Market Analysis

U.S Department of Energy

Solar Decathlon 2023

Build Competition

University of Colorado Boulder Team

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Target Market

In 2020 buildings accounted for 36% of global energy demand and 37% of energy-related CO_2 emissions. The residential sector alone contributed 22% of global energy demand and 17% of energy related CO_2 emissions were due to direct and indirect residential impacts [1]. Reducing emissions and energy demand has been at the forefront of building design in recent years, however, it is not the only design priority, especially when it comes to affordable housing.

According to the National Low Income Housing Coalition, there are currently 10.8 million extremely low-income families in the United States and there is a shortage of more than 7 million affordable homes [2]. This shortage provides a great opportunity for designers and builders but there are many challenges when it comes to affordable and sustainable development.

With the threat of climate change, and recent events like the War in Ukraine, energy volatility is on the rise. At the same time, there is a shortage of affordable housing, supply chain challenges, increasing material cost, and a shortage of skilled labor. As a country, we don't have enough housing and the housing we do isn't affordable. We are simultaneously dealing with a shortage of affordable housing and an increase in energy inequality due to the race to decarbonize our buildings. What if we could solve both issues at the same time? Better affordable housing saves money, increases occupants more comfort and health, improves IAQ, decreases greenhouse gas emissions, and reduces energy inequity.

Project Background

The redevelopment of the Ponderosa Mobile Home Park has been a controversial project since its inception. The community, first settled in the 1950s. Since the 1990s, the city has been trying to purchase the park to prevent the development of luxury developments. In 2017 the park was purchased, and the city has invested more than $3 million dollars to upgrade the utility infrastructure. Through a partnership with Habitat for Humanity, the 48 mobile home community will be redeveloped into an affordable community.

One of the main differences of the projects is financing, in which the city is planning to front more the $3 million to pay for zero interest loans. This new model is something that the city sees being expanded across the city to help manage the affordable housing crisis according to Kurt Firnhaber, the director of Boulder Housing and Human Services.

At the crux of the dilemma is that the ponderosa community are some of the last affordable locations within Boulder. According to a survey conducted by CU Boulder students, most of the residents fall in the federal government's definition of "extremely low-income", earning less than $26,000.

The new homes will be deed-restricted towards families earning 60% AMI (Area Median Income) or about $53,000 for an individual. In order keep the cost of the home affordable, the city plans for residents to only pay 30% of their income on the home. Typically, people who spend more than 30% of their income on housing are cost burdened. As such the city plans to spend about $3 million from its Affordable Housing Fund to subsidize the mortgages.

Affordability and Cost-Effectiveness

The estimated up-front building cost is $245,000. This equates to $197/SF. The beauty of this design is that, once built, it requires little maintenance or upkeep. Throughout the design process, robust materials and simple systems were chosen for the purpose of maximizing lifetime and minimizing repairs. Even the hydrogen energy storage system only requires a "check-up" once every few years. All required maintenance and monitoring for the hydrogen system is provided by ElektrikGreen. Although the cost per square foot may be slightly higher than most affordable homes, our building will operate free of charge throughout its lifespan. Just as important, the home will operate free of carbon. The solar and hydrogen let the home ignore the grid, eliminating the dreaded monthly power bill. This could save the homeowner as much as $100 a month. The home can even operate entirely on its own during a power outage for up to three days. These more expensive decisions were made up front in favor of eliminating monthly costs for the homeowner down the road. These initial costs also resulted in more resilient materials and technologies, allowing the home to benefit more per dollar spent. In a drastically increasing energy market

Livability

Sustainable Standards

The three elements of sustainable development are economic, environmental, and social [3]. While economics and cost are often the biggest challenges in affordable housing design, environmental impact and carbon emissions are major design considerations as well. However, the high cost of sustainable building materials and technologies creates a substantial design barrier [4]. Regarding the social impact of sustainable development, lack of affordable housing is related to poor health outcomes [5] and therefore, air quality free of the most harmful pollutants is a critical design consideration.

Some other barriers that impact affordable housing design and construction include a shortage of skilled labor, poor construction quality, high cost of land, and frequency and extent of maintenance [4]. Research found that "after less than two years of low-income homeownership, about half of the more than 350 new homeowners surveyed faced unexpected costs, and about a third need home repairs they cannot afford" [6]. These results raise concerns about the initial quality of affordable housing and the long-term sustainability of low-income homeownership. It is important to provide low-income families with effective pre-purchase services as well as ongoing assistance to ensure homeownership is a successful asset and not a major burden.

Affordable Standards

The U.S. Department of Housing and Urban Development defines affordable housing as a dwelling that a family or household can obtain–whether through rent, purchase, or other means that costs no more than 30 percent of gross income, including utilities. By definition, cost is the highest priority for affordable housing communities [7]. The different types of cost come in the forms of building material cost, labor and installation cost, monthly rent or mortgage payments, monthly energy bills, and ongoing maintenance costs. Since this study is aimed to assist in design decisions, upfront material and labor cost associated with construction are considered.

Monthly energy costs can be directly related to the building design so operational energy consumption must be considered as a design decision factor. Sozer (2010) found that improving

building envelope design at the design development phase of a hotel in Turkey can provide a 40% reduction in operational energy [8]. Operational energy is defined as "the energy required during the entire service life of a structure such as lighting, heating, cooling, ventilating systems, and operating building appliances" [9]. Reducing operational energy consumption reduces monthly energy bills, carbon emissions and environmental impact.
and building archetype dictates the makeup of embodied energy versus operational energy. Hong (2020) found that the total embodied energy of the residential buildings accounted for 22%–91% of the total life cycle energy over a 60-year period" [10]. Therefore, investigating both embodied energy and operational energy of a home can indicate the overall life cycle energy and environmental impact.

According to US census data, low-income households spent on average 8.1% of their income on energy costs, compared to 2.3 percent for wealthier households. This often leads to families cutting something such as groceries, medical expenses, etc.

Shown highlighted in blue (mobile homes, low income, and <1000 SF homes) have some of the largest yearly energy demand and costs compared to the baseline.

Summary Annual Household Site Consumption and Expenditures in the West--Totals and Intensities, 2015

West	Homes (million)	Site Energy Consumption Per SF (kBtu)	Energy Expenditures Per SF ($)	750 SF kBtu	% Change From Baseline	750 SF $	% Change From Baseline
All homes	26.4	33.4	0.85	25050	0%	637.5	0%
MTN North	4.2	38.7	0.73	29025	16%	547.5	-14%
Housing Type							
All homes	26.4	33.4	0.85	25050	0%	637.5	0%
Single Family Detached	16.2	32.6	0.8	24450	-2%	600	-6%
Single Family Attached	1.6	33	0.83	24750	-1%	622.5	-2%
Apartments	5.3	32.2	1	24150	-4%	750	18%
Mobile Homes	1.4	48.4	1.3	36300	45%	975	53%
Total Square Footage							
Fewer than 1,000	7.4	46.2	1.27	34650	38%	952.5	49%
1,000 to 1,499	6.2	43.3	1.10	32475	30%	825	29%
1,500 to 1,999	3.9	37.5	0.95	28125	12%	712.5	12%
2,000 to 2,499	3.1	32.7	0.83	24525	-2%	622.5	-2%
2,500 to 2,999	1.9	31.7	0.75	23775	-5%	562.5	-12%
3,000 or greater	3.8	23.1	0.57	17325	-31%	427.5	-33%
2015 annual household income							
Less than $20,000	5.0	39.2	1.01	29400	17%	757.5	19%
$20,000 to $39,999	5.3	35.3	0.82	26475	6%	615	-4%
$40,000 to $59,999	3.6	33.5	0.83	25125	0%	622.5	-2%
$60,000 to $79,999	3.5	34.9	0.85	26175	4%	637.5	0%
$80,000 to $99,999	2.4	34.0	0.84	25500	2%	630	-1%
$100,000 to $119,999	2.3	28.8	0.75	21600	-14%	562.5	-12%
$120,000 to $139,999	1.2	30.9	0.79	23175	-7%	592.5	-7%
$140,000 or more	3.1	29.6	0.87	22200	-11%	652.5	2%

The Resulting Design

The home was designed with these two sets of standards in mind. A user-centered approach was taken to maximize occupant comfort and to incentivize energy-saving behavior. Decisions regarding the interior of the home often went above and beyond minimum livability requirements in order to create what our team felt was a comfortable living setting. For example, the interior lighting is planned to provide well over the required lumens in every room of the house. But at the same time, dimmers are used frequently in case the homeowner prefers dimmer conditions. Another way our team incentivizes lower energy use is using advanced yet simple energy monitoring technology. Homeowners will be able to see how much energy they are consuming, how much is being produced by the panels, and how much is available via hydrogen storage. By keeping an eye on these metrics, residents can make choices with the goal of not having a monthly energy bill. For instance, a cloudy forecast and low hydrogen levels could mean holding off on laundry until it's sunny again.

Buildability

Since our team was making modifications to already existing construction drawings, we have professionally generated and stamped drawings of our final design. In addition, we developed more details than required because of our complicated design modifications. We wanted to ensure that if none of our team was on-site, builders could look at our plans and details and move forward solely based on those. This is especially important given that Habitat uses the volunteer model to build homes. We made sure that builders could easily understand since not only do they have to build it, but they have to teach folks with no experience how to build it. If they do have questions, our team is available on standby to provide verbal and written clarification.

Scalability

Our design was not prefabricated although it certainly has all of the elements to be. The framing is simple given the rectangular footprint of the home. Pre-fabrication could certainly be done ahead of time in warehouses for builders who have the resources and are battling winter conditions or other factors. The only real complexity of this building that may be foreign to many is the air barrier system. There are some tricky maneuvers necessary to ensure the envelope is as tight as possible. This is further complicated by the conditioned space over unconditioned garage design. However, we have details for all of this and the air and vapor barrier supplier, 475 Building Supply, has full documentation and tutorials on building with their materials.

Within the current housing market, we feel our design is poised to take off. Just the fact that the unit is an above-garage unit makes it extremely enticing in our local market here on Colorado's front range. We feel confident that this same appeal will hold in other urban markets where folks are beginning to build more above-garage units as ADUs. When you factor in that the home has no monthly bills, the design becomes even more attractive. But by far the biggest draw of this design is the hydrogen energy storage system. Such a system has never been seen before in the United States. We feel that we have introduced it in a cost-effective manner by implementing it in such a small footprint. The small size of the home allows the money that would typically be put into more space to be re-invested into the hydrogen system.