconces with diffuse, luminous surfaces and distribution onto nearby walls provide surface lighting near living spaces for the dual purpose of functional lighting and to suggest warmth near the

eating areas. Throughout the house, light colored surfaces and mirrors compliment the surface illumination to create a sense of spaciousness in the small footprint. Each unique luminaire type in the house, in each zone, has its own lighting zone so that each space can have a range of lighting scenes, each contributing to a unique function and feel of the home as needed at a specific time. This will help the small footprint meet a range of space needs. The lighting control intent is manual-on with automatic-off at regularly scheduled times of day through the energy information system. The off times will coincide with high daylight hours and midnight to offer a reset to all-off in the house.

Integrated Systems

With the integration of three single-zone heat pumps, the SPARC House allows the occupants to thermally control each of its three modules separately. This enables the ADU's heating set point to be minimized whenever it's not occupied, saving the homeowners both energy and money. The heating system functions in tandem with an Energy Recovery Ventilation (ERV) system to more effectively retain both heat and humidity in the air, which has a notoriously low presence in alpine climates and is important for optimal indoor comfort.

The Transition to Solar

Solar power is a rapidly developing renewable energy source that is projected to expand within the US substantially over the next decade. A Harris Interactive poll conducted in 2012 on behalf of SunRun, a residential solar company, found that 77% of respondents that didn't already have it, would install a rooftop solar array if cost was not a factor. The same study indicated that 97% of Americans overestimated the cost of going solar.²⁰ Even a decade ago, a misinformed public perception prevented scores of people from investing in solar power. Furthermore, the average cost of installing residential solar starting in 2010 over an eight year period dropped almost 65% from \$7.34/watt to \$2.70/watt in 2018.²¹ Fortunately, the perception of solar energy today is vastly improving as additional data is released. More recently in 2019, CITE Research reported that 70% of survey respondents would even support a national mandate requiring all newly constructed homes to include solar panels. Within this study, the demographic that was most receptive to the concept included younger adults, aged 25 to 34.

BUILDABILITY

The CU Boulder Team's approach to buildability merges innovative

construction methods with long-standing local expertise. In order to combat the construction limitations that burden mountain towns, the team worked with Fraser contractors to understand what was working there and what wasn't. Through this, the team was able to pay special attention to specific construction elements (such as moisture management in walls) informed by lessons learned from contractors' already-established history with residential construction in Fraser.

Panelized Prefab: The Modular Movement

Modular construction is not a new concept to the building industry. In fact, it has been steadily on the rise. A McKinsey & Company report released in 2020 revealed that the portion of new North American real-estate construction attributed to permanent modular construction increased by 50% from 2015 to 2018.²² There's still a long way to go, though, with modular construction representing less than 4% of the country's housing market as of last year. A form of prefabrication, modular construction allows a house to be built in separate components in a climate-controlled factory to then be assembled on site. More recently, a new age of prefabrication has been brought on by advanced digital planning and production technologies.

Advantages to modular construction measured through impact on project delivery as reported by Dodge Data & Analytics in 2020 include:

- Improved Productivity
- Improved Quality
- Increased Schedule Certainty
- Improved Cost Predictability
- Reduced Waste Generation by Construction
- Increased Client Satisfaction
- Improved Safety Performance²³

In mountain towns where build seasons last only a few months, being able to construct in a climate-controlled factory means that timelines are no longer contingent on weather conditions. McKinsey & Company reported that modular can even cut down construction timelines by 30-50%. This allows for the house construction to be underway in a facility at the same time that site work is being done, therefore by the time the site is ready, the house can be transported in pieces and assembled on site in a matter of a few days. By improving productivity and schedule certainty, modular construction

also reduces the need for labor, which is important in the current skilled labor shortage. This in turn helps to reduce cost. Panelized construction is more suitable to be used in mountain towns as opposed to volumetric construction because the panels can be transported on the bed of a truck in a 'stacked' formation and therefore are able to reach more remote locations. Volumetric modules often require oversized load trucks, which can be expensive and are not ideal for transportation to more secluded mountain towns.

In the lens of its environmental impact, because prefabrication construction takes place in factories that commonly use material optimization methods, lumber is cut by high precision machines which result in up to 15% less waste during framing and more reuse of excess materials.²⁴

Keep it Simple

In order to create a home design that was easily replicable and adoptable across mountain towns, the CU Boulder Team needed to ensure that major design elements were standardized and streamlined. While today's modular construction allows for more flexibility in design than previous years, the team still felt it was important to minimize construction costs and complexity

of the structure by implementing measures such as a repeated



range of window sizes used throughout the house. The L-shaped form, composed of three identical rectangular modules, was another intentional design decision that allowed for maximized use of space and simplicity of assembly in the case of mass replicability. While implementing a straightforward basis of design, the SPARC House still allows limitless features to customize and elevate the house to a home, unique to the style of the homeowner. These opportunities can range from exterior siding treatment all the way to interior finishes.

Simple Homes & Swedish Influence

In the early stages of the design process, the CU Boulder Team formed a partnership with Simple Homes, a panelized modular startup based in Denver, Colorado, that focuses on innovative residential design. Their practice is uniquely integrated around a Scandinavian-inspired panelized building system used to streamline the construction process with advanced laser-precision technology and high quality production machinery. The modular construction industry is far more progressive in Sweden, where around 80% of all housing is a product of panelized construction.²⁵ Before the recent technological revolution

that began 20 years ago, the US construction industry was notoriously known for its slow development over the past century.²⁶ Now, it's stumbling to catch up with countries like Sweden that have established modular construction as a sustainable and viable solution for the local housing market as it slowly takes over former methods.

Built in a Day

After completion of the panelized construction in-factory, the SPARC House wall panels were placed on a Simple Homes truck and driven to the final site in Fraser. There, with the help of a local crane operator, a Fraser contractor, and the Simple Homes team, the panels were set and assembled in less than a single day, creating minimal noise interference for the neighborhood. In a broader scope, this kind of pace suggests that more housing can be introduced in a shorter period of time, meaning local contractors can fit a high number of projects into a season that meet the needs of the community.

CLOSING THOUGHTS

Through close market research, the team recognized and wanted to underscore the notion that beyond considering the goals set forth within the design philosophy,

which target the big-picture issues faced by mountain towns, including climate change, the SPARC House has to be a home first and foremost.

There is a balance - a sweet spot - where innovation and technology meet livability and practicality.

In Swedish, the concept of “not too much or too little” is known as ‘lagom’.²⁷ Scandinavian influence has crept into multiple facets of the CU Boulder Team’s project, from chosen modular construction

methods to the SPARC House’s minimalistic design. The word ‘lagom’ has also been latently central to the CU Boulder Team’s journey from the beginning of the design process when it was first introduced, until the end as construction wraps up. The truth is, in order for a house to be a home, all of the high-performance technology and unique design features need to make sense for the residents, their values, their lifestyle, and the unique circumstances that surround them. In the end, it’s about much more than a competition; it’s about a future.

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