sustainability

MDPI

Article

Refocusing on Sustainability: Promoting Straw Bale Building for Government-Assisted, Self-Help Housing Programs in Utah and Abroad

Bryan Dorsey

Department of Geography, Environment, and Sustainability, Weber State University, Ogden, UT 84408, USA; bdorsey@weber.edu

Abstract: Central to this housing program evaluation and policy analysis is the need to clarify competing definitions of self-help housing and to delineate the role of straw bale building in creating more sustainable, subsidized housing programs. Straw bale home construction is shown to be achieved at a lower cost, with lower embodied carbon than conventional housing, yet the building technique is not widely practiced as part of government-assisted housing, internationally, nor among mutual self-help housing (MSHH) programs in the United States, due in part to limitations of code adoption. Community Rebuilds, a federally subsidized MSHH program in Moab, Utah, is compared to other self-help housing programs in the state and stands apart with current "living building" development. Interviews and survey results from Community Rebuilds staff, contractors, and homeowners provide qualitative insights regarding the value of social capital, and embodied carbon calculations were used to assess the sustainability of conventional versus natural building methods and materials. Results confirm the need for increasing straw bale building code adoption and the creation of more sustainable self-help housing options in the U.S. and abroad.

Keywords: living buildings; residential code; self-help housing; straw bale construction

Citation: Dorsey, B. Refocusing on Sustainability: Promoting Straw Bale Building for Government-Assisted, Self-Help Housing Programs in Utah and Abroad. *Sustainability* **2021**, *13*, 2545. https://doi.org/10.3390/su13052545

Academic Editor: Manuela Almeida

Received: 18 December 2020
Accepted: 9 February 2021
Published: 26 February 2021

1. Introduction

Although collaborative housing in Europe has received considerable attention in recent years [1–3], scant attention has been given to the study of the informal housing sector and the role of self-help housing in the United States [4–7]. Research that draws a connection between straw bale building code and self-help housing is even rarer, with only one article detected from a case study of a low-income housing project in the United Kingdom [8]. This is understandable given that the only mutual self-help housing program in the United States involving straw bale building methods was found in Moab, Utah. As with housing studies focused on the informal sector, the majority of these studies focus on the developing world.

This article addresses a gap in the literature specific to government-assisted, self-help housing (SHH) programs in the U.S. and increasingly popular natural building methods that are transitioning to the formal housing sector. Another void in contemporary research is the conceptual and theoretical study of sustainability as it applies to housing studies. Given the need to reduce global carbon emissions, it is argued that subsidized housing projects should implement lower embodied energy construction methods and materials. Mukhija and Scott-Railton [5] noted that assisted, or "aided" SHH, is rarely discussed in academic journals but is more often the subject of government agency reports and non-profit housing organization's newsletters or postings on websites. However, Czischke, Carriou, and Lang provide an important update on SHH in Europe by advancing the call for "affordability and higher environmental sustainability standards" [2]. The comparative analysis of SHH programs in Utah herein may lend insight as to how these two objectives may be achieved both in the U.S. and Europe. This study relies primarily on qualitative analysis, with some supporting demographic statistics to build on sustainability theories, and makes policy recommendations based on emerging building codes for straw bale residential construction in self-help housing programs. Leading research questions to be addressed herein include the following:

1. How might self-help housing be more clearly defined, and how does this contribute to the broader international discussion of collaborative housing studies and sustainable home building?
2. Should government-assisted self-help housing programs target sustainable building design with low embodied energy and carbon emissions, and if so, why is there little to no supporting straw bale building code in the U.S.?
3. What policy reform can be made based on analysis of contrasting mutual self-help housing programs in Utah, given what shall be termed an "environmental economic crisis" in the context of international housing?
4. What role does the self-help home program participant (eventual homeowner) play in advancing the knowledge and practice of low embodied carbon, straw bale home building?

2. Differing Definitions of Self-Help Housing and Previous Studies

While collaborative housing, co-housing, and self-help housing are similar terms, they may differ in that the latter usually involves individually owned private homes, often void of communal living conditions, despite shared labor, i.e., social capital, in the construction process. Self-help housing fits with what Lang, Chatterton, and Mullins discuss as "community-led housing" in England, whereby the concept of "strategic niche management" is used to identify various "grassroot innovations." The authors note that "attempts to drastically roll out low carbon housing have stalled" [3]. In the case of straw bale building, a nearly literal grassroot innovation has been identified as a low embodied carbon building method demanding the attention from the international community and those involved in collaborative or self-help housing program development. As such, this study focused primarily upon the role of straw bale building as a clear leader in low-carbon housing ideally suited for lower-income housing development and less on the theoretical, academic debates of housing itself.

To have self-help housing studies be clearly focused and of more significant validity, it is essential to make distinctions between "government-assisted self-help" and "unassisted self-help." Scholarly publications sometimes blur the distinction between the two. Assisted, and more distinctly, government-assisted self-help housing is prevalent in the formal housing sector, whereas more broadly occurring, unassisted self-help home building and maintenance occurs more typically in the informal sector [9]. Assisted self-help housing is almost always code-compliant due to funding mechanisms used to support such programs. There is also the distinction between "self-built" housing that implies owner-built and occupied homes, as opposed to "self-help" housing which relies upon and even requires some form of communal labor in the construction process. It is understandable that there is often some confusion between these terms and respective home building programs since the boundary between the formal and informal housing sectors shifts with building code revisions, additions, and varying levels of compliance. While macro-level data analysis of self-help housing can lend great insight, such as recent studies by Brown, Mukhija, and Shoup [10] and Durst and Cangelosi [4], there is a risk of misleading findings due to aggregation of statistical data.

Durst and Cangelosi [4] noted the following important differences between "self-built" and conventional housing in their analysis based on the American Housing Survey (AHS) data (1997–2011) from the U.S. Census Bureau. "Self-help" dwellings ("self-help" and "self-built" are used interchangeably by the authors) were found to be about 400 ft^2 (37 m^2) larger than conventional homes. They found that, nation-wide, the average housing value of self-help homes was USD 293,352, close to that of conventional houses, USD 299,820; the average value of self-built dwellings in urban areas was USD 408,641, significantly higher than those in rural areas averaging USD 245,743. The figures for rural areas are similar to those found in selected Utah cities, though the median home value in 2019 in Salt Lake City was not much higher. This research addressed their suggestion for more detailed case studies and qualitative research to better understand the extent to which self-built, or in this case, assisted self-help housing, "circumvents land use regulations and building codes, [and] the challenges this poses for local governments . . . " [4]. If self-built is disaggregated from self-help housing, which is not an option from the review of AHS data in 2019, it is observed that self-help housing does not circumvent code, but can actually assist in the establishment of more energy-efficient building code. The debate as to whether or not regulation often leads to more, rather than less, informality [10–12] is an important subject but lies beyond the scope of this study.

The primary form of American government assistance for low- and very-low-income housing comes from the U.S. Department of Agriculture's (USDA) Mutual Self-Help Housing (MSHH) loan program, a variation on the Housing and Urban Development (HUD) Section 502 homeownership program. While HUD manages the Self-Help Homeownership Opportunity Program (SHOP), the Rural Housing Service (RHS) has oversight of the USDA MSHH program. These government-funded programs are typically managed by localized non-profit, self-help organizations (SHOs). RHS requires that households participating in an MSHH-funded project provide approximately 65% of the construction labor on their own and each other's homes under qualified supervision. The reduction in labor costs is cited as essential to assisting individuals and families who may be otherwise unable to attain homeownership.

Total floor area, including garage area, is an important determinant in net embodied carbon and overall sustainability of housing. The few academic studies of MSHH programs and managing SHOs found that self-help homes were typically larger than conventional homes [4,5]. In their study of SHOs in California, Mukhija and Scott-Railton [5] observed what they termed the disappearance of "modest housing," as more contemporary homes had two-car garages and increasing floor areas, and therefore higher construction costs. The authors are critical of this relaxation of USDA MSHH stipulations on house size and recommend a return to more "modest" home design standards. A similar pattern of larger than average houses with two-car garages was observed among four of the five programs in this study from Utah. The median American house size had continued to rise to almost 2386 ft^2 (222 m^2) in 2018 [13]. The 2019 Census [14] indicated the median size of a completed single-family house was only slightly lower than the previous year (2301 ft^2). While encouraging with regard to sustainability, it remains to be seen if this will become a downward trend.

Another crucial consideration in determining the sustainability of a home is the energy use for heating/cooling and electricity use in the home. As floor areas increase, heating and cooling costs typically rise as well, though the amount of energy used obviously varies according to occupants' lifestyles. In a study of Australian homeowners, energy use varied as much as 33% between homes of the same design [15]. According to the American Housing Survey data from 2019, there were 768,000 of a total 124,135,000 housing units in the U.S. (0.6%) that were "severely inadequate" in terms of heating. The Census Bureau defines this as a home that census respondents deemed as "having been uncomfortably cold last winter for 24 h or more because the heating equipment broke down, and it broke down at least three times last winter for at least 6 h each time" [14]. This is important background information when addressing lower-income housing, particularly mobile and modular homes being replaced in MSHH programs.

3. Underpinnings in Sustainability Theory: Shifting toward "modest" Houses with Lowered Embodied Carbon

While it has been argued that community planning efforts involving housing should address social, environmental, and economic interests of community members [16], less attention has been focused on creating a more sustainable housing stock for lower-income families and individuals in subsidized SHH programs. The broader sustainability issues, such as long-term damages to natural resource systems [17] resulting from high embodied energy/carbon construction practices are rarely considered. In their widely cited report for the Worldwatch Institute, Roodman and Lennsen [18] estimated that 3 billion tons, or approximately 40% of global consumption, were consumed by the residential and commercial building sectors. When comparing CO_2 emissions by different sectors in the U.S., it is instructive to note that in 2019, the residential sector accounted for almost 19% of total emissions [19]. The United Nations [20] estimates that buildings and construction account for approximately 40% of global CO_2 emissions, hence the imperative to establish natural building programs that link these sectors with social equity, i.e., affordable SHH, in a move toward broader sustainable community development.

Given the need to reduce global carbon emissions, it is essential to develop the world's housing stock using energy-efficient design and building methods. Addressing the ecological footprint of home construction is slowly emerging in housing studies [21,22]. Energy-efficient housing and contemporary net-zero homes are gaining popularity in residential planning throughout the world [23], including the U.S. [24] and South Korea [25], though few studies focus on the importance of straw bale construction. Whole-life CO_2 emissions of a low-income house in the U.K. using straw bale walls over its 60-year design life were found to be reduced by more than 60% when compared to conventional walls [8].

MSHH programs ought to embrace this shift in architectural education and practices identified by Canizaro and Tanzer [21]. Conventional building materials such as structural insulated panels (SIPs), usually composed of two sheets of particle board heavily glued to an interior polystyrene foam board, differ significantly from natural building materials that are composed of renewable resources. Natural building materials, such as straw bales covered by natural lime plasters, are more environmentally responsible since the life-time of the material is taken into consideration [26]. This cradle-to-grave, or manufacturing-to-disposal, consideration regarding building materials has gained some traction through the Building Research Establishment's Environmental Assessment Method (BREEAM) and its contemporary sustainability rating system, Leadership in Energy and Environmental Design (LEED). While LEED certification has not been widely practiced in the formal residential building sector in the U.S., an even more rigorous standard has been set through the Living Building Challenge (LBC) design certification by the International Living Future Institute [27]. Magwood [28] outlined key differences in rating systems, including Energy Star ratings used by SHOs in Utah, and noted that the LBC has the only certified ratings that include embodied carbon/energy calculations.

Rather than net-zero design, whereby homes equipped with photovoltaic (PV) systems produce more electricity than they consume, the living building is designed to achieve net-positive energy, water, and waste production, i.e., carbon sequestration. As a result, the LBC home not only generates more energy than is consumed, but it harvests, treats, and uses all water needed without being dependent on municipal culinary and waste water infrastructure. Similar to LEED-certified homes, the LBC home is constructed to remove and salvage materials that might otherwise enter into the waste stream, yet the LBC home takes a more comprehensive and regenerative approach to include the surrounding community. LBC homes currently being built by the Moab SHO, Community Rebuilds (CR), have both grey and black water systems constructed under "test permit" status from the Grand County Health Department.

Magwood [28] used the Inventory of Carbon and Energy [29] calculations to estimate that the net amount of embodied carbon (CO2e per pound or kilogram generated in the extraction, production, and transportation of materials) in a conventional 1000 ft^2 (93 $m^{2)}$ home, based on typical code compliance, is just over 22,000+ lbs. (10,000 kg.); whereas the net carbon footprint for a low-carbon home built to code is roughly 740 lbs. (335 kg.). Ironically, a high-performance home using materials such as polystyrene foam board and fiberglass insulation may have a net carbon footprint of nearly 30,000 lbs. (~13,500 kg.). In contrast, a high-performance, low-carbon home utilizing straw bale insulation, lime and clay plasters, etc., can be constructed with a negative (sequestered) carbon footprint of nearly 28,000 lbs. (−12,688 kg.). The 1000 ft^2 (93 m^2) homes built by CR fall into this latter category of carbon sequestration when considering the materials used for foundation, walls, windows, flooring, ceiling, and roof. For a full comparison of embodied carbon and carbon sequestration estimated for the different materials of these six building components, see Magwood's [28] *Essential Sustainable Home Design*. Accepting Magwood's analysis, most of the Section 502 self-help housing stock might be defined as "sub-standard."

4. Evolution of Straw Bale Construction and Code

Evaluation of MSHH programs aimed at reducing housing costs ought to give some consideration to energy use and construction methods with accompanying building code. The literature on straw bale building (SBB) is vast, and much of this work remains outside of scholarly journal publications (e.g., Hammer [30]; Magwood [31]; Magwood [28]). Earlier calls for architectural engineering studies of SBB [32] have been answered by ongoing research, but much work remains [33]. Due in large part to the sustained efforts and work by architect Martin Hammer at the University of California—Berkeley, detailed building code for straw bale home construction was adopted into the International Residential Code (IRC) as Appendix S. The code development has been instrumental in bringing this age-old natural building method more mainstream but remains either disregarded or unknown among participants and policy-makers in assisted self-help housing. Eisenberg and Hammer [34] provided a brief history of straw bale building code evolution and note that the first permitted straw bale building was a retreat center built in Kortright, New York, in 1989. Henderson [35] detailed the documentation of the evolution of straw bale building and challenges of establishing building code [36], but much has changed since her landmark study, the most important being the passage of the IRC, Appendix S. If self-help organizations (SHOs) include straw bale construction, administrators will typically need to contend with the void in local natural building code adoption.

Discussion of the need for building code for straw bale construction is predicated on the argument that straw bales are an economically and ecologically sustainable form of wall insulation [28,34,37]. Cascone, Rapisarda, and Cascone [38] provided an excellent review of the importance of using straw bales for both thermal and acoustic properties. Straw bale homes are nothing new, and prefabricated, straw-insulated wall panel systems are developing rapidly. Buildings using straw-insulated panels are reaching eight stories in France [39]. Recent developments in China focused on engineering, particularly thermal value testing, utilizing straw bale construction [40]. In the U.S., some states endorse building code that supports low-cost, energy-efficient housing, but only the California State Building Code: 18,944.30 [41] points to the need for straw bale construction. Further research is needed to identify detailed increases in code as a national and possibly international trend.

Although "greening" of state building code is an essential step toward encouraging more sustainable building practices, there are drawbacks and other broader land-use planning measures that can be taken. The International Green Construction Code (IGCC) does not include residential construction, and therefore officials trained in IGCC are not well equipped to evaluate "green," also known as natural-building, residential code. An alternative would be to work on the greening of comprehensive plans, zoning codes, and provide incentives for higher density development with connections to transit [42–44]. Further insight into sustainable community development may be gleaned from the evaluation of ecovillages and cohousing communities [45,46].

5. Methodology

This study relied on both qualitative and quantitative analyses, the former consisting of interviews with MSHH program directors and a small sample of Community Rebuilds (CR) homeowners in Moab, Utah. Data from the U.S. Census Bureau, the American Housing Survey, and estimated embodied carbon/energy of houses (expressed in U.S. pounds) formed the basis of quantitative analysis for the study. The study adopted a methodology similar to that used by Mukhija and Scott-Railton [5] that provides the most closely related research of MSHH programs in California. The author compared four of ten SHH programs available in Utah, using interviews of program administrators as well as participants, and a variety of reports, including participant profiles publicly available on respective websites. All but two interviews were kept anonymous, and the survey distributed to CR homeowners was approved by an Institutional Review Board. Though peripheral to the main findings, the brief survey was administered via email to approximately 30 CR straw bale homeowners. CR staff members assisted in disseminating the survey and were able to attain responses from thirteen participants, a small but significantly representative sample of more than 30% of CR program homeowners in Moab and Crested Butte, Colorado. CR also has straw bale homes built in Bluff, Utah. Analysis and results focus primarily on CR since it was found to be the only SHH program using natural building methods.

Mukhija and Scott-Railton [5] compared changes in three MSHH programs over a 30-year time span, beginning in the 1980s, then 1990s, and 2000s. Since the Utah SHOs were all formed around 2000, there was less focus on longitudinal data. Their study of programs in California provided insight regarding rising housing costs and loan amounts, while average incomes in California remained flat, yet there was no discussion of energy efficiency, which ultimately adds to housing operation and maintenance costs. Updates on much of their data can be found in the National Rural Housing Coalition's [47] most recent survey, including the Coachella Valley Housing Coalition featured in their study. The USDA sponsors over 160 MSHH programs nationally, and numerous websites provide information on these programs, with state-by-state listings at https://www.selfhelphousingspotlight.org. According to these listings, Community Rebuilds in Moab is the only program in the U.S. utilizing straw bale construction.

Methods of housing program evaluation and sustainability assessment for Utah SHOs were based upon embodied carbon calculations previously noted by Magwood [28] (Table 1). Magwood's [28] calculations drew on estimates generated by the Inventory of Carbon and Energy (ICE) [29], Version 2.0, available from Circular Ecology [48]. High performance conventional, code-compliant houses constructed by SHOs that rely on the use of concrete, polystyrene foam board, wood framing, sheetrock, oriented strand board (also known as particle board), fiberglass batt insulation, and asphalt shingles have an embodied energy/carbon load of 30,000 lbs. for a floor area of 1000 ft^2 (93 m^2).

Table 1. Estimated embodied carbon for different building methods.

Type of 1000 sq. ft. (93 m^2) Home (Typical Materials Used in Foundation, Floors, Walls, Ceiling, and Roofing)	Embodied Carbon for Foundation, Floors, Walls, Windows, Ceiling, and Roofing Materials
Conventional code-compliant (concrete, vinyl flooring and siding, wood framing, OSB, sheetrock, fiberglass batts, asphalt shingles)	22,000 + lbs. (10,000 kg.)
High-performance conventional, code-compliant (concrete, polystyrene foam board, wood framing, sheetrock, OSB, fiberglass batts, asphalt shingles)	30,000 lbs. (13,500 kg.)
High-performance non-conventional, requiring special permit (if allowed) (minimal concrete, adobe, wood post and beam framing, straw bale insulation, natural lime plasters on interior and exterior walls, recycled metal roofing)	28,000 lbs. (−12,700 kg.) Carbon sequestered

Sources: Adapted from Magwood [28] and Inventory of Carbon and Energy [29].

The study area spanned the state of Utah, with particular focus on the City of Moab, though additional cities of Logan, Orem, Provo, and Saint George were given consideration since MSHH programs are found in those cities or surrounding areas. Though Salt Lake City is not part of rural Utah, demographics for the largest Metropolitan Statistical Area (MSA) in the state were noted since Habitat for Humanity has housing projects there. Table 2 shows basic demographics for the cities and important comparisons on estimated house size, home values, and monthly mortgage payment information. The issue of USDA Rural Development funds funneled to MSHH to subsidize housing in areas that are more suburban than rural is another concern that deserves further research. Preliminary conclusions can be drawn from comparing Tables 2 and 3 for Utah, though nation-wide, longitudinal studies are needed.

Table 2. Demographics for the study area.

City	Logan	Moab	Orem	Park City	Salt LakeCity	St. George
Population 2019	51,542	5336	97,830	8526	200,567	89,587
Population increase (% change 2010–2019)	6.9%	5.3%	10.8%	12.8%	7.6%	23.1%
Ave. household size	2.8	2.48	3.32	2.55	2.43	2.8
Median household income	\$39,719	\$48,879	\$61,373	\$105, 263	\$56,370	\$55,061
Median home value (owner occupied)	\$181,500	\$231,700	\$247,100	\$991,900	\$289,200	\$261,800
Ave. home size (change from one year earlier) *	1977 ft^2 (−17%)	1653 ft^2 (+2%)	3492 ft^2 (+31%)	2101 ft^2 (−19%)	1928 ft^2 (−6%)	2673 ft^2 (+21%)
Monthly owner costs w/mortgage 2014–2018	\$1173	\$1241	\$1417	\$2391	\$1534	\$1428
Monthly owner costs w/out mortgage 2014–2018	\$370	\$309	\$400	\$1108	\$482	\$382
Percent owner occupied housing (2014–2018)	38.7%	53.2%	59.6%	59.8%	48.4%	65%

Source: U.S. Census Bureau, 2019. * Available online: https://www.movoto.com/market-trends/ (accessed on 23 November 2020).

Table 3. Home building assistance programs in Utah.

SHH Program (Estimated # Homes Built Since Founded)	Main Locations in Utah	Estimated Construction Cost (Excluding Labor)	Average Home Size (Square FootAge) (# Bedrooms and Bathrooms)	Estimated Ave. Embodied Carbon/House (Program Total)
Community Rebuilds (30 since 2010)	Moab (Grand County)	\$80,000-\$90,000	1000 ft^2 2 bedrm., 1 bath	Negative 28,000 lbs. (−12.7 metric tons)
Fresh Start Ventures * (no data, 2018)	Orem Pleasant Grove (Utah County)	\$30,000-\$70,000	500 ft^2	11,000 lbs. (5 metric tons)
Habitat for Humanity (240 since 1986)	Cache, Salt Lake, and Utah Valleys (state-wide)	\$110,000-\$120,000	1200 ft^2 2–4 bedrm., 1 1/2 bath	30,000 lbs. (13.6 metric tons)
Mountainlands Community Housing Trust (158 since 2002)	Park City (Summit County)	\$400,000-\$600,000	1400–1800 ft^2 3–4 bedrm.s, 2 bath	50,000 lbs. (22.7 metric tons)
Neighborhood Housing Solutions (350 since 2001)	Cache Valley (Cache and Box Elder Counties)	\$140,000-\$160,000	1250–1700 ft^2 3–4 bedrm.s, 2 bath	45,000 lbs. (20.4 metric tons)
Self-Help Homes (400 since 2000)	St. George: (Washington Co.) Orem–Provo: (Utah and Wasatch Counties)	\$260,000-\$360,000	2350–2500 ft^2 3 bedrm., 2 bath	75,000 lbs. (34 metric tons)

Sources: Websites for respective programs (see References). *Note: Fresh Start Ventures (FSV) offers assistance primarily to individuals transitioning from correctional institutions to homeownership.

6. Results: Analysis of SHH Programs in Utah

There are currently nine different SHH programs in Utah offering loans subsidized by the USDA MSHH program. Listed generally from north to south these include Neighborhood Housing Solutions (Logan, Northern Utah), Mountainlands Community Housing Trust (Park City area), Habitat for Humanity (Salt Lake City area and throughout the state), Self-Help Homes (Orem, Utah Valley, and Saint George area of Southern Utah), Uintah Basin Association of Governments (Roosevelt, East-Central Utah, 129 homes since 1999), Six County Association of Governments in Central Utah (some MSHH, but no reporting), Housing Authority of Southeastern Utah (Moab office, 120 homes since 2000), Community Rebuilds (Moab, small-scale natural building program), and Southeastern Utah Association of Local Governments (in the initiation phase of MSHH). Based on the availability of housing data, this study analyzed five of these programs to make comparisons in cost, scale, and sustainability, expressed as embodied carbon.

Table 4 includes information for five Utah MSHH programs evaluated here and one additional SHH program that is unique and does not include MSHH funding. The Fresh Start Ventures (FSV) program based in Orem differs significantly from other SHH programs in that the SHO assists individuals and households transitioning from correctional institutions back into the community. FSV provides financial assistance for the construction of accessory dwelling units, also known as "tiny houses," or residential structures with floor areas less than 500 ft^2 (46.5 m^2) (Figure 1). Tiny homes, and tiny house villages, use fewer resources than their conventionally larger counterparts due to economies of scale. Though FSV was not included in the recent study by Evans [49], her research provides an important starting point in registering tiny house villages. These small communities help to address what has been termed the "housing crisis" in the U.S. [50]; typically defined in terms of economic boom and bust [51] but more broadly defined herein to include an interconnected "environmental economic crisis" in housing.

Figure 1. Fresh Start Ventures tiny home. Available online: https://www.freshstartventures.org/tiny-homes (accessed on 20 November 2020).

Utah SHOs used in this comparative evaluation include the internationally renowned Habitat for Humanity program and three similar programs—Mountainlands Community Housing Trust, Neighborhood Housing Solutions, and Self-Help Homes—while the Community Rebuilds (CR) program stands somewhat apart. All programs have similar income level qualifications established by the USDA and HUD but vary according to median household income and size: minimum of USD 37,000/yr. to USD 39,000/yr. and maximum median income of USD 59,300/yr. in Moab, USD 64,300/yr. in Utah County, and USD 70,700/yr. in the more affluent Wasatch and Summit Counties.

6.1. Results Regarding Embodied Carbon and Energy Use

Given the average home size of 1500 ft^2 for Cache County SHO-built houses and 2500 ft^2 for Utah County SHO houses, the embodied carbon ranges from 45,000 lbs./home to 75,000 lbs./home for respective programs (see Table 3). High-performance non-conventional houses, on the other hand, using adobe, wood post and beam framing, straw bale insulation, natural lime plasters on interior and exterior walls, and recycled metal roofing have a negative or sequestered 28,000 lbs. of embodied carbon. This is a difference of approximately 75,000 lbs. to 100,000 lbs. when comparing conventional to non-conventional, straw bale homes. The estimate is only for the housing units themselves. When conventional heating systems, i.e., natural gas-powered furnaces, are compared to electric heating units powered by on-site (roof-top) PV electrical systems, the embodied carbon calculations increase to an even greater difference. If attaching monetary value to carbon emissions at a debatable, artificially low back-stop rate of USD 45/ton for U.S. electricity industries [52], the difference in cost for carbon emissions is just over USD 2000/home when comparing conventional to straw bale residential building. In simple economic value, this figure may seem negligible, though calculations of the total tonnage of embodied carbon per SHO show a more significant difference in sustainability (Table 3).

Although embodied carbon and energy use are inextricably linked, as a starting point for comparing and evaluating the energy efficiency of homes in the differing programs, it should be recognized that reports for all programs except CR note that new home construction contracting and building code compliance include Energy Star ratings. Energy Star is a program administered by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy that promotes energy efficiency. The EPA revised its Energy Star standards in 2006 with the goal of attaining higher efficiency in home building, though no consideration is given to embodied carbon. Habitat for Humanity continues to recommend that all of their affiliates in the U.S. meet or exceed Energy Star standards. "Doing so ensures a truly affordable home for our partner families as energy prices continue to rise" [53]. Their goal is to have every Habitat home built to last "well beyond the lifetime of the mortgage." Indeed, the main website for Habitat for Humanity [53] discloses that the organization makes use of "100 football-fields worth of Styrofoam insulation" donated from the Dow building products division. Polystyrene foam board is not considered a sustainable building material, particularly when including disposal of the material when a home reaches its lifespan.

Neighborhood Housing Solutions in Logan and Self-Help Homes [54] in Orem are representative of conventional MSHH programs in the state. The former assists residents in Northern Utah in the Cache Valley area, while the latter is located in Central and Southern Utah with growth rates of 10%–23%, respectively. These conventional homes with two-car garages, shown in Figure 2, are relatively large when compared to Community Rebuilds (CR) [55] homes in Moab that do not exceed 1000 ft^2 (93 m^2) (Figure 3). Figure 3 shows a standard solar photovoltaic array used on all CR homes. In terms of energy efficiency, an evaluation of heating systems based on data from the most recent American Housing Survey [14] proves insightful. The Mountainlands SHO is different from the other two conventional housing programs since it operates in Summit County, home to the ski town of Park City where median home value is just under USD 1 million.

Figure 2. Conventional mutual self-help housing (MSHH) home in Orem, twice the floor area of Community Rebuilds (CR) straw bale home, attached two-car garage, no photovoltaic solar electrical system. Source: Self-Help Homes, Available online: http://www.selfhelphomes.org/projects/gallery/28 (accessed on 7 September 2020).

AHS [14] results for Utah show that of the total 1,023,855 occupied housing units, only 2435 had house heating from solar energy (0.2%). The vast majority, 827,604 houses rely on utility gas heat, accounting for 80.8% of the total energy used for heating. There were no estimates made for electricity use/generation from solar panels, but the number for residential installations of grid-connected photovoltaic capacity reached a high in 2016 (much of this was from utility companies totaling 1241 units measured as megawatt peak (MWp)) [56].

As previously noted, less than 1% of American homes were found to have "severely inadequate" heating [14]. However, MSHH homeowners in Utah are unlikely to deal with "severely," or even "moderately inadequate" heating systems in Utah given U.S. Environmental Protection Agency (EPA) Energy Star guidelines; homeowners participating in the Moab SHO had highly adequate, high-efficiency heating through passive solar design with wall and ceiling insulation of R-30 to R-50, respectively (R-value is the standard resistance of heat transfer, or flow through building insulation materials). Insulation and heating systems are only part of the sustainability evaluation of a home but are critically important in determining embodied energy/carbon for differing construction types in SHH housing. While most MSHH construction in Utah utilizes conventional building methods, the Moab SHO is far more "modest" in terms of floor area and energy use and uses only straw bale construction.

Figure 3. Straw bale home in Moab, <half the floor area of conventional MSHH, no garage, photovoltaic solar panel array. Source: Community Rebuilds, Available online: https://www.communityrebuilds.org/past-homeowners-and-homes?lightbox=dataItem-j9924zd11 (accessed on 23 November 2020).

6.2. Community Rebuilds (CR) in Moab: Further Results Regarding Costs, Labor, and Code

Though smaller in scale compared to conventional SHOs in Utah, CR, operating primarily in Moab, is shown to be the most sustainable community housing assistance program in the Western U.S. region. Since its inception in 2010, CR has built more than thirty-five homes utilizing straw bale insulation. The program is subsidized by the U.S. Department of Agriculture's Rural Development (USDA RD) agency and was developed in part by Dave Conine, former director of the USDA Utah RD program. Through informal interviews [57], it was found that his inception of the program was based on personal experience in building straw bale structures. His work with Emily Niehaus, founder and former Executive Director of CR, was recognized as exemplary rural development by the Obama Administration in 2015.

In order to be eligible for program assistance, CR homeowners must have lived in Moab (or other participating community) for at least two years, and have an annual income that is between the "very low" level of USD 37,050 and "low" level of USD 59,300. These annual income levels vary depending on whether the county is classified as rural or urban (Table 3). The agreement between USDA RD and CR requires that a minimum of 40% of individuals qualifying for a home be in the "very low" income category, and none can earn more than the "low" income level [58]. Most homeowners in all five SHOs qualify for 502 Direct Loans, which are low-interest, require no down payment, and have a subsidy option, all made available from the USDA RD program.

All of the CR straw bale homes, built in Moab as part of the USDA MSHH program, have floor areas of roughly 1000 ft^2 (93 m^2), less than half the U.S. median house size (2322 ft^2) [14]. Most of the homes use a similar floor plan, and none has an attached garage

(Figure 2). CR homes in Moab cost an average of USD 70/ft^2 to build (Community Rebuilds, 2020), nearly half the cost compared to the approximate USD 150/ft^2 for the average Utah home (based on U.S. Census, 2018); however, building costs can vary significantly in the U.S., ranging from USD 100/ft^2 to USD 200/ft^2 and higher, depending on location and availability of building materials. The lower building costs can be attributed to both reliance on local building materials such as straw, clay, and sand and the low labor costs that result from reliance on volunteer laborers.

The CR student education (internship) program serves as the extended family that provides most of the labor to build each home. This differs from the other two conventional MSHH programs in the state where families from participating groups provide labor on all homes in the group. Correspondence and interviews with the former and current CR program directors [58] emphasize the importance of the education program in keeping home costs as affordable as possible and playing a key role in meeting the CR mission: "to build energy efficient housing, provide education on sustainability, and improve the housing conditions of the workforce through an affordable program" [59]. CR interns are housed in a communal straw bale dormitory, provided with a stipend for communally shared meals, and commit to a six-month period during which they work side by side with homeowners and licensed building contractors with experience in straw bale construction. The education program equips volunteers not only with skills to build straw bale homes but an in-depth study of natural building, including concepts of embodied carbon in building materials. Interns often commute by bicycle or walk to nearby SB home construction sites thereby contributing to the overall sustainability of the CR program. In contrast, the SHH program in the Orem–Provo and Saint George areas establishes working groups of eight to ten participating households that assist one another in the building process, and no household moves into their home until all homes are completed.

The development of building code for straw bale construction in Moab can be instructive for other SHH programs and policy formation. Over the past twenty years, homes utilizing straw bale insulation have been constructed in the Moab area, including at least thirty-five CR homes, despite only recent adoption of building code based on IRC, Appendix S. Moab City officials attempted to have the straw bale code adopted at the state level in 2017 but were unsuccessful. Until 2019, Moab City Building officials issued permits for straw bale construction under the "Alternate Means and Materials" portion of the building code since they did not have a specific code that applied to straw bale. Like many communities, Moab does not allow load-bearing walls upon which the bales support the roof framing and covering of the house, i.e., the structure must be an engineered post and beam building. CR building contractors report supportive interaction with City officials regarding permitting and inspections. This positive relationship is fostered by the current Mayor of Moab, Emily Niehaus, founder and former Executive Director of CR.

All interviews and correspondence with SHO directors and building officials revealed positive, reciprocal relationships between parties involved in planning, building, and inspections of homes. Findings from this study reveal that government-assisted, self-help homes typically conform to code, if the code exists. However, very few counties, and even fewer American cities, with self-help housing programs have adopted code specific to natural building methods. This begs the question: would straw bale building code adoption encourage an increase in homes utilizing straw bale construction? It has been observed that natural building methods that may have originally been a part of the informal building sector slowly transition into formal, code-compliant housing [34,35]. Moab is an exception in that the Zoning and Building departments for the City have recently adopted a policy with specific requirements for straw bale construction (see https://moabcity.org/520/Straw-Bale-Construction-Requirements). These requirements were also approved by Grand County Building Officials. Other municipal and county building departments may allow for straw bale construction through "alternate methods and materials" code, or conditional use permits, though further research involving ongoing interviews with SHO directors and building officials is needed to assess the extent to which this occurs.

Regulations for energy efficiency are not required, though most conventional SHOs appear to use Energy Star standards. Most relevant to lower embodied carbon in straw bale building regulation is the specification that cement plasters are prohibited over clay plaster, i.e., the walls must "breathe." Regulations on natural plasters are critically important to the findings of this study and resultant policy recommendations since plastering is labor-intensive, and MSSH programs require homeowners to contribute 65% of the total labor during home construction. The CR education program generates much of the labor for the time-consuming plastering that employs traditional methods of a "brown coat" of plaster, then a thinner 1/2–1 inch finish coat with natural colorants. Depending on local sourcing of clay, sand, and lime, natural plasters will usually have lower embodied carbon than cement stucco or composite exterior home finishing products (see Magwood [28] for detailed estimates of embodied carbon amounts for specific building materials). According to the CR Homeowner Guide [59], volunteer labor can contribute between USD 70,000 and USD 100,000 to the total cost of the home. When discussing embodied carbon, or embodied energy in different building methods and materials, SHO directors, with the exception of the CR director, had "little to no familiarity" with concepts or calculations.

In an effort to gage perceptions and understanding of energy efficiency among CR program participants, a survey of straw bale homeowners was conducted in the spring of 2020. As noted in the methodology discussion, given the small sample size, the survey provided more valid qualitative results rather than quantitative analysis. Responses suggest that homeowners who entered the program prior to 2019 are unaware of building code updates. Furthermore, homebuyers in Moab, and particularly Crested Butte, face the challenges associated with inflated real estate values typical of booming resort towns in Utah and Colorado. Park City (Summit County) staff for the Mountainlands SHO report median home costs between USD 400,000 on the east side of Summit County and USD 600,000 closer to the Park City ski resort. Despite these challenges of rising real estate values in Moab, all but one respondent recommended building and owning a straw bale home to others.

Survey results shown in Table 4 reveal that straw bale wall insulation was perceived to be most important in terms of energy efficiency, airtight construction was ranked second in importance, and heating/cooling systems were ranked as third most important. Interestingly, solar PV roof arrays were ranked as a close fourth in importance. One respondent commented that passive solar design should have been added to the list of building elements for the survey question and noted that would have been of highest importance to them. This was an oversight in the survey design, and it must be recognized that passive solar design is a key efficiency feature of CR homes, all of which are oriented such that most windows face south. Indeed, one homeowner commented that the large south-facing windows were among the most important features of their home, both aesthetically and in terms of energy efficiency. Conventional MSHH homes in Utah include design guidelines for south-facing orientation of windows, though few homes were observed to adhere to the recommendation. More stringent code adoption and enforcement could address this issue.

When asked how familiar homeowners were with the concept of embodied carbon for various building materials, 23% of respondents were "very familiar," about half were "somewhat familiar," 8% were "not so familiar," and none was "not at all familiar." This question was followed by another asking "if you are familiar with the concept of embodied carbon, how important is this to you in your home?" About a quarter of respondents indicated that embodied carbon is "extremely important" to them, and almost half of respondents chose "very important" as a response. None chose the responses of "little to no importance." These survey results suggest that CR homeowners are somewhat educated on the concepts of carbon emissions associated with home building materials and energy efficiency and recognize the importance of embodied carbon in evaluating sustainability.

The importance of the educational program component is essential to the acknowledgment of straw bale building as a more sustainable option.

Table 4. CR homeowner survey results: ranking of building elements.

Building Element	% Ranked Most Important (1)	% Ranked Second in Importance (2)	% Ranked Third in Importance (3)	% Ranked Fourth in Importance (4)	% Ranked Least Important (5)	Total Score (1–5)
Straw bale wall insulation	85	0	7.5	0	7.5	4.5
Airtight construction	0	46	23	15.5	15.5	3
Heating/cooling systems	8	15	38.5	38.5	0	2.9
Solar PV roof array	8	23	23	23	23	2.7
Energy-efficient appliances	0	15	8	23	54	1.9

Source: Community Rebuilds Homeowner Survey [59], based on 13 respondents.

When asked to submit written commentary regarding what they view as the greatest strengths and/or possible weaknesses of the program, most respondents commented on the benefits of being engaged in the building process for their home, as well as affordability and energy efficiency. It should be noted that homeowners are required to contribute an average of 20 h/week in building their homes. Comments from one respondent emphasize one of the key benefits of the CR program: "Educating future natural builders, with an emphasis on including underrepresented groups, which will hopefully make natural building more accessible and affordable for people all over the country/world." Again, one respondent commented on the perceived weakness or constraint of "land availability in towns where real estate is expensive." This comment underscores the previously mentioned challenge of the contemporary housing crisis.

The last question of the survey had CR homeowners rank aspects of their SB home compared to other homes they have lived in, using a scale of 1–5, whereby "1 = substantially worse than other homes you have lived in," and "5 = substantially better the other homes you have lived in." The three areas of comparison were listed as "noise blocking and reduction, utility bills, and temperature stability." All thirteen homeowners consistently ranked all three aspects of their SB homes as "substantially better" than previous homes, with the exception of one respondent ranking noise blocking and reduction as 3 out of 5. These results clearly indicate that CR homeowners view their current SB home to be a substantial improvement over previous homes, some of which may have been mobile trailer homes that receive priority in the selection process of CR participants.

7. Discussion and Conclusions: Promoting Straw Bale Building for SHH

Distinctions between assisted self-help housing and more broadly defined self-help housing that includes self-built housing are important for any future empirical housing studies. Although many straw bale homes are self-built, it remains uncertain as to how many homes are not code-compliant. The government-subsidized self-help programs discussed here all had houses built to code, though building code and zoning regulations (beyond the scope of this study) do not restrict home size or resultant embodied carbon levels. As shown in Tables 1 and 3, comparisons of estimates on average home sizes, home construction costs, and embodied carbon/energy for differing building materials used by the four SHOs vary significantly. All four programs, subsidized by U.S. tax dollars, either through the U.S. Department of Housing and Urban Development (HUD) and/or the U.S. Department of Agriculture (USDA), compete. Since 2010, the top one percent of households owned more wealth than the entire middle class [60]. Due to this concentration of wealth, and economic impacts of the COVID-19 pandemic, it is projected that many individuals and families will require assistance in attaining homeownership in the near future.

While housing programs, such as Habitat for Humanity, Neighborhood Housing Solutions, Self-Help Homes, and Mountainlands Community Housing Trust operating in Utah, are effective in creating more socially sustainable, affordable housing, the CR program stands out by generating more comprehensively sustainable community development. In addition to providing quality housing at affordable rates for lower-income individuals and households, CR homes are arguably more energy-efficient than conventional low-income housing. As previously noted, the use of straw bales in exterior wall construction has been shown to increase R-values (insulation values) and reduce overall carbon emissions [8,28]. Additionally, CR homes have significantly lower embodied carbon levels when compared to conventional homes built through other self-help housing programs. The CR homeowner survey results confirm that homeowner respondents value the energy efficiency and low embodied carbon associated with their home. Three of the conventional MSHH programs in Utah have a combined estimate of almost 27,000 tons of embodied carbon, whereas the CR homes sequester 420 tons. While embodied carbon is a function of scale, it has been duly noted that conventional homes built by participating households of the Self-Help Homes program in Orem, Utah, are larger than the average American home, and the average home size in Orem increased by more than 30% between 2018 and 2019. In effect, the inequitably subsidized MSHH program is simply keeping pace with building trends for the larger than average household size in suburban Utah.

As briefly discussed, CR has been pursuing Living Building Challenge (LBC) certification with four new homes that are being built in Moab. Similar to the 35 straw bale homes previously built through the program, these dwellings will be almost half the floor area and built at half the cost of the average home in the U.S. Although delays due to the COVID-19 pandemic have slowed the progress on construction, the homes are scheduled for a twelve-month performance period to verify that they are energy- and water-positive. These homes are an experiment in the establishment of more environmentally and economically sustainable community development that will assist lower-income families and individuals to attain energy-efficient houses that are built from non-toxic building materials. If another survey were to be administered to homeowners who will occupy the LBC dwellings, it would be beneficial to gage any possible shift in the perceived sustainability of houses. Sustainability levels could be assessed not only in terms of energy efficiency but also water conservation and overall embodied carbon impacts. These aspects of housing and broader community development are likely to gain more attention as global carbon emissions continue to increase.

USDA MSHH policy-makers should be aware that straw bale construction has been successfully developed in all different climate regions, therefore the CR program could be replicated throughout the United States and abroad. Of course, a program like CR in Moab benefits from its geography, and parts of the U.S. that have less solar energy potential may not be as successful regarding overall sustainability. Though the arid southwestern region of the U.S. is favored, improvements in solar PV systems and lower costs may expand potential to the northern Midwest and Northeastern regions. It also stands to reason that, given the current evolution of prefabricated straw bale building panels (though not as sustainable as the more labor-intensive bale wall construction), MSSH programs can be transferred to similar HUD programs in urban areas. These applications and distinctions deserve further research.

The other key factor for future research involves the social and economic benefits of shared labor and subsequent transfer of knowledge to increase interest and understanding of natural building methods. Similarly, understanding and awareness of embodied energy/carbon in straw bale construction versus high-efficiency housing (presented in Table 1, based on Magwood [28]) need more thorough assessment. It is emphasized that the CR internship program is essential to sustainable community development for several reasons. First, interns gain invaluable knowledge and experience in natural building techniques that provide them with skills to pursue careers related to natural building, and in some cases, interns go on to build their own straw bale structures. Second, the CR Internship Education program is the core of the voluntary labor that makes the labor-intensive process of straw bale placement and natural plastering affordable, i.e., labor-intensive building is viewed positively rather than as a deterrent. There is significant potential to expand upon community engagement opportunities for university students to work with CR interns, both of whom may go on to participate in natural building workshops and internships. Exposure to self-help housing programs that incorporate natural building methods may broaden the horizons for students pursuing advanced degrees in community development, land use planning, architectural design, and other related fields. Participation in academic programs that focus on concepts of embodied carbon, carbon emissions reductions, and overall increased energy efficiency (LBC guidelines [27]) is of particular importance given the current need to address issues of climate change. Educational programs can, in turn, lead to broader changes in building code adoption and compliance.

The current LBC project in Moab also allows for an opportunity to modify or add new residential building codes that may have otherwise gone unchanged. While progress has been made to expand the adoption of straw bale building code at municipal and county levels, few states in the Southwestern region, other than California and New Mexico, have used the International Residential Code, Appendix S, as a springboard to establish code to promote natural building. The recent adoption of straw bale building regulations in Moab has been established without adoption by the State of Utah. Thorough cataloging of which cities, counties, and states have adopted some form of IRC Appendix S would greatly assist policy-makers, building officials, and interested homebuilders alike. Just as the use of straw bale construction has been recommended for MSHH programs, the establishment of code in urban and rural areas may well lead to a broader awareness of the need for carbon sequestration in the greater context of the American housing stock.

Author Contributions: Sole authorship.

Funding: This research received no external funding.

Institutional Review Board Statement: IRB exempt status confirmed by Weber State University IRB members.

Informed Consent Statement: An informed consent statement was used in the survey of Community Rebuilds home owners.

Data Availability Statement: Survey data available from the author upon request.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Czischke, D. Collaborative housing and housing providers: Towards an analytical framework of multi-stakeholder collaboration in housing co-production. *Int. J. Hous. Policy* **2018**, *18*, 55–81. [CrossRef]
2. Czischke, D.; Carriou, C.; Lang, R. Collaborative housing in Europe: Conceptualizing the field. *Hous. Theory Soc.* **2020**, *37*, 1–9. [CrossRef]
3. Lang, R.; Chatterton, P.; Mullins, D. Grassroots innovations in community-led housing in England: The role and evolution of intermediaries. *Int. J. Urban Sustain. Dev.* **2019**, *12*, 52–72. [CrossRef]
4. Durst, N.; Cangelosi, E. Self-help housing and DIY home improvements: Evidence from the American Housing Survey. *Hous. Stud.* **2020**, 1–19. [CrossRef]
5. Mukhija, V.; Scott-Railton, J. The importance of design in affordable housing: Lessons from mutual self-help housing in California. *Hous. Policy Debate* **2013**, *23*, 765–780. [CrossRef]
6. Ward, P.M.; Peters, P.A. Self-help housing and informal homesteading in peri-urban America: Settlement identification using digital imagery and GIS. *Habitat Int.* **2007**, *31*, 205–218. [CrossRef]
7. Ward, P.M. Self-help housing ideas and practice in the Americas. In *Planning Ideas that Matter: Livability, Territoriality, Governance, and Reflective Practice*; Sanyal, B., Vale, L.J., Rosan, C.D., Eds.; MIT Press: Cambridge, MA, USA, 2012; pp. 283–310.
8. Sodagar, B.; Rai, D.; Jones, B.; Wihan, J.; Fieldson, R. The carbon-reduction potential of straw-bale housing. *Build. Res. Inf.* **2011**, *39*, 51–65. [CrossRef]
9. Durst, N.J.; Wegmann, J. Informal Housing in the United States. *Int. J. Urban Reg. Res.* **2017**, *41*, 282–297. [CrossRef]

10. Brown, A.; Mukhija, V.; Shoup, D. Converting garages into housing. *J. Plan. Educ. Res.* **2020**, *40*, 56–68. [CrossRef]
11. Monkkonen, P.; Ronconi, L. Land use regulations, compliance and land markets in Argentina. *Urban Stud.* **2013**, *50*, 1951–1969. [CrossRef]
12. Portes, A.; Haller, W. The informal economy. In *The Handbook of Economic Sociology*; Smelser, N.J., Swedger, R., Eds.; Princeton University Press: Princeton, NJ, USA, 2010.
13. US Census Bureau. Highlights of Annual 2018 Characteristics of New Housing. 2018. Available online: https://www.census.gov/construction/chars/highlights.html (accessed on 6 June 2020).
14. US Census Bureau. American Housing Survey. 2019. Available online: https://www.census.gov/programs-surveys/ahs.html (accessed on 2 November 2020).
15. Eon, C.; Morrison, G.M.; Byrne, J. The influence of design and everyday practices on individual heating and cooling behaviour in residential homes. *Energy Effic.* **2017**, *11*, 273–293. [CrossRef]
16. Moss, M.L.; Grunkemeyer, W.T. Building shared visions for sustainable communities. *Community Dev.* **2010**, *41*, 240–254. [CrossRef]
17. Bradshaw, T.K.; Winn, K. Gleaners, do-gooders, and balers: Options for linking sustainability and economic development. *Community Dev.* **2000**, *31*, 112–129. [CrossRef]
18. Roodman, D.M.; Lenssen, N. *A Building Revolution: How Ecology and Health Concerns Are Transforming Construction*; Worldwatch Paper 124; Worldwatch Institute: Washington, DC, USA, 1995.
19. US Energy Information Administration. Energy and the Environment Explained. 2020. Available online: https://www.eia.gov/energyexplained/energy-and-the-environment/where-greenhouse-gases-come-from.php (accessed on 2 November 2020).
20. United Nations. UN Environment Annual Report, 2017. 2017. Available online: https://www.unenvironment.org/resources/un-environment-annual-report-2017 (accessed on 8 September 2020).
21. Canizaro, V.; Tanzer, K. Environmental architectures and sustainability: A taxonomy of tactics. *J. Arch. Educ.* **2007**, *60*, 4–14. [CrossRef]
22. Moos, M.; Whitfield, J.; Johnson, L.C.; Andrey, J. Does design matter? The ecological footprint as a planning tool at the local level. *J. Urban Des.* **2006**, *11*, 195–224. [CrossRef]
23. Khalil, H.A.; Khalil, E.E. *Energy Efficiency in the Urban Environment*; CRC Press, Taylor and Francis: Boca Raton, FL, USA, 2015. [CrossRef]
24. Retzlaff, R.C. Green building assessment systems: A framework and comparison for planners. *J. Am. Plan. Assoc.* **2008**, *74*, 505–519. [CrossRef]
25. Kim, S.-K.; Lee, S.-J.; Kwon, H.J.; Ahn, M. Zero-energy home development in Korea: Energy-efficient and environmentally friendly design features and future directions. *Hous. Soc.* **2015**, *42*, 222–238. [CrossRef]
26. Spiegel, R.; Meadows, D. *Green Building Materials: A Guide to Product Selection and Specification*; John Wiley & Sons: New York, NY, USA, 1999.
27. International Living Future Institute. Living Building Challenge. 2020. Available online: https://living-future.org/lbc/ (accessed on 14 July 2020).
28. Magwood, C. *Essential Sustainable Home Design: A Complete Guide to Goals, Options, and the Design Process*; New Society Publishers: Gabriola Island, BC, Canada, 2017.
29. Inventory of Carbon and Energy (ICE). 2020. Available online: http://pinpoint.ukgbc.org/resource/8277-inventory-of-carbon-and-energy/ (accessed on 3 March 2020).
30. Hammer, M. A straw bale residential building code for the United Sates. In *The Last Straw: The International Journal of Straw Bale and Natural Building*; Bales, Codes and Permits, Issue 62, Straw Bale Construction, Technical; The Last Straw Journal: Paonia, CO, USA, 2013.
31. Magwood, C. *Essential Prefab Straw Bale Construction: The Complete Step by Step Guide*; New Society Publishers: Gabriola Island, BC, Canada, 2016.
32. Swan, A.J.; Rteil, A.; Lovegrove, G. Sustainable earthen and straw bale construction in North American buildings: Codes and practice. *J. Mater. Civ. Eng.* **2011**, *23*, 866–872. [CrossRef]
33. Mutani, G.; Azzolino, C.; Macrì, M.; Mancuso, S. Straw Buildings: A Good Compromise between Environmental Sustainability and Energy-Economic Savings. *Appl. Sci.* **2020**, *10*, 2858. [CrossRef]
34. Eisenberg, D.; Hammer, M. Straw bale construction and its evolution in building codes. *Build. Saf. J. Online* **2014**, *2*, 25–29. Available online: https://www.strawbuilding.org/Resources/Documents/Strawbale_Construction_Building_Codes.pdf (accessed on 7 July 2020).
35. Henderson, K. Ethics, Culture, and Structure in the Negotiation of Straw Bale Building Codes. *Sci. Technol. Hum. Values* **2006**, *31*, 261–288. Available online: https://www.jstor.org/stable/29733940 (accessed on 14 November 2020). [CrossRef]
36. Henderson, K. Achieving legitimacy: Visual discourses in engineering design and green building code development. *Build. Res. Inf.* **2007**, *35*, 6–17. [CrossRef]
37. Harrison, R. *Prefurbia: Reinventing Land Development from Disdainable to Sustainable*, 5th ed.; self-published; 2018.
38. Cascone, S.; Rapisarda, R.; Cascone, D. Physical properties of straw bales as a construction material: A review. *Sustainability* **2019**, *11*, 3388. [CrossRef]

39. Evangelista, S. *Straw Houses in the Front Line of Sustainable Construction*; Ecole Polytechnique Federale de Lausanne, 30 January 2015. Available online: https://phys.org/news/2015-01-straw-houses-front-line-sustainable.html (accessed on 21 June 2020).
40. Yang, J.; Liu, Y.; Yang, L. Analysis and Improvement Recommendations on Straw Bale Building in Northeast China. In *Proceedings of the 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC 2019)*; Xian University: Xian, China, 2020; pp. 199–209. [CrossRef]
41. State of California Health and Safety Code. Division 13—Housing, Part 2.5—State Building Standards, Chapter 4.5—Guidelines for Straw-Bale Structures, Article 1—General Provisions and Definitions, Section 18944.30. 2018. Available online: https://law.justia.com/codes/california/2018/code-hsc/division-13/part-2.5/chapter-4.5/article-1/section-18944.30/ (accessed on 14 September 2018).
42. Shapiro, S. Code green: Is "greening" the building code the best approach to create a sustainable built environment? *Plan. Environ. Law* **2011**, *63*, 3–12. [CrossRef]
43. Wheeler, S.M. *Planning for Sustainability: Creating Livable, Equitable and Ecological Communities*, 2nd ed.; Routledge: New York, NY, USA, 2013.
44. Cullingworth, J.B.; Caves, R. *Planning in the USA: Policies, Issues and Processes*, 4th ed.; Routledge: New York, NY, USA, 2014.
45. Blay-Palmer, A. Sustainable communities, an introduction. *Local Environ. Int. J. Justice Sustain.* **2011**, *16*, 747–752. [CrossRef]
46. Daly, M. Quantifying the environmental impact of ecovillages and co-housing communities: A systematic literature review. *Local Environ.* **2017**, *22*, 1358–1377. [CrossRef]
47. National Rural Housing Coalition. 2017 Impact Report. Available online: https://ruralhousingcoalition.org/wp-content/uploads/2017/04/Impact-Report-FINAL-FOR-Web-1.pdf (accessed on 18 September 2020).
48. Circular Ecology. Inventory of Carbon and Energy (ICE) Database, Version 2.0. 2020. Available online: https://circularecology.com/embodied-carbon-footprint-database.html (accessed on 3 October 2019).
49. Evans, K. Tackling homelessness with tiny houses: An inventory of tiny house villages in the United States. *Prof. Geogr.* **2020**, *72*, 360–370. [CrossRef]
50. Berkovec, J.; Chang, Y.; McManus, D.A. Alternative lending channels and the crisis in U.S. housing markets. *Real Estate Econ.* **2012**, *40*, 8–31. [CrossRef]
51. Fresh Start Ventures. 2020. Available online: https://www.freshstartventures.org (accessed on 4 June 2020).
52. Cleary, K.; Palmer, K. Resources for the Future. 2020. Available online: https://www.rff.org/publications/explainers/carbon-pricing-201-pricing-carbon-electricity-sector/ (accessed on 24 November 2020).
53. Habitat for Humanity. 2020. Available online: https://www.habitat.org/newsroom (accessed on 23 November 2020).
54. Self Help Homes. 2020. Available online: https://www.selfhelphomes.org (accessed on 6 June 2020).
55. Community Rebuilds. Mission Statement, Image, and Notes on Cost. 2020. Available online: https://www.communityrebuilds.org/what-we-do (accessed on 20 June 2020).
56. Solar Energy Industries Association (SEIA). Utah Annual Solar Installations. Available online: https://www.seia.org/sites/default/files/2020-09/Utah.pd, (accessed on 20 November 2020).
57. Conine, D. *Unpublished Informal Interviews with Former Director of the USDA, Utah Rural Development Program*; Utah Rural Development: Salt Lake City, UT, USA, 2016.
58. Epperson, R. *Unpublished Correspondence and Interviews with Community Rebuilds Executive Director*, Moab, UT, USA, 2019.
59. Community Rebuilds Homeowner Survey. Survey of CR Homeowners, Conducted March 2020. 2020. Available online: https://www.surveymonkey.com/results/SM-JSKHDB7N7/ (accessed on 1 October 2020).
60. Sawhill, I.V.; Pulliam, C. *Six Facts about Wealth in the United States*; Brookings Institute: Washington, DC, USA, 2019; Available online: https://www.brookings.edu/blog/up-front/2019/06/25/six-facts-about-wealth-in-the-united-states/ (accessed on 3 June 2020).