Article

Building a Foundation of Pragmatic Architectural Theory to Support More Sustainable or Regenerative Straw Bale Building and Code Adoption

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ABSTRACT

This article proposes an alternative theoretical framework for architectural design and associated land use practices based on pragmatism and a "spectrum of sustainability". The current normative and dominant discourses of environmental efficiency contribute to addressing the need to lower carbon emissions; however, the academic literature tends to overlook qualitative research of more sustainable natural building methods such as those using straw insulation and natural lime plasters. Given that this less conventional architectural design and building method has been shown to sequester carbon, why hasn't straw bale building received more attention in the sustainable architecture discourse? A study of challenges and misperceptions regarding straw bale residential building lends insight to the need to take a pragmatic approach to more affordable residential development. Most building certification programs primarily target improved energy efficiency, yet the Living Building Challenge certification begins to evaluate the oft overlooked social factors and the biophilic environment. A brief recapitulation of quantitative analysis of embodied CO_2 levels/dwelling associated with self-help affordable housing programs addresses the immediate need to assess rising housing costs. An additional qualitative study using Architectural Education Strategies (AES) of the two existing straw bale buildings in Ogden, Utah involves evaluation of their educational values and illustrates a possible shift toward pragmatism in architecture. The qualitative analysis underscores the importance to salvage, reuse, and recycle building materials as a pragmatic way to reduce both CO_2 emissions and building costs. Review of building code adoption offers further understanding of the barriers to broader acceptance of this highly sustainable building method.

KEYWORDS: embodied carbon; natural building code; pragmatism; straw bale building; regenerative architecture; sustainable building

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INTRODUCTION AND OBJECTIVES: MOVING FROM NORMATIVE TO REGENERATIVE, PRAGMATIC ARCHITECTURAL THEORY

The objectives of this article are essentially three-fold. First, discussion of architectural theory focuses on a move from normative to regenerative architecture, grounded in the need to take a pragmatic approach to reducing carbon emissions associated with the construction and operation of buildings that employ natural building methods and materials. The second objective is to review advances in straw bale building code and several affordable housing programs utilizing straw bale building designs, one of which provides a strong model for architectural education, which leads into the final objective of this study. Third, qualitative research methods, specifically, Architectural Education Strategies (AES) are applied to evaluate the educational value of two existing straw bale structures. Greater education of straw bale construction methods and the benefits of natural building is an important factor in more wide-spread adoption of the practice.

Sustainable architecture, also referred to as environmental or ecological architecture/design, has been in the academic literature beginning more than ten years ago [1–7] (summarized by Kallipoliti [8]). Although Hutton [9] calls for a retirement of the term sustainability to be replaced by "regenerative design" in architecture, it seems unlikely that sustainability will disappear from the current jargon of the debate. Among the better-known bodies of work on environment/society concerns in the closely allied studies of land use planning and landscape architecture is Design with Nature by Ian McHarg [10]. McHarg's concepts regarding human adaptation, which emerged at the start of rising environmental consciousness, marked by Rachel Carson's Silent Spring [11], were prescient of current adaptations to climate change. Half a century later, "green" building, or more specific "natural" building continues to evolve to greater sophistication since one of the oldest known straw bale homes was built in Nebraska around 1900. More sustainable, or "regenerative" architecture focused on embodied energy of varying building materials, expressed as carbon emissions associated specifically with straw bale building has limited earlier study [12], yet the detailed analysis of natural building methods is rapidly expanding [13,14].

While normative architecture is often consumed by rules dictating how buildings "should be" rather than how they are [15], and pragmatism offers the potential to link "the environmental ethics of sustainability to the design, construction, and use of buildings" [1], there may be a fertile middle ground in more sustainable, pragmatic architectural theory. In simplest terms, pragmatism is defined as taking a practical approach to problem solving. Even more than twenty years ago, Thomas Fischer, then dean of the College of Architecture and Landscape Architecture at the University of Minnesota, argued that pragmatism is not necessarily atheoretical, but "urges us to look to the consequences of what we do, which the discipline of architecture, infused with an idealistic focus on intentions, frequently resists” [16]. Fischer’s quote is a sobering reminder that preoccupation with theory, regardless of discipline, can obscure our search for practical solutions to mitigate current environmental crises. In light of rapidly rising global levels of CO_2 emissions, much of “what we do” in modern society is relatively unsustainable, and much of what we build typically bears no exception. If conventional residential design is “less sustainable”, shouldn’t sustainable architecture address “more sustainable” building materials, methods, and design principles? Sustainable architecture is presented here in the context of a “spectrum of sustainability” (Figure 1), given that complete sustainability is rarely, if ever achieved. As such, pragmatic architectural theory may lead us only to “more sustainable architecture”, or possibly regenerative architecture and design. Straw bale building, shown here to be a practical solution to reducing carbon emissions, is nevertheless viewed in some communities to be impractical, or “fringe” in terms of acceptable, code-compliant residential development. The comparison between straw bale building in Moab versus Ogden, Utah in this study illustrates the issue.

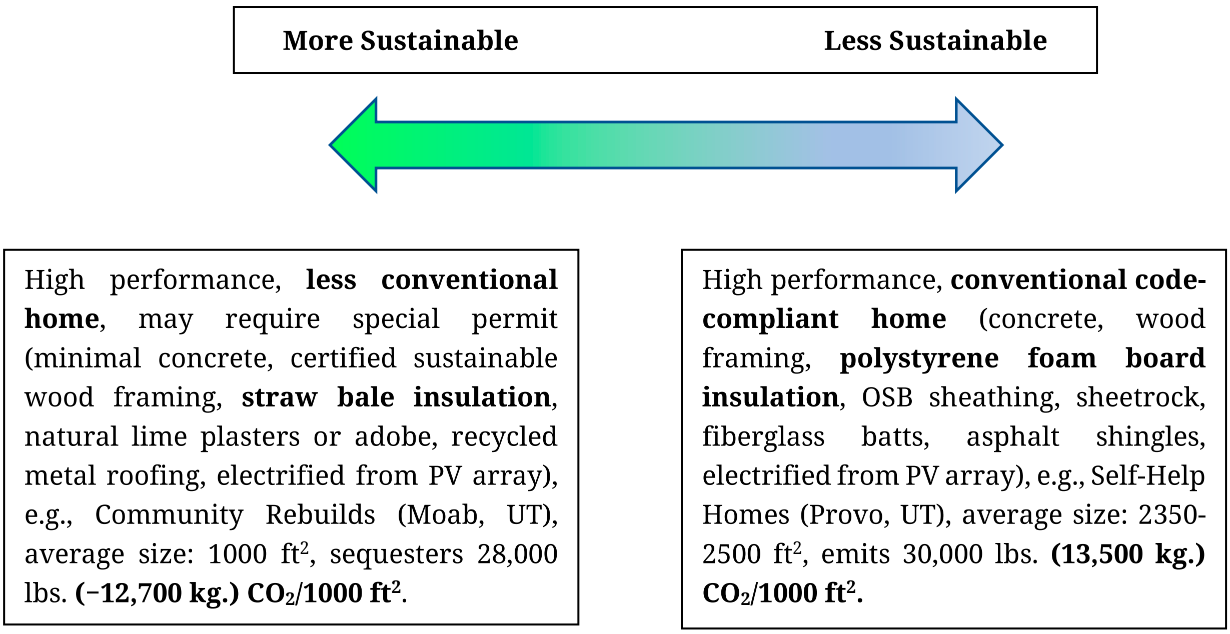

Figure 1. Spectrum of sustainable residential building materials/methods. Sources: Carbon data adapted from Magwood [17] and Inventory of Carbon and Energy [18].

Cucuzzella [19–21] points to a shift in normative architecture and environmental design from creative environmental solutions to design that has become more commonly driven by the conformity of meeting standards, such as those catalogued in Leadership in Energy and Environmental Design (LEED) certifications. There is no denying that technological advances in architecture have come at the cost of vastly altering our sense of creativity [22], and simplicity equated with the Mies van der Rohe “less is more” approach to design, much of which relied on steel and glass, is now deemed as less sustainable with regard to embodied energy/carbon. Indeed, the search for low carbon design embracing simplicity is anything but simplistic when it comes to standards and certifications. Nevertheless, some standards have begun to incorporate sustainability and social factors previously overlooked, e.g., the Living Building Challenge, and to some extent, the Building Research Establishment Environmental Assessment Method (BREEAM). The WELL Building Standard is a fairly recent attempt at assessing “wellness”, e.g., indoor air quality and natural lighting, still in a phase of development in terms of the cycle of innovation and market adoption [23]. Schroeder states “the problem” as he sees it:

“when stakeholders of a design team think they can meet their sustainability objectives by applying for a BREEAM or LEED rating, a much wider scope of problems becomes dissociated through narrow framing. Furthermore, ‘real world’ problems are displaced and dissociated from design practices through a system of awarding credits and points” [24].

It is argued here that point systems and certifications can be of value, especially if embodied energy (carbon) levels are included in the building evaluation process; though formal analysis and certification is not always needed, as will be shown by the two buildings presented in this study. Nevertheless, some consideration of embodied energy assessment is critically important to determining how “sustainable” buildings are situated in the “real world” facing the immediate need to reduce CO_2 levels and provide more affordable housing units. While work by Cucuzzella and Goubran [25] focuses primarily on public places such as museums, libraries and parks, this study touches on the importance of a nature center in the public eye, though the focal point is the proliferation of more sustainable, lower income residential development, and the role of non-profit organizations and universities in promoting natural building. More affordable, regenerative, natural building solutions demand our attention since it is estimated that an additional 6.8 million more affordable housing units are currently needed for extremely low-income families in the U.S. [26].

What may be viewed as a need to bridge the gap between conventional architecture and a pragmatic theory of architecture is embodied by a void, though narrowing, between academia and natural building designers, architects and contractors. An exception can be found in British Columbia, Canada at the Wood Innovation and Design Centre (WIDC), built in 2014 by Michael Green Architecture. Chupin, Hazbei and Pelchat [27] provide an important study of sustainable architectural education programs in Canada, including the WIDC, though none include natural building involving straw bale construction. Their methodology of analyzing programs is based on three types of educational strategies: labeling, with an emphasis on quantitative environmental performances, e.g., LEED certified; iconic, with an emphasis on a visibility of sustainability features or communicational devices, e.g., highly visible PV panels; and experiential, whereby the building itself serves as a model to be experienced. As an example, the authors ranked the WIDC building as “moderate” in terms of labeling for its potential to set an example for tall wood building code; "high" iconic value in its aesthetically appealing mass timber construction features; and "high" experiential value as students can experience being in the building to take classes. Their methods and terminology are helpful in identifying the learning opportunities entwined with the two straw bale buildings in the Ogden study.

Natural Building and Embodied Carbon

There are many natural building techniques using natural materials rather than synthetics, such as adobe, cob, rammed earth, stone, wood, and others, but only straw bale building is considered here, mainly due to its high carbon sequestration potential. Timber frame and sustainably harvested wood structures are also important natural building materials/methods that often underlie straw bale homes. Qualitative attributes of these materials, especially aesthetics, are difficult to compress into quantitative rubrics. Despite warnings that design and building can be driven purely by quantified rating systems and "points" for more sustainable building certifications, such criteria are central to establishing building code, or in the case of this study, the exclusion of more progressive sustainable building code in some communities. In Ogden, Utah, only one public building and one private garage/studio structure could be identified which embody the pragmatic, regenerative approach to architecture using straw bale construction. The natural question that arises is what makes straw bale construction more sustainable than other methods of building lower income housing, and what inhibits its more wide-spread acceptance?

What might be termed the "pragmatic school" of more sustainable architecture operates largely on the periphery of academia and focuses on practical building methods. The periphery is an important qualifying note because some independent scholars, e.g., Magwood [13] and King [14] often have some involvement with academics at universities, yet their work is rarely found in academic journal publications. The pragmatic school may be best exemplified by non-profit/non-government organizations such as Builders Without Borders (international), Builders for Climate Action (Canada), Canada Mortgage and Housing Corporation, and the Natural Building Alliance (U.S.). Builders Without Borders (BWB) has straw bale building projects mainly in economically developing regions of the world, but also engages in projects in more economically developed countries, e.g., a small straw bale structure was on exhibit in the U.S. Botanical Garden in Washington, D.C. in 2008 (see photos by Bill Steen [28]).

The Natural Building Alliance promotes networking and holds periodic conferences, e.g., Rocky Mountain Natural Building Conference in Moab, Utah, October 2021, that bring leading thinkers such as those noted above, with builders of different backgrounds. The conferences traditionally involve experiential workshops to learn about new natural building methods and materials as well as the rapidly expanding research and understanding of embodied energy, or embodied carbon in building. Indeed, any attempt to identify a more sustainable form of architecture ought to include consideration of Building Emissions Accounting for Materials (BEAM) [29], i.e., CO_2 emissions generated in the extraction, manufacturing, construction, use, and disposal of building materials, as well as the operational emissions of the building itself; collectively referred to as Life Cycle Assessment (LCA). Canadian, Chris Magwood's [13] Essential Sustainable Home Design provides an in-depth discussion of carbon sequestration in the context of straw bale building, as well as a comparison of previously mentioned certification programs including LEED for homes (in the U.S. and Canada) which has no rating of embodied carbon, and the more progressive Living Building Challenge (LBC)(U.S. and Canada), and National Green Building Standard (U.S. only), both of which rate embodied carbon for residential buildings. LBC is part of a program established by the International Living Future Institute, which emphasizes a comprehensive, "regenerative" approach to design based on seven performance categories, or "petals": place, water, energy, health + happiness, materials, equity and beauty [30]. This regenerative design concept is seen to be integral to pragmatic theory in architecture.

King [14] cautions that what we know about embodied carbon is expanding so quickly that within the next five years (since authors contributed to his landmark book), the subject will have vastly shifted to much greater depth, e.g., Magwood et al. [31]. Nevertheless, some discussion is mandatory here to better comprehend the fundamental differences between what has been termed conventional "net-zero" building to a more sustainable form of building in which carbon is actually sequestered. Catherine De Wolf, Barbara Rodriguez-Droguett and Kathrina Simonen (in King, [14]) present a comprehensive overview of embodied carbon in architecture for the reader interested in learning more. An important distinction between embodied carbon and embodied energy lies in the fact that some energy used in the extraction, manufacturing and disposal of building materials may be from renewable resources. Exact calculations of embodied carbon and LCA are complex and end-of-life impacts involve a great deal of uncertainty during the building phase. As a point of reference regarding LCA, over a 30 year life span the typical new building (deemed "not energy efficient") emits in excess of 40,000 kg CO_2, a typical 1000 square foot, new building on a "decarbonized grid" emits about 30,000+ kg CO_2, a new net-zero building with no operational impacts emits upwards of 15,000 kg CO_2, an existing building retrofitted to a more energy efficient one emits about 10,000 kg CO_2 [32]; whereas a straw bale building will sequester an estimated 12,000 kg CO_2, i.e., negative 12,000 kg CO_2 (no LCA specified) [13].

In addition to LCA, the Social Life Cycle Impact Assessment (sLCIA) of building methods gives a broader view of the impacts of residential construction that goes beyond materials and building operations. Guidelines for sLCIA were established by the United Nations Environment

Program [33]. There is a distinction between social impacts and performance, the latter argued to be more robust by including qualitative rather than singularly quantitative assessment [34]. Given that straw bale construction can be labor intensive, sLCIA would be essential to evaluate the differences between traditional straw bale building in which bales are stacked in a wall, then covered in three coats of plaster, versus pre-fabricated Structural Insulated Panels (SIPS) using loose or compressed straw fill as insulation. Dry-bale SIPs have been tested for structural performance without plastering [35], however, further research on moisture in SIPs covered with non-porous covering is needed. Prefabricated straw bale wall systems are being developed in Europe and Canada [36], and will most certainly have an effect on future sLCIA, though full consideration of both prefabricated straw bale wall systems and life cycle assessment are beyond the scope of this study. A recent study of LCA for a load bearing straw bale residential building in Slovakia revealed that the production of straw is an important factor, and the technology, tillage methods, and distance of transport have a significant impact in overall LCA quantitative results [37].

Brief Background on Sustainability and a Broadening Perspective Based on Pragmatism

To better understand the key role of straw bale building methods in establishing a more sustainable/affordable housing stock, a brief recap of the criteria for sustainability is necessary. Although sustainability has become an increasingly popular buzzword following the Brundtland Report [38], particularly in reference to community development and land use planning ideals; detailed sustainability evaluations of conventional home design are still uncommon in a discourse typically dominated by economic concerns. In their discussion of “gleaners, do-gooders, and balers [straw bale builders]”, Bradshaw and Winn [39] provide meaningful guidelines for any economic development strategy to be considered sustainable. They identify three criteria relevant to architecture and land use: affordability, cost effectiveness, and level of risk. In theory, “sustainable economic development initiatives must minimize and reverse long-term damage to the natural resource system by protecting and expanding options for future generations”. Broader definitions of sustainability have come to address not only economic and environmental concerns, but also social equity.

The “3 E’s” of the sustainability three-legged stool depicted and explained by Cullingworth and Caves [40] in their classic American text for land use planning include environment, equity and economy. In addition to the 3 E’s a fourth E, “equanimity” might be added that may be conceptually consistent with LBC [30] objectives of “happiness” and “beauty”. Equanimity is not commonly used in the sustainability jargon, but its basis lies in a state of mental calmness, usually defined and experienced on the individual level, but refers here to a broader cultural sense of calm that is needed. The current global crisis of climate change and the Covid-19 pandemic force us to re-evaluate how we interact in social space, particularly in the built environment. Straw bale home owners often speak of a sense of calm in their homes, partly due to the noise dampening effect from thick walls, but also from a sense of assurance that the home is constructed primarily of non-toxic, natural building materials. Similarly, Cucuzzella, Chupin, and Hammond [41] identify three domains of sustainability in design projects for cities: environmental, social (equity), economic, and an essential fourth cultural domain. In the context of Utah, and more localized study in the Ogden cultural setting, this fourth domain is critically important in understanding possible constraints on the acceptance of natural building design. The Mormon culture of Utah has a history of being politically conservative, indeed presidential election results have shown the majority of Utahns to vote for Republican candidates, the exception being Salt Lake, Summit and Grand Counties where the majority of voters voted for Biden in the 2020 election [42]. This is important to realize since Grand County is the only county in Utah known to have adopted building code explicit to straw bale construction. For those unfamiliar with Utah geography, Moab is located in Grand County in the central, southeastern part of the state. Moab also has the most progressive lower income housing program in the state: Community Rebuilds (comparisons noted in Figure 1 are discussed in more detail below).

The estimate that buildings account for one-fourth of the world's wood harvest, two-fifths of its material and energy usage, and one-sixth of its fresh water usage [43], though somewhat dated, lends some perspective to the scale of the crisis. As an indication of the significant discrepancy in global resource use, resultant greenhouse gas emissions for the U.S. are often estimated at 20% of global emissions, whereas the entire African region contributes only 2–3% of the total [44]. It has also been estimated that 40 percent of U.S. carbon dioxide emissions are generated by residential and commercial buildings [45]. There is a vast disparity between the consumption of resources for higher income, formal sector residential construction in more economically developed countries of the North in comparison to lower income, informal housing for economically developing countries in the South. This is not to suggest that resource intensive housing does not exist in the South, but by comparison the great majority of small, simple dwellings in the regions of Sub-Saharan Africa and South Asia could be classified as "tiny houses", or Accessory Dwelling Units (ADUs), with floor areas of 450–500 square feet (42–46 square meters) in the U.S. The key point here is that dwelling size is critical to the evaluation of natural versus conventional building methods due the cost and amount of building materials needed, and resultant overall embodied energy/carbon footprint of a single-family dwelling. When comparing U.S. Department of Agriculture subsidized Mutual Self-Help Housing (MSHH) programs, it was found that there is a significant difference not just in the size of homes, and closely correlated cost/dwelling, but also embodied carbon levels (Figure 1). The Community Rebuilds (CR) MSHH program in Moab, Utah has comparatively smaller homes at an average of 1000 ft^2 (93 m^2), sequestered up to 28,000 lbs. (−12,700 kg) of CO_2 [13], at an average cost of $100,000; whereas the Self-Help Homes MSHH program in the Orem-Provo area of Utah has home sizes of 2350–2500 ft^2, average costs of $260,000–$360,000, and embodied carbon levels of 75,000 lbs. (34,000 kg) [46]. Studies of affordable straw bale housing in Canada supported by the Canada Mortgage and Housing Corporation have also shown the benefits of energy efficiency of straw bale construction [17].

Straw Bale Construction Basics: Misperceptions, Realities, and a Window into the Truth

At the most practical and theoretically pragmatic level, it should be recognized that straw bale wall systems are a highly efficient regenerative, natural building method in terms of home insulation. The thermal performance and acoustic properties of straw bale construction are well documented [47], with detailed quantitative study of microscopic fibers for varying types of straw by Tlaiji, et al. [48]. Tlaiji, et al. [48] note that between 1990 and 2020 the number of scholarly articles involving studies of straw bale thermal and mechanical performance is steadily increasing. By their count, the greatest number of articles originated in France (more than 35), second most from the U.K. (more than 25 articles), followed by the U.S., Italy, and "Arab" countries (more than 20 articles from each) [48]. France also has one of the tallest structures using straw insulated panels, reaching eight stories in height [49].

Straw bale walls typically have resistance to heat transfer values (R-values) of R-40 to R-50, or higher; whereas fiberglass batt insulation used in conventional wall construction has R-values of R-12 to R-20, depending on thickness (see Magwood et.al., [31] for contrasting embodied carbon estimates of each). In many regions, straw is burned as a waste product, so the use of straw as exterior wall insulation is viewed as a form of sequestration (as noted in Figure 1). It is estimated that 200 million tons of straw are burned in the U.S. each year [50]. Table 1 presents an overview of the common misperceptions and corresponding realities associated with straw bale building. Owens [51] and Gromicko [50] reiterate some of these points in their lists of pros and cons of straw bale building. While Table 1 is by no means meant as a complete accounting of the misunderstandings regarding this seemingly "fringe" sustainable construction method, it serves as a starting point to identify barriers toward bringing it into more of the mainstream of sustainable architecture. Those interested in more sustainable building methods, particularly aspiring students of more regenerative architecture, may want to read Wayne Bingham's Shelter: An Architect's Journey into Sustainability [52]. After practicing conventional architecture for more than thirty years, Bingham went from being an award-winning architect using glass, steel, and concrete in his designs to “changing paradigms” as he designed and built a straw bale home in Eastern Idaho.

Table 1. Misperceptions and realities of straw bale building.

Misperceptions of straw bale building	Realities of straw bale building
Structures are prone to failure from pest/rodent infestation or decay of straw	Bale inspection & correct application of plaster creates “sealed” wall systems that allow straw bale walls to “breathe” and inhibit any decay, combustion or pest/rodent infestation [13,53]
Structures can be a fire hazard	Testing for Fire Resistance Ratings (one-hour burn) has shown that compact bales encased in plaster covered walls are highly fire resistant, more so than conventional wood frame, OSB or sheetrock walls [48]
No building code exists to ensure proper construction methods	International Residential Code, Appendix S [54] specifies building code for straw bale structures that can be adopted by local government
Structures are only appropriate in rural areas with arid climates	Straw bale homes are being built successfully in both urban and rural settings throughout the world in all climate conditions (the possible exception being arctic or polar climate regions) [54]
Structures have an unconventional appearance	Straw bale homes can be designed to have a conventional appearance and walls can be smooth, if bales are properly placed and plastered; however, many straw bale structures have celebrated, unique, creative unconventional designs [55]
Straw bale building is too labor intensive and therefore too expensive	While true that plastering can be particularly labor intensive, the process can provide local employment opportunities; generally, straw bale building is less expensive ($\$/ft^2$) than conventional home construction [13]; dry-bale wall panels have been tested for structural performance without plastering [35]
Straw bale homes are not eligible for financing or home insurance programs	Various mortgage companies and insurance carriers have financed and insured straw bale homes; International Association of Certified Home Inspectors can offer some assistance [56]
Environmental and socio-economic concerns do not “justify” the need for lower cost straw bale residential development	Lower embodied energy/carbon levels address current findings by the Intergovernmental Panel on Climate Change (IPCC) to reduce carbon emissions and the Biden Administration’s call to create a larger, more affordable housing stock [57]

Symbolic of the architectural paradigm shift, there is a tradition in straw bale building of creating a small cabinet door, or window called a “truth” window (Figure 2), that reveals the true nature of the straw material used as insulation in the exterior walls. The window shown in Figure 2 was salvaged from a neighbor’s home, and was going to be discarded, but has been re-purposed in the author’s straw bale garage/studio space. The truth window is a metaphor for the pragmatic approach in architectural design, and what Cucuzzella, Chupin and

Hammond [41] refer to as an "eco-didactic turn" needed in art and architecture. Verification of sustainable, natural materials such as straw made visible in a truth window is essentially what Cucuzzella [25] terms facticity, or an avoidance of deception. Interestingly, pragmatists like Richard Rorty [58] were skeptical of absolute truth, hence the use of quotation marks around the loaded term "truth" that lies in the eyes of the beholder. Healthy skepticism and humanistic acknowledgment that complete objectivity is not possible, given the human condition are noted here as further underpinnings of pragmatic architectural theory as a foundation for more regenerative natural building.

Figure 2. Truth window, interior wall of straw bale structure. Source: Photo by author, author's garage/studio, Ogden, UT.

The so-called "truth" in the window can also be viewed as educational for those who might be skeptical of the construction process, and doubt the practical use of straw bales to create a smooth, plastered wall giving no tangible evidence of the materials lying within the walls. Indeed, some straw bale structures have level, smooth interior and exterior wall finishes that might resemble a conventional plaster or stucco wall, whereas other, more "artistic" structures sometimes have undulating walls with a lumpy appearance. Custom straw bale homes are known to have more creative nonconventional designs, such as arching or curvilinear rooflines, living rooftops, curved walls, and ornate windows and doors (see images and designs by leading straw bale builders and architects in Steen, Steen, and Bingham, [55]; Wanek [59]). The aesthetics, or "beauty" (as noted by LBC [30]) of straw bale homes is certainly subjective, and resists quantification as part of any certification program. Rounded, or "bull-nose", corners on plastered interior walls of straw bale structures are another hallmark feature that lend to the "softening" of the interior space which is complimented by noise dampening effects of thick exterior straw bale walls (bales are typically laid "flat" at the width of 18 inches, or 45 cm).

One might dismiss exterior wall surface appearances as a mere issue of aesthetics, yet architectural review standards upheld by municipalities, homeowners' associations, or other entities often take the matter very seriously. Arguably the more significant difference between conventional stucco construction and straw bale has more to do with underlying materials and their even less tangible, respective amounts of embodied carbon. A conventional exterior wall composed of oriented strand board (OSB), a.k.a., wood particle board, heavily glued and sandwiched around a sheet of polystyrene foam insulation board has a significantly higher level of embodied carbon than a wood frame, straw bale wall. The conventional structural insulated panel (SIP) is commonly covered in building wrap, e.g., Dupont Tyvek™, or other plastic material made of high-density polyethylene fibers, which can then be covered with galvanized steel masonry mesh, a.k.a., lathe, and sealed with a cement-based, latex stucco product. Conversely, the straw bale wall is structurally solid with no masonry mesh, and finished with a natural lime plaster (no cement) that allows the wall to "breathe". Grandsaert [60] conducted compression tests on straw bale walls and found that the bale wall segments with metal stucco mesh did not perform as well as those without mesh. The issue is still debated and requires further research.

Such distinctions in building materials lend insight to the "truth" behind truly more sustainable natural building methods and some less than natural, synthetic materials that are sometimes subsumed under the label of "green" building methods. The building industry is no stranger to green-washing that can occur in other types of commercial development. The issue of green-washing, or false sustainability in architecture has received attention in acclaimed literature [61] and the media [62,63]. As previously cited, Cucuzzella [25] articulates the schism between the perception of sustainability and its facticity; whereas Santini [64] addresses the concern of green-washing in her review of architectural education programs. Though a review of architectural education programs that train students in natural building is beyond the scope of this study, the aforementioned Community Rebuilds program offers an internship program that provides hands-on experience in straw bale building (discussed further in subsequent sections).

Pragmatic Theory at Work: International Residential Code Appendix S (IRC-AS) and the Community Rebuilds (CR) Program

Establishing residential building code is one of the leading constraints to widespread acceptance of straw bale building in the U.S., however broader consideration of Sustainable Development Code (SDC) has come to include natural building. While some architectural engineering studies have begun to emerge [65,66], much work remains, particularly in the realm of fire resistance ratings for prefabricated wall panels using loose fill straw insulation. Further complicating the code issue is that the International Green Construction Code (IGCC) has not included residential construction, nor have officials been adequately trained to evaluate natural building residential code. Perhaps most important is the aforementioned issue that “green” building code and standards tend to separate sustainable architecture from vital cultural and social impacts [25]. Goubran, Masson and Walker [67] offer an essential insight: “the slow and accumulative nature of code and standards might not be capable of coping efficiently with the complexity of the challenges we are facing”. By acknowledging the “complexity of the challenges”, pragmatism allows us to recognize that codes and standards are the modern rubric in which building exists, even though some codes can be counter-productive, as addressed in the qualitative study below.

An important breakthrough in the advancement of straw bale building code came in 2013 with passage of International Residential Code, Appendix S (IRC-AS) which details straw bale building materials and methods [68]. IRC-AS was a joint effort, driven mainly by architect Martin Hammer at the University of California—Berkeley and straw bale building pioneer David Eisenberg. A thorough history of the challenges in establishing straw bale building code prior to IRC-AS are detailed by Henderson [69,70]. General comments in the preamble of IRC-AS [54] lend insight to the global applications of this pragmatic approach to architecture:

“Since the 1980s, the use of strawbale construction has steadily increased and there are now strawbale buildings in all 50 U.S. states, as well as in more than 50 countries throughout the world. It is estimated that there are over 1000 strawbale buildings in California alone. Strawbale construction has been used primarily in the construction of residences, but it has also been used for schools, office buildings, wineries, retail buildings, a municipal police station and a federal post office”. Furthermore, “three countries outside of the United States—Germany, France, and Belarus—have limited strawbale building codes, [and] New Zealand has official guidelines for strawbale construction” [54].

Since most states, as well as municipal and county building departments in the U.S. have still not adopted code based on IRC-AS, this quote from David Eisenberg, whom Henderson credits as the “guru of straw bale building” may prove to be sage, practical advice (based on a theory of pragmatism), particularly for those wanting to build code-compliant straw bale structures:

“Whatever attitude and expectations you take into the building department that’s what you will find. If you go looking for a fight, there will be one waiting for you. But if you go looking for help and in a cooperative mood with an expectation you will get help, the odds go way up you are more likely to have that kind of experience, depending on who you are. They can be whoever you expect them to be and it will be based on how they are treated in that relationship”—David Eisenberg (in Henderson [69]).

Straw bale building code in California cites the shortage and rising costs of construction-grade lumber, and mandated reduction in the burning of rice straw, material that could be used in housing construction. Far ahead of other states, the code notes that “practicing architects and engineers have determined that [previous] statutory guideline are either unnecessary or detrimental. Some of the requirements are considered costly and severely restrict the development of straw-bale housing” [71]. This is an important caveat, and lends insight as to why so few self-help housing programs use straw bale building methods. The code further states that “tests and experience with straw-bale construction demonstrate that it is a strong, durable, and thermally superior building system that deserves a larger role in modern construction”. While not all states, nor all communities throughout the world, have rice straw, other types of straw, particularly from alfalfa, can be used effectively in straw bale home construction. In the state of Utah, Community Rebuilds straw bale homes are currently being built to county code, granted through the City of Moab Building Department.

During the uranium mining boom in the 1950s, Moab became home to both miners and ranchers, many of whom lived in substandard housing. By the 1960s and 70s, trailer homes, known for having low energy efficiency, had become the norm for the community’s housing stock. In an effort to address the environmental health (social) problems of dilapidated trailer homes in the community, Community Rebuilds (CR), a non-profit organization was established about ten years ago by founder Emily Niehaus. More than thirty straw bale homes have been constructed in and around Moab since the start of the program. Interested readers are encouraged to view the brief, highly creative YouTube segment celebrating the tenth anniversary of the program, available at communityrebuilds.org. All CR homes are modest in scale (1000 ft^2), use straw bale building methods and materials, and are equipped with photovoltaic (PV) arrays that power these “beyond net-zero”, completely electrified homes. To be clear, these are hybrid homes that blend traditional straw bale building with the latest in technological developments for PV electric, mini-split systems that have an outdoor compressor/condenser and an indoor vent/evaporator; and all appliances are high-efficiency electric units. The combined heating/cooling systems are most practical for small homes as they do not require ductwork in the home, and temperature can be regulated in each room. Air conditioning is often needed for increasingly hot summer temperatures (induced by climate change) in lower elevations of the desert southwest. Although most CR homes have a similar rectangular design with simple prefabricated roof truss systems to reduce building costs, each home has its unique character that owners add. Figure 1 briefly compares CR with the previously noted Self-Help Homes program in the Orem-Provo area of the Wasatch Front.

The most recent homes by CR in Moab are being built to satisfy Living Building Challenge (LBC) certification, including grey water systems allowed through an “experimental” permit from the local health department. CR interns working on the homes receive instruction on natural building thereby fulfilling the LBC criteria for “inspiration and education” [30]. Homeowners who qualify for participation in the CR program, e.g., have lived in Moab at least two years and have a maximum median household income of $59,300, help to meet LBC “equity” criteria of “equitable investment” and “universal access to nature and place” [30]. Intentions of LBC certification are well meaning, but training and testing for compliance are both expensive and time consuming. These are only a sampling of the “real world” problems that Schroeder [24] warns of when trying to meet credits or point values established by certifications like LBC. It could be argued that CR may not have pressed ahead with experimental grey water systems on homes if they were not being assessed for LBC compliance, though program staff have sought “experimental” permits for a variety of building methods and materials. Once again, this sort of experimental, or trial through experience approach is fitting of pragmatic, natural architecture that the CR program exemplifies.

Qualitative Methods and Results for Analysis of Two Pragmatic, Sustainable Architecture Projects in Ogden, UT

The methodology for this study is centered on a simple qualitative approach whereby two of the only known straw bale structures in Ogden, Utah are analyzed in terms of (1) the sustainability of building materials/methods, and (2) social impacts, i.e., architectural educational value that is central to pragmatism. Architectural Education Strategies (AES) associated with sustainable buildings in Canada [27] form the methodological basis for evaluating the educational values of the two buildings in Ogden. The first of the two buildings considered here is the Ogden Nature Center (ONC). Returning to McHarg’s concept of design with nature, the ONC was designed to be in harmony with the natural surroundings, i.e., the biophilic element espoused by the Living Building Challenge (LBC) program. The ONC-Education Center was designed and built well before the LBC program was devised, yet the Center and its surroundings of the ONC are certainly compatible with the principles embedded in the LBC program.

The Ogden Nature Center’s Education Center (ONC-EC) (Figure 3) is a building open to the public and designed for environmental education. Nature centers are ideal locations for fostering natural building, where more sustainable building materials and methods can be integrated in environmental education programs [72]. Among the more contemporary, progressive and ambitious projects is the Ecology School, a nature education center with a large dormitory and dining commons on a 105-acre historic farm on the Saco River in the state of Maine. As part of the project, Kaplan Thompson Architects hope to build “the most sustainable building” in the Northeastern U.S. [73]. Their goal is to achieve Living Building Challenge 3.1 certification, which includes low embodied carbon measurements. The

Ecology School building project bears some resemblance to the ONC-EC which was conceived more than fifteen years earlier, though the latter was not designed with any targeted certifications. The ONC-EC provides an important precedent setting building in Ogden where straw bale building remains nearly nonexistent. Believed to be the first straw bale structure in Ogden, it was approved by Ogden City building officials under International Building Code which has a clause for “alternative materials, design and methods of construction and equipment”.

(**a**)

(**b**)

Figure 3. (**a**) Ogden Nature Center Education Building. Source: EDA Architecture [74]. Close-up view of straw bale wall at left side of entry. (**b**) Ogden Nature Center Education Building. Source: EDA Architecture [74]. Education Center entrance with solar chimney visible at back, left.

Built in 2005, the L.S. Perry Education Center building serves as a venue for nature education programming and provides visitors an opportunity to learn about environmental/sustainable architectural design. Interpretive signs within the building help to educate those willing to take a self-guided tour. This 7100 ft^2 “green” building was designed by Utah architect Robert Herman of EDA. His work is noted as a “celebration of natural light [to] create a meaningful sense of place” [74]. The project was recognized by the Utah Society of the American Institute of Architects with a 2008 Honor Award for Design and a 2008 Honor Award/First Prize in Environmental Design and has been featured in several conferences. The design of the Education Center features a natural lighting controls system, a displacement cooling system augmented by operable windows and a solar chimney, and underfloor radiant heating. Salvaged Douglas fir timbers and wood siding for the building came from a historic railroad trestle that once crossed the Great Salt Lake about eight miles west of the Nature Center. Exterior walls of the structure utilize local, organically grown straw bales finished with two types of plaster: a lime-based plaster for the exterior walls and an earthen plaster for the interior, composed, in part, from local soils. Other exterior walls are insulated with recycled, shredded blue jeans and loose-fill cellulose derived from recycled paper/newsprint. The roof is comprised of structural insulated panels (SIPS), which consist of an insulating foam core sandwiched between two structural layers of oriented strand board (OSB). The cost of the building is reasonably low in comparison to others of its scale, which was about $1,053,000, or roughly $148/ft^2 in 2005.

Applying the educational strategy evaluation criteria identified by Chupin, Hazbei and Pelchat [27], using a scale of low, moderate, to high, the ONC-EC building is ranked as follows:

- Labeling: environmental performance for the building is "high", largely due to insulation values of the straw bale insulated exterior walls of R-40 to R-50 (Figure 3a), and the cooling system from natural ventilation enhanced by the solar chimney (visible in Figure 3b); no certifications were sought (as previously noted, the building pre-dated LBC), so quantification of sustainability measures is "moderate", but the design received awards for environmental sustainability; about 20 virtual signs/labels inside the building explaining the sustainability features (largely qualitative, not quantitative) add to the educational experience explained below;
- Iconic: "high" due to highly visible solar chimney (Figure 3b), and salvaged timbers (Figure 3b) that demonstrate the advantages and strong aesthetics of sustainable architecture to visitors;
- Experiential: "high" since the building houses the Education Center for the ONC, the building serves to educate visitors by experiencing sustainable architecture, its natural design features, and compatibility with the natural setting, or sense of place; signage explains architectural design and other pragmatic, experiential learning opportunities are emphasized at the Education Center.

The second, and more recent of the two straw bale buildings in Ogden is a 600 ft^2 garage/studio that could serve as an accessory dwelling unit (ADU), but at present the structure has no plumbing. If plumbing and heating are added to the garage/studio building, installation of 8–10 PV panels would suffice to power systems that could include a heat pump that uses CO_2 instead of CFCs (e.g., SANCO2™). Most heat pumps combined with air conditioning systems eventually leak CFCs thereby potentially offsetting overall environmental efficiencies. The design/build project allowed Weber State University faculty and students to gain first-hand experience in natural building methods and materials. A permit for the structure was issued retroactively since no code allowed for straw bale building in the City of Ogden. Similar to the previously stated case of California, building codes can be unnecessary, or even detrimental to innovative, more sustainable building methods. "Forensic engineering", i.e., engineering calculations and reports compiled after the structure was built proved problematic, yet city building department officials were intrigued by the use of straw bale insulation in the post and beam structure, and the structure passed inspection. Salvaged timbers for the framing were not conventional dimensions (5“X7”), further complicating the engineering calculations and inspection process.

Salvaged timbers (shown in Figure 4a) are an important feature in lower embodied carbon buildings. Post and beam framing using salvaged timbers from Rocky Mountain Power was both ecologically sound and economically beneficial. Note that roofing is best assembled before straw bales are brought on site to protect bales from weather (Figure 4a). Also visible in Figure 4a is the pre-existing concrete slab, or “plinth”, that was repaired and reinforced with minimal new concrete and rebar for the post footings. Concrete rich in Portland cement has among the highest embodied carbon levels of all building materials, so whenever possible stem walls are preferable to concrete slabs. New innovations such as hempcrete, which uses less cement mixed with crushed hemp stalk, can make practical use of a waste product from hemp production.

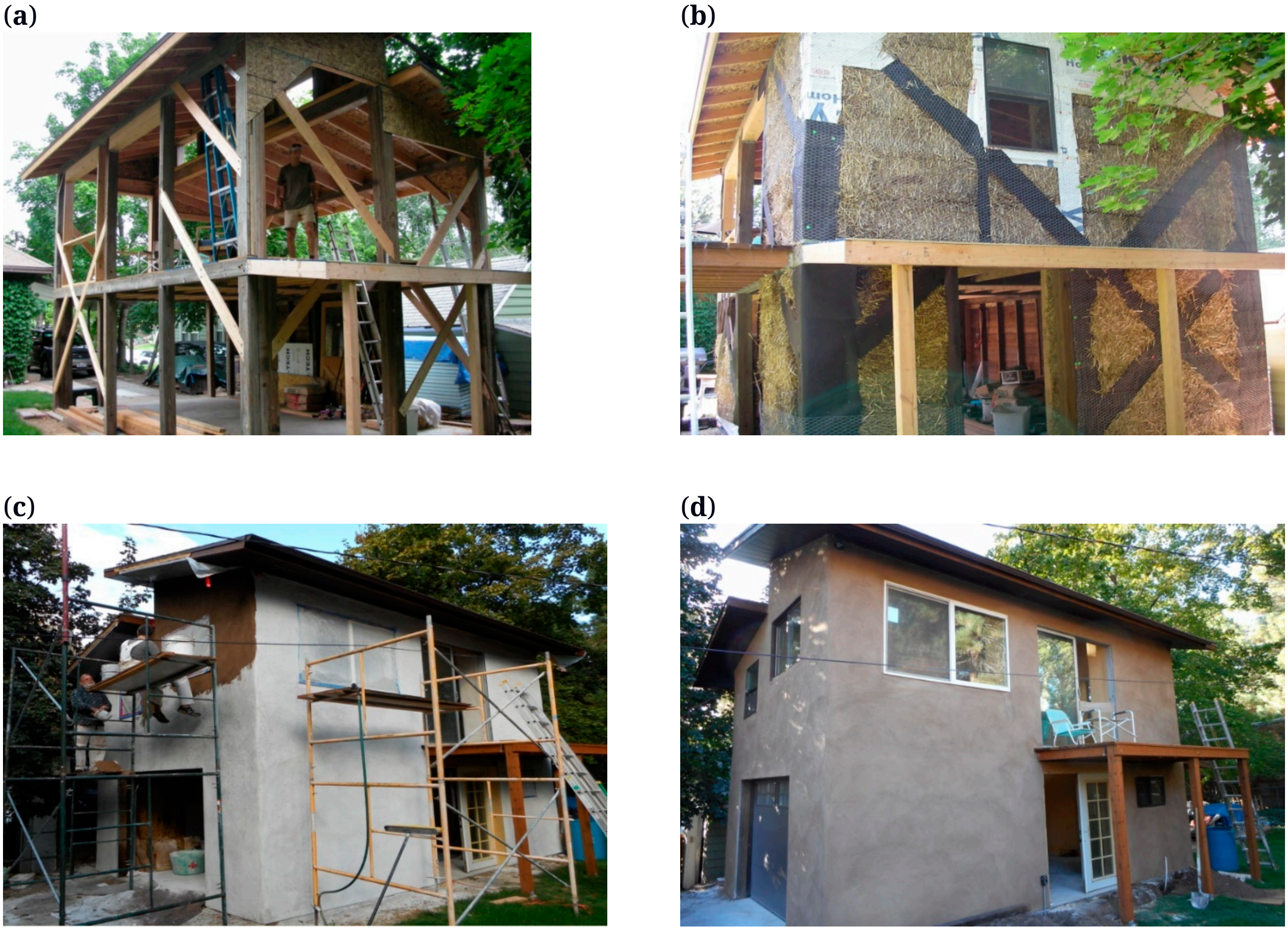

Figure 4. (**a**) Straw bale framing and finishing. Photos of author’s garage/studio in Ogden, UT (author’s photos). Post and beam framing using salvaged timbers. (**b**) Straw bale framing and finishing. Photos of author’s garage/studio in Ogden, UT (author’s photos). Straw bales set firmly in place. (**c**) Straw bale framing and finishing. Photos of author’s garage/studio in Ogden, UT (author’s photos). Plaster finish coat being applied. (**d**) Straw bale framing and finishing. Photos of author’s garage/studio in Ogden, UT (author’s photos). Nearly completed structure.

Given that an estimated 160 million tons of construction waste and demolition materials are produced annually in the U.S. [75], one of the objectives of the project was to reuse windows and doors that were reclaimed from other building projects; only the garage door was purchased as a new product. Other materials used in the construction that were newly purchased included floor joists, rafters, fasteners, roofing felt, and asphalt shingles. Ideally, Forest Stewardship Council (FSC) certified lumber would have been purchased by a local distributor. FSC lumber is considered a stronger certification since it is used globally and originated in civil society, whereas Sustainable Forest Initiative (SFI) lumber is a North American certification which is represented mainly by industry.

Granted that spending additional time tracking down used building materials may seem less than pragmatic, it is necessary to search for local materials that can be reused to reduce embodied CO_2 levels in materials and their transport. The recycling, salvage and reuse of building materials was ranked as the third most popular Sustainable Development Code (SDC) in the U.S. in November, 2021 [76], and gives an indication that planners and building department officials are becoming increasingly aware of the need to address the issue. Incidentally, the number one ranked SDC is mixed use zoning, and "green zone" planning is ranked number two in popularity. A green zone can be established to give priority to building permits and projects with designations from sustainable regulatory agencies or third-party certifications, such as LEED or Living Building Challenge [76]. For better or worse, these certification programs seem to be here to stay and help to advance more sustainable architecture.

One of the misperceptions of straw bale building (previously shown in Table 1) is that structures have an unconventional appearance, but when bales are finished flush to one another, and ample plaster/straw mix is used to fill any cavities between bales or framing, the walls can have a smooth conventional appearance. According to renowned straw bale builder, Andrew Morrison [77], wall undulations are part of the natural imperfections that add to the beauty of a structure (among the most comprehensive sources of straw bale building information available online is Morrison's https://www.strawbale.com/ [77]). In the case of the garage/studio structure, bales were purchased from a local farmer west of Ogden, then carefully and tightly stacked in offset rows much the way bricks are traditionally stacked, thereby adding structural integrity to create as smooth a surface as possible (Figure 4a). Ideally, straw used in the bales should be organically grown without any synthetic fertilizer or pesticide applications, though bales used in the project were not certified organic.

As is the case with many experiential educational opportunities, much can be learned from "mistakes" or observance of doing things in different ways, i.e., differing building methods. The structure was missing window sills to prevent water from damaging the plaster finish below the windows, and eves with a full three-foot (1 meter) overhang were needed to protect plastered walls from weather. IRC-Appendix S specifies code for a minimum three-foot eve for all straw bale structures. The truth window (Figure 2) reveals orange baling twine showing that bales were laid "on-edge". The decision whether to lay bales flat or on-edge is hotly debated in straw bale construction and has been the subject of a survey revealing advantages and disadvantages of both methods [78]. Figure 4b illustrates how straw bales are set firmly in place with wire mesh encasing, and all exposed wood surfaces are covered with vapor barrier before applying plaster. If using a wire mesh between bales and plaster finish, it is essential to securely attach the mesh to the bales. In this case, wire mesh was stitched to the bales using baling twine. The use of stucco mesh is a common requirement in most building codes when using cement-based plasters or stucco materials, however, early compression tests suggest that a strong bond between the straw and natural lime plaster negate the need for stucco mesh or chicken wire [60]. Though barely visible in the lower left corner of Figure 4b, it is essential to construct a raised foundation for the first course of bales to prevent moisture from the exterior or foundation entering the bale wall. In this case, pressure treated 2 × 4 framing with foam board insulation and a vapor barrier were constructed as a base to prevent moisture absorption. Immediately following preparation of the bale walls, a base coat and "scratch" coat of Limestrong™ plaster were sprayed and troweled onto walls before a colored finish coat was applied (as shown in Figure 4c). Limestrong™ plaster is a pozzolanic hydraulic lime plaster made from lime sourced from ancient sea beds around the Great Salt Lake and pumice sourced from southeastern Idaho. Using locally produced building materials is cited as an important consideration for lowering embodied CO_2 and a tenet of pragmatic architecture.

The garage/studio project totaled less than $12,000 in materials, the majority of which was spent on plaster materials, and labor was about $2500, most of that going to a professional plasterer. At a cost of less than $15,000 ($25/ft^2) for the straw bale structure, there is a significant difference from a conventionally designed and built space that would likely cost an estimated $50,000–$70,000, depending on architectural fees and building contractor costs. The structure was completed in six months from demolition of the pre-existing garage in the fall of 2016, and serves as an informal model for students and community members interested in building an affordable ADU (Figure 4d). Although the garage/studio structure is not open to the public, methods of architectural education strategy evaluations [27] give some insights regarding its sustainability:

- Labeling: traditional straw bale and plaster walls render environmental performance for the building as "moderate", and the structure set precedent for straw bale building permitting in Ogden City with extensive quantitative engineering calculations; virtual "labels" including engineering reports that are on display inside the building add to educational experiences for visiting WSU students during sustainability course work. An additional “label” from a hand-out used in course presentations might be added to the truth window to quantify sustainability factors: “Straw bale insulation sequesters carbon at −78 kg. CO_2 per 4 × 8 wall @ R-28; whereas polystyrene foam board emits + 38 kg. CO_2 per 4 × 8 wall @ R-28” [13];

- Iconic: “low” visibility in the community, though many visitors have expressed interest in building their own straw bale homes; some builders have wondered why there aren’t more straw bale homes built in the area, and speculate on a potentially large niche market;
- Experiential: the privately-owned building serves as a “moderate” means of experiential education for visiting community members and university students interested in natural building; students who assisted in the construction were asked to write a brief “reflection” paper about their experience, an anonymous excerpt from one of the papers warrants attention regarding the essence of more sustainable natural building: “Beavers don’t question the need to tamp mud on their homes, nor do some birds seem to question the use of a discarded plastic wrapper in a nest but humans can consciously choose between building materials that make sense and those that don’t”.

In 2020, a “net-zero” home was built through a formal partnership between Weber State University and Ogden City Community Development to create more affordable housing, though the 2500 ft^2, six-bedroom, two-bathroom home sold for about $350,000. The project was part of the solar decathlon competition established by the U.S. Department of Energy, and resulted in low energy operational costs estimated at less than $100/year (detailed report with design specifications is available at https://weber.edu/solardecathlon [79]). In terms of size, cost and embodied CO_2, the “net-zero” home is similar to other federally subsidized housing such as the previously mentioned Self-Help Homes program roughly 50 miles to the south in the Provo-Orem area. Another home is scheduled to be built as part of the infill project to replace dilapidated homes in Ogden’s East Central Neighborhood. Unfortunately, Ogden Community Development officials have been resistant to building a straw bale demonstration home following the Community Rebuilds model citing challenges of compliance with historical district facades. As previously discussed, plaster finishes on straw bale buildings can mimic stucco finishes like the exterior of the solar decathlon home. Reluctance on the part of WSU faculty and administrators to pursue the project pivots on a lack of experience in straw bale construction that typically inhibits wide-scale practice of natural building.

Detailed comparisons of the Community Rebuilds straw bale home program with other subsidized conventional home programs [46] does not include evaluation of impacts from educational home tours that CR homeowners accommodate as part of their contractual agreement for participation in the program. Home tours and volunteer work on CR homes remains a valuable part of experiential, engaged-learning coursework for WSU students pursuing sustainable land use studies offered by the Department of Geography, Environment and Sustainability. Experiential learning in home design and construction is part of the pragmatic tradition espoused by John Dewey [80] and other pragmatists [58]. Future research on the broader effects of home tours and internships for natural building programs like CR would be helpful to better understand the proliferation of straw bale building and cultural acceptance such as that found in Moab. If architectural education strategy evaluations [27] were to be applied, the CR program would certainly rank as “high”, if not very high experiential value, perhaps lower in iconic value, and high in quantitative labeling, particularly with regard to upcoming evaluations of the recently built Living Building Challenge homes.

CONCLUSIONS AND QUESTIONS FOR FURTHER CONSIDERATION

More regenerative architecture involving natural building methods and low embodied CO_2, on one end of the spectrum of sustainability is essentially grounded in a theory of pragmatism in architectural ideology. The “how to” approach in architectural theory has been criticized [1], but some of the basics of straw bale construction are presented here since few academics and building contractors are familiar with this particular natural building method. Returning to the comparison of the normative architectural theoretical approach of what “should” be built, versus the more sustainable pragmatic approach of what “is” being built, the distinction blurs when the question remains, should low income housing programs similar to Community Rebuilds (CR) be replicated in other places? Pragmatically speaking, the reality is that CR has built over thirty-five homes that sequester carbon, and their goal is to continue to build more homes that use a hybrid blend of natural building materials and methods, with high efficiency energy photovoltaic systems. Additionally, nature centers, such as the Ogden Nature Center-Education Center (ONC-EC) examined in this study offer significant potential to showcase what has been built, and what can be built, e.g., the Ecology School buildings in Saco, Maine. These buildings serve as critically important educational venues that assist in expanding the knowledge and acceptance of straw bale building, and may someday contribute to the establishment of a natural building culture. Despite the fact that the ONC-EC received awards for environmental design, it seems to have done little to foster more straw bale building in Ogden thus far.

Furthermore, the fact that the ONC-EC was built before Living Building Challenge (LBC) standards were established, yet would likely meet LBC criteria and testing lends credence to the argument by Cucuzzella, Chupin, and Hammond [41] and their colleagues that quantitative assessment of sustainable architecture is not always prerequisite to the advancement of the alternative paradigm of natural building embraced by Eisenberg and Hammer [68], and many architects like Bigham [52]. All are consistent with a proposed paradigm shift toward the theory of pragmatism in architecture, as are recent developments in embodied carbon (CO_2) advanced by Magwood [13,36], and King [14]. Indeed, quantitative inventories of CO_2 emissions either sequestered or emitted by either conventional or natural building materials and methods are central to pragmatic problem solving in architecture today.

Critics of straw bale building see the labor-intensive process of setting bales and plastering as one of the barriers to wide-scale practice of natural building. The same could be said of brick work or other masonry facades on buildings, yet neither building methods are cost prohibitive, particularly when self-help housing agreements require homeowners to contribute a specified amount of time as “sweat equity”. Service-learning and internship programs are a pragmatic way of reducing labor costs while perpetuating the diffusion of natural building knowledge and home building skills. Workshops, work gatherings, a.k.a., straw bale work “parties”, can also be highly beneficial to reduce building costs, and at the same time, help volunteers to learn about natural building methods. These gatherings are essential in fostering a natural building culture that may give support for others interested in building their own straw bale homes. The CR internship program serves the dual purpose of reducing home building labor costs as part of the affordability of Mutual Self-Help Housing (MSHH), and providing experiential learning opportunities. Further research involving detailed analysis of sLCIA is needed to evaluate the full spectrum of costs and benefits in natural building and affordable housing programs such as CR.

The next question is one of scaling and adoption of building code. Should, or can sustainable pragmatic residential building be implemented in any region if climatic variability is not a viable barrier, nor availability of International Residential Code-Appendix S that can be replicated by local government officials? If the answer is yes, then the corollary question that should be posed is whether or not the political will exists to encourage natural building and beyond net-zero, low cost residential development. If the political will is lacking, are there individual community members willing to work toward local changes? The Ogden study suggests that there are often individuals willing to build public structures or demonstration homes whereby conventional builders can learn about natural building materials and methods, yet community development and building officials seem resistant to less conventional building practices. In contrast, the CR program in Moab proves that a “natural building culture” can be established, and furthermore, that U.S. housing subsidies such as those made available through the Department of Rural Development MSHH, and similar programs should be used to fund more affordable straw bale homes. To be sure, CR hybrid homes are in a somewhat rural area, though Moab is growing rapidly, and there is no logical reason why natural building could not, or should not be expanded in more urban settings such as Ogden.

Finally, what is the role of the university in advancing natural building methods, code creation and adoption for affordable housing? Until more academics and building inspection officials recognize a more pragmatic approach to creating residential development and public spaces such as the ONC-EC building, there is less likelihood of wide-scale change. The garage/studio structure built in Ogden could easily be replicated for an expansion of ADUs where lower income housing is in significant shortage. Thus far, Ogden City planners and neighborhood development officials are less than interested in natural building methods incorporating straw bale insulation. The net-zero, solar decathlon home built in Ogden's East Central Neighborhood is a strong starting point, so the potential exists to build a straw bale demonstration home, but city officials are not yet receptive. WSU faculty and students who have participated in field courses where students volunteer to work on a CR straw bale home with builders and interns in Moab have expressed frustration that no similar program exists in Ogden. Further research is needed to determine whether or not education and observation of programs similar to CR in Moab would assist in creating a natural building culture in cities like Ogden.

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CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

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