PREFabricated and modularized building as an affordable housing solution for millennials: a case study

By

Brenda Defoe

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<td>Office of Science and Technology</td>
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<td>Photovoltaics</td>
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<td>sq. ft.</td>
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ABSTRACT

Today, Millennials are the largest and most diverse generation in America. As a result, this generation — totaling approximately 80 million young people\(^1\) — is poised to have a significant impact on housing preferences and how cities are developed. Because housing is a key component of the United States economy, housing that is decent and reasonably priced is a contributing factor in creating sustainable communities. Furthermore, in an economy of slow wage growth and increased student loan debts, reducing the attainment of traditional goals associated with the “American Dream” will have significant implications on the future of the U.S. housing market. Yet, developers have neglected to increase the efficiency and rate of affordable housing production due to a lack of investment in productivity, innovation and technology. In addition, an increased awareness of the social and environmental issues that this generation faces have led many to believe that opportunities to make an environmental impact through choices, like homebuying is necessary. As Millennials begin to enter the housing market, preferences for energy efficiency, green building and smart home technology will influence the types of homes that are built. These shifts will create new challenges for the built environment — and in a context of evolving cultural preferences and market forces — it will become necessary to design homes that respond to these changes in order to benefit future generations. The question is, how can a type of construction, specifically prefabricated or modular building provide affordable housing opportunities for Millennials and contribute to sustainable development? This paper will explore prefabricated/modular construction’s role in creating affordable housing for a new generation.

INTRODUCTION

Millennial Characteristics

In 2014, American Millennials — roughly a quarter of the Nation’s population reached an estimated 80 million people. For the most part, members of this generation differ significantly from their elders. As the most racially diverse generation in American history, this generation is, and will be an important force in the economy for decades to come. Millennials are important because of their size, and the way they grew into adulthood. They are “digital natives”, increasingly connected and networked through social media. As the first generation to have had uninterrupted internet access — they have never had to adapt to new technologies because they’ve had a hand in shaping them.

Millennials also stand out because they are the most educated generation to date, yet they are also the first modern generation to have record levels of student loan debt, poverty and unemployment. These difficult economic circumstances are a result of the Great Recession (2007-2010), a time when older Millennials were coming of age. In their mid-twenties when the recession began, many Millennials struggled to find footing in the labor market. As a result, the lives of adult Millennials were shaped by the experience of trying to establish careers at a time when opportunities were relatively scarce. And, although the economy is recovering, the Great Recession is still influencing the lives of Millennials and will ultimately do so for decades to come.

Marked by transformations at every traditional milestone, this generation is choosing to organize their lives in ways that are very different from their predecessors.
Because of shifts in parenting styles, choices about marriage, homebuying and family, Millennials have been distinctive about how they choose to develop as adults. These behaviors make Millennials statistically different in ways that will undoubtedly impact all of society. Perhaps more than any other generation, Millennials are redefining what it means to be adults in a complex world by continuously re-creating their identities.

As consumers, Millennials expect more choices and more selectivity. This generation has grown up with an array of choices but also feels less compelled to conform to consumer choices of their peers or other preceding generations. They desire ultimate control and customization, and represent an estimated $200 billion in direct spending power as reported by Fromm, Lindell and Decker (2011). Additionally, Fromm et al. (2011) suggests that “their indirect spending power each year is approximately $500 billion, largely because of their strong influence on their parents. It’s predicted that Millennials’ spending power will increase as their earning power grows” (p. 8). Characteristically, Millennials are more adventurous and less consistent than Baby Boomers when it comes to shopping, but they will pay more for items they value rather than participating in one-stop-shopping. Through strategic consumership, those who have a fondness for specialty items tend to shop locally with retailers with whom they can establish relationships, while also shopping at big-box stores for bulk items.

More importantly, when it comes to social consciousness, because Millennials have been exposed to the world through the internet and globalization, they feel responsible for taking care of it. This is closely linked to consumerism as a force of
positive social impact and has become the new standard for how companies address social and environmental issues in order to drive meaningful change. According to a Cone Communications’, 2013 Cone Communications Social Impact Study: The Next Cause Evolution, Millennials believe:

a product is no longer just a product. It’s a donation to cancer research. It’s a tree planted. It’s a step toward a better world … this universal corporate dedication to society-at-large is a good thing [because] it’s putting the resources of leading thinkers and companies behind some of the most pressing social and environmental issues. (p. 4)

As a key population segment, this is nothing to take lightly. Millennial consumers are a burgeoning force in the broader American culture and economy. As this group grows in number and influence so too will their expectations for social impact because they will shape the way companies do business in the future.

Not surprisingly, these ideals translate to the natural environment. Having been exposed to numerous environmental concerns such as climate change, the loss of natural resources and rapid land development, Millennials are well aware of the challenges they face when it comes to sustainability. Barton, Fromm and Egan (2012) wrote that:

the generation that was taught to recycle in kindergarten wants to be good to the planet and believes that collective action can make a difference. Millennials believe that working for causes is an integral part of life, and they are drawn to big issues. Instead of making one-off charitable donations in cash or in kind,
they are more likely to integrate their causes into daily life by buying products that support sustainable farming or “fair trade” principles, or by joining large movements that aim to solve social and environmental problems. (p. 7)

All in all, Millennials look for ways to make their homes and lifestyles greener as their actions are consistently more eco-sensitive. Additionally, this generation has a higher level of intent and follow through, including a willingness to pay more for eco-friendly products and services. In short, Millennials are emotionally committed to matters concerning the environment and are likely to act through everyday choices.

Millennial Living Arrangements

In terms of lifestyle choices, many Millennials are choosing to delay marriage in favor of education. Today, fewer Millennials (26%) are married by the age of 32 than Gen Xers (36%) and Baby Boomers (48%)\(^2\). As result, Millennials are not establishing households in their 20s as traditionally expected. Instead, more Millennials are likely to be living at home — a trend that began during the Great Recession when more young Millennials remained in their parents’ homes instead of moving out on their own. In 2013 report called *A Rising Share of Young Adults Live in Their Parents’ Home*, the Pew Research Center reported that “men of the Millennial generation are more likely than the women to be living with their parents — 40% versus 32% — continuing … the steady rise in the share of young adults who live in their parents’ homes [because of] a combination of economic, educational and cultural factors” (p. 1). Since the rate of household formation has fallen, fewer Millennials will enter the independent rental or

\(^2\) As reported by the Pew Research Center’s *Millennials in Adulthood* (2014).
homebuyer market making the demand for housing and residential investment lower than the level expected for more typical rates of household formation. Moreover, the Council of Economic Advisers (2014), noted that “the share of Millennials living at home has increased even among those with jobs, which points to … factors outside the labor market” (p. 38). Additionally, the Council of Economic Advisers (2014) report also observed that:

young adults today are less likely to be homeowners than young adults of previous generations. The decline in homeownership among Millennials, however, only looks particularly sharp when compared to the homeownership rates of 18 to 34 year-olds during the housing boom. (p. 39)

Not surprisingly, when looking at the larger picture, the decreased likelihood of homeownership among Millennials is in line with recent declines in homeownership across the Nation.

Nevertheless, there are several other factors that contribute to the lowered likelihood of Millennial homeownership. As previously discussed, labor force participation, increased college enrollment debt and delays in marriage suggest that Millennials are not delaying homeownership altogether, but are waiting until they are more financially established before purchasing a home because of challenges that linger in the wake of the Great Recession. With this in mind, it is also important to remember that homeownership decisions are often linked to job prospects. The idea of maintaining flexibility in regard to location could provide an advantage as Millennials consider job opportunities that may come their way. Today however, one of the largest
possible contributors to the decrease in Millennial homeownership is the current lending environment. Again, the Council of Economic Advisers (2014) report reasoned that:

the share of those under age 30 with credit scores below 680 — a lower credit score on the spectrum from 300 to 850 — is approximately 67 percent, whereas this portion of the credit score distribution is less represented among older age groups. With regulatory constraints leading lenders to apply additional credit overlays for those with low credit scores, Millennials are likely to face challenges obtaining mortgage credit. (p. 40)

It is also worth mentioning that while these challenges do not explain all of the living arrangement trends present today, the effects of these conditions are likely to be substantial and become more complex as incomes stagnate and the cost-burden of independent living continues to rise. In report called The State of the Nation’s Housing 2015, the Joint Center for Housing Studies (2015) notes that “even before the Great Recession, both the number and share of US households paying more than 30 percent of income for housing were on the rise” (p. 5). As prices for home buying and renting skyrocket in major metropolitan areas, the demand for affordable housing will increase. According to the Joint Center for Housing Studies (2015):

the cost-burdened share of renters … held near record highs in the face of stagnating incomes and steadily rising rents. In 2013, almost half of all renters had housing cost burdens, including more than a quarter with severe burdens (paying more than 50 percent of income for housing). Although these shares
remained slightly below their peaks in 2013, the total number of renters with housing cost burdens increased over the year because the total number of renters increased. (p.5)

While cost burdens have been a part of low-income households for quite some time, it is rapidly spreading to moderate-income households throughout America. On average, the Joint Center for Housing Studies (2015) points out that “in the ten highest-cost metros — including Boston, Los Angeles, New York, and San Francisco — three-quarters of renters earning $30,000–45,000 and just under half of those earning $45,000–75,000 had disproportionately high housing costs” (p. 5).

Furthermore, much to the detriment of the Millennial generation, many young Americans are being forced to choose between or cut back on food, healthcare, and other critical living expenses. Given these points, affordable housing must make a significant improvement in order to ensure quality of life for America’s largest generation. Unfortunately, Federal and private funding initiatives lag far behind the need for decent, affordable housing.

**Affordable Housing**

Conventionally, affordable housing means that no more than 30 percent of one’s income is spent on housing. However, according to the U.S. Department of Housing and Urban Development (HUD), “an estimated 12 million renter and homeowner households now pay more than 50 percent of their annual incomes for housing” (“Affordable Housing”, n.d.). And, while talk of affordable housing is abundant, little has
been done to ensure that affordable housing remains accessible for millions of young Americans. In 2015, HUD observed that:

- current federal programs do not meet existing needs, and population changes are expected to escalate those needs, even though specific challenges will vary by geographical region. New approaches to housing assistance are needed.
- Whether federal policy continues to rely on the private market or shifts to assisting households more directly through cash payments or the tax system, the private market will be crucial to ensuring sufficient housing units are available for the full range of the housing market. (p. 230)

In addition, the growing realization that stable, safe, and affordable housing is critical to the development of healthy and sustainable neighborhoods may lead to shifts in affordability policies. Thus, in order for true sustainable development to occur, Federal policies must be designed to enable families of all types to have access to good jobs, schools, parks, and other resources that are free from violence, pollution, and other harmful elements.

Alternatively, one can not discuss affordable housing without also looking at the private sector since Federal housing policy cannot be separated from lenders, builders, and realtors in the private sector. Unfortunately, relying on market factors to influence housing policy has resulted in the scarcity of new, affordable housing units. As more Millennials are forced to choose between high rental rates and homeownership, private market suppliers must adapt and provide sustainable models for housing and community development in order to achieve optimal policy and practice. For the real
estate industry, this means rethinking, innovating and evolving. Because housing is a key component in the U.S. economy, providing housing that is decent and affordable will not only contribute to the improved economic, environmental and social health of Millennials, but will ultimately contribute to sustainable development overall. And while, many Millennials have been challenged by circumstance, this group remains optimistic. The hope is that an improving economy, access to credit, and the sheer size of this group will eventually demand different real estate products that better meet their needs at each stage of their lives.

In the end, demographic shifts will have long-term implications on housing demand. As more Millennials enter into adulthood, they will seek homes and environments that support career-building and social life. At the same time, this generation is at risk of being priced out of many sought-after neighborhoods and will ultimately settle in less expensive communities that allow them to connect to urbanized commercial hubs that are located near mass transit routes convenient to jobs. In the short term, this relatively large demographic cohort cannot be sustained by the same type of housing that their predecessors expected. As a group that embraces flexibility and technology, prefabricated housing may offer affordable options that many cities have failed to provide.
METHOD

Millennials

The subject of this paper is Millennials between the ages of 19 and 34. There are various definitions of the Millennial generation; however, a widely accepted definition is anyone who was born between 1980 and 2000. There are approximately 80 million Millennials in the United States today. As one of the most diverse demographic segments in the United States, 1980 is important because it was when births in the U.S. began climbing upward after being in decline. Similarly, 2000 is important because it was around this time that births started to decline. This year was also a turning point as a new medium — the internet — became a powerful commercial force in shaping the American, and global economy. Since then, life has not been the same. As a vital part of the market, the sheer size and buying power of this generation means that they are not just consumers, but a unique opportunity to shape a future that is more accessible and sustainable.

Affordable Housing

According to the U.S. Department of Housing and Urban Development (HUD), “affordable housing” is housing that is affordable if a family spends no more than 30 percent of their income to live there. However, HUD estimates that “12 million renters and homeowners now pay more than 50 percent of their annual incomes on housing” (“Affordable Housing”, n.d.). By examining data and trends from the U.S. Census Bureau, the U.S. Department of Housing and Urban Development (HUD), and
organizations such as the National Association of Home Builders this paper will
examine shifts in homeownership and affordability — and what this means for
Millennials and the U.S. economy.

**Prefabricated Building Construction and Sustainability**

The U.S. construction industry contributes an estimated $600 billion\(^3\) annually to
the U.S. Gross Domestic Product (GDP). However, the construction industry ranks as
one of the worst performing industries in terms of return on investment. With
construction being such a large part of the U.S. GDP, the lack of progress in
productivity and innovation via technology and prefabrication is troublesome. Yet, the
re-emergence of smaller segment of the construction industry — mainly, prefabrication
and modularization — is influencing design and construction processes. Prefabrication
and modularization are construction processes that have been around for centuries,
but the development of technology and software such as Building Information
Modeling (BIM) is driving increased interest in this form of sustainable development.
Because sustainable development includes sustainable building design and
construction, efforts need to focus on the development of prefabricated/modular
building design, the use of low environmental impact building materials, and the
analysis of the effects of design choices over the complete life cycle of a building. By
examining trends in prefabricated/modular building, this paper will explore how this
construction technique may contribute to sustainable development and affordable
housing while also minimizing environmental degradation.

\(^3\) As reported by the U.S. Department of Commerce, Bureau of Economic Analysis, 2016.
LITERATURE REVIEW

While there are economic benefits associated with construction activities, without careful and holistic consideration of the overall effects that this may have on the environment, the U.S. may never reach true sustainability. Since the process of construction is closely related to issues such as water contamination, environmental degradation and social inequality, policy-makers and those in the construction industry must consider new and innovative techniques when it comes to developing the built environment. One way this may be achieved involves changing the way the construction industry approaches the building process through the use of prefabricated or modular construction. The following literature review is intended to explore characteristics of the Millennial generation and how this may inform sustainable development through technological advances in prefabricated building. This literature review will also help define relationships between urban development and demographic changes and the importance of policies that support the implementation of these types of solutions in achieving the overall well-being of 80 million American Millennials.
The Millennial Generation

In a report called *Millennials in Adulthood: Detached from Institutions, Networked with Friends*, the Pew Research Center examines characteristics and statistics of Millennial adults ranging in age from 19 to 34. As a generation, this group is many things, including complex. According to Pew Research survey (2014) results, “they are relatively unattached to organized politics and religion, linked by social media, burdened by debt, distrustful of people, in no rush to marry — and optimistic about the future” (p. 4). As a group, they are quite different from their predecessors when they were the same age. They are also more racially diverse and are more liberal with beliefs that support same-sex marriage and marijuana legalization.

The report also notes that Millennials have also shied away from marriage as only 26% of the generation is married. Furthermore, most unmarried Millennials (69%) say they would like to marry, but lack what they deem to be a necessary prerequisite — a solid economic foundation. According to the Pew Research survey (2014), “Millennials are also the first in the modern era to have higher levels of student loan debt, poverty and unemployment, and lower levels of wealth and personal income than their two immediate predecessor generations (Gen Xers and Boomers)” (p. 8). Overall, the Pew Research survey indicates that while highly educated, this generation is facing and will face some economic hardships, and this will undoubtedly shape the American market.

Next, in a report by the Council of Economic Advisers — an agency within the Executive Office of the President — fifteen economic facts about Millennials are
examined. The results indicate several implications for the future of Millennials in the market. Because the Millennial generation has taken part in many important transformations over the past few years, policy choices made in regard to education, wages and housing will impact this generation for years to come.

Consequently, research shows that macroeconomic conditions in childhood and young adulthood shape an individual’s trajectories and can have lasting impacts on earnings, savings and trust in institutions among these individuals. This suggests that the Great Recession is still affecting Millennials behavior in the short-term and will continue to do so in the long-term.

**Affordable Housing**

*The State of the Nation’s Housing 2015* report examined homeownership patterns from 1993 to 2014. According to the report “the number of homeowners fell for the eighth straight year, signaling persistently weak demand in this key market segment” (p. 1). Just before the market crashed, younger gen-Xers were a significant segment of first-time homebuyers. As a result, homeownership rates among gen-Xers aged 35–54 have fallen further than those of any other age group. With gen-Xers accounting for a large amount of first-time and trade-up markets the drop in homeownership rates will be a critical factor in the weakness of owner-occupied housing market. Coincidentally, as homeownership decreases, rent increases have been on the rise. However, as more Millennials enter the market, evidence suggests that the demand for first-time homeownership will begin to emerge.
Still, with income growth failing to match rent and housing increases, affordability will not change much in the future as large shares of households are still struggling with household cost burdens. Meanwhile, the number of affordable housing units falls far short of what is need, which means that preserving and increasing the stock that does exist must take priority.

**Sustainable Urban Development**

In *Policy Instruments for a Sustainable Built Environment*, Kibert (2002) addressed policy issues that can influence industries to create a sustainable built environment. Because many of the global environmental problems are directly or indirectly related to the built environment, in order for policy instruments to be effective, they must address the wide range of activities that connect to the built environment. For this paper, Kibert (2002) examines: the supply chain, building creation and disposal, and building operations.

About 40 percent of all resource materials end up in the built environment, and as a result the construction industry dominates materials consumption. In addition, construction activity contributes to a fraction (8%) of U.S. GDP, thus the material impacts of construction outweigh the benefits especially when one considers that an estimated 90% of all materials extracted from the natural environment are in the built environment. With this in mind, policy must address this issue in order to provide solutions for the future. One way of doing this is through green building or sustainable construction. Several organizations such as: The U.S. Green Building Council
(USGBC), The National Association of Home Builders (NAHB), and Federal and local
governments have been actively engaged in how to build in an environmentally-friendly
manner. In the end, the minimization of waste and conservation of resources can be
achieved by designing policies that require industries to consider life cycle processes
in the items that they design.

Next, Jabareen (2006) notes that the future is in danger unless we act
collectively to alter our lifestyles. Specifically, Jabareen (2006) urges that changes are
needed not only in our behavior but also in the design of the built form.

The challenge however, has been a lack of agreement about the most desirable
form when it comes to urban sustainability. Jabareen (2006) goes on to list aspects
that are believed to contribute to sustainable urban forms. These include, but are not
limited to: compactness, sustainable transport, mixed land uses, diversity, and
greening. Ultimately, Jabareen (2006) identifies four sustainable urban forms that have
overlapping concepts and ideas — they consist of compact cities, the eco-city,
neotraditional development, and urban containment. These forms all seek to decrease
energy use, reduced waste and pollution, reduced automobile use, and preserve open
space and sensitive ecosystems.

**Prefabricated and Modular Building**

In *Prefab Houses*, Gössel (2014), explores the origin, design and construction of
various prefabricated homes around the globe. According to Gössel (2014), “a prefab
is a mass-produced house” which is primarily constructed in a factory setting then
assembled on site later. Once regarded as a cheap solution to housing shortages, the prefab has evolved to include sophisticated design. Today however, when considering issues relating to energy use, cost, and the management of resources — prefab houses offer a solution that may lessen the overall impact of man-made dwellings.

In a 2011 report called, *Prefabrication and Modularization: Increasing Productivity in the Construction Industry*, McGraw-Hill Construction Research & Analytics examines the re-emergence of prefabrication and modularization processes. This is due to the fact that Building Information Modeling (BIM) is influencing design and construction processes, and how teams collaborate when building. In addition, the increased interest and growth in “green” building is slowly influencing some in the construction industry. Through an internet survey of hundreds of Architecture, Engineering and Construction Industry (AEC) professionals, McGraw-Hill Construction collected data on the impact of prefabrication and modularization on key industry productivity metrics including: project schedules, costs, safety, quality, eliminating waste, and creating green buildings. Findings reflect that drivers are influencing an increase in “green” building techniques.

While prefabrication/modularization are construction processes that have been in construction industry for centuries, the emergence of BIM has heavily influenced design and construction processes today. Furthermore, the growth in green building has also had an undeniable impact on the construction industry. The key driving factor has been productivity. Reductions in project schedules and budgets are important

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4 Building Information Modeling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.
benefits that all firms are interested in. However, the most challenging aspect of this type of building is that most people do not use it simply because they do not know it is an option. In Prefabrication and Modularization: Increasing Productivity in the Construction Industry (2011), almost half of the non-users surveyed indicated that the reason they did not use prefabricated/modularization is because the architect or developer did not design it into the project. These findings suggest that while the cost benefits are better known, there is still a need for greater understanding, education and wider applicability of prefabricated/modularization.

In an interview with McKinsey & Company (2014), Broad Group chairman and CEO, Zhang Yue talked about traditional construction practices and how the industry can change. As the CEO of a company that built a 57-story modular building in 19 days, Yue discusses how the construction industry is underperforming. Specifically, Yue explains how the construction industry and infrastructure development in China has failed even as modern technology advances. In China, regulations are so stringent that they dictate what materials must be used as well as the standards of thickness required. All in all, Yue hopes to be a model for other countries in order to show how construction can maximize efficiency and reduce environmental impact.

In this book, Ryan Smith — Director of the Integrated Technology in Architecture Center (ITAC), an interdisciplinary research consortium at the University of Utah College of Architecture + Planning in Salt Lake City, Utah — discusses prefabricated architecture’s origins, benefits and challenges. Smith (2010) documents numerous examples of good design, experimentation and collaboration while also examining the
sustainability, material use and some tradeoffs of building off-site. Additionally, as one of the most comprehensive and up-to-date compilations of prefabricated architecture around the world, Smith’s (2010) book also documents the constraints and execution of manufacturing, factory production, transportation, and assembly through dozens of examples of prefab projects by contemporary architects and fabricators from around the world, allowing easy access to information on the most significant advances in the prefabrication/modularization industry.

SUSTAINABLE URBAN DEVELOPMENT

The United States is undergoing a transformation. Changes in populations are creating a demand for new products and services. In response to climate change, dwindling natural resources, public health issues, and infrastructure problems — better solutions are needed to face the challenges created by a rapidly changing population. In effect, communities that address these issues will develop into sustainable places to live, work and play.

Today, one of the major aspects of sustainable development consists of rethinking urban development in the context of the 21st Century. Local and state entities are evaluating the economic, social, and environmental issues that are changing the process of building cities, and are developing solutions aimed at sustainability. How these places choose to accommodate for these changes will determine if cities maintain successful communities. However, of the many factors that are influencing the built environment — restrictive capital markets, the depletion of
natural resources, population demographics, and technological advances — affordability must also be examined as a priority.

With this in mind, one of the most important indications of recent economic drivers is occurring in the built environment. With the majority of the American population living in urban areas, the need for cities that are prosperous, affordable, and resilient is vital. For Millennials, urban cores are currently the ideal choice for living. As cities attempt to address land development in a meaningful way, the growth of the Millennial population is changing the fabric of the urban living environment. Poorly designed dwellings, overcrowding, traffic congestion, environmental degradation, and social inequality must be resolved if officials intend to address issues of development in the modern city.

For the Millennial generation, these challenges have been compounded by a lack of affordable housing. In order to plan for, and create livable spaces at high densities, the built environment must be reimagined. Developing and maintaining quality housing that is accessible and affordable is crucial to the success of all. What is more, for years experts have recognized that our built environment directly affects habitats, ecosystems and water quality. Thus, in order to promote a future that is not only economically viable, but environmentally sound, communities must address the problems of haphazard development and sprawl through behavior changes and innovative design. According to Jabareen (2006), “prospects for the future are dire indeed, unless we act collectively and alter our lifestyles. Urgent changes are needed not only in our behavior but also in the design of the built form” (p. 38).
One way to do this includes revolutionizing the way in which cities are built. When it comes to the effects of urban development — automobiles and factories tend to get most of the blame. Yet the primary cause of most greenhouse gases can be attributed to the construction and operation of buildings in the U.S., and across the globe. In fact, the United Nations Environment Programme (UNEP) (2009) estimated that: “the building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy” (p. 3). In the United States, buildings are anything but ecologically sensitive. In fact, the emissions produced by cooling, heating and powering homes “have been rising by close to 2% a year, thanks in large part to bigger homes stuffed with more energy-hungry devices” (Henson, 2006). Furthermore, the average American home has more than four times the living space per person than in the 1950s. This illustrates the severity of the situation and the need for architectural designs that aid in solving problems associated with building construction. Because buildings are energy-intensive — the overall impact of construction must be thoughtfully integrated toward reductions in energy and material waste. And since building stock is projected to double by 2030, there is enormous potential to reduce energy consumption in the U.S. construction industry through alternative practices.

To this end, sustainability as a concept has become synonymous with reducing environmental degradation, and a key factor in sustainable construction practices includes the environmental impact of buildings during and after their lifecycle. As Smith (2010) wrote:
[The] environmental impact of building requires a quantifiable measure of impact in the total lifecycle from design through facilities management. It stands to reason, therefore, that by controlling the means and methods by which buildings are produced through prefab, architects and construction professionals are able to ensure more sustainable materials and practices for construction as well as have greater opportunity to predict energy performance. (p. 219)

So, the question is: can a type of construction, specifically prefabricated/modular building provide affordable housing opportunities for Millennials and contribute to sustainable development through prefabricated, off-site building processes that not only look good, but shrink the environmental footprint of construction at the same time?

**PREFABRICATION AND MODULARIZATION**

**What is Prefabricated or Modular Construction?**

Prefabrication and modularization are terms that are typically associated with construction processes that occur off-site. Today, this building technique is used to define any structure that is either produced in a factory then brought to a build site to be completed — or when components or modules are industrially fabricated then brought to a site for final assembly. Though this technique is not widely used in traditional construction as we know it today, prefabrication and modularization are not new activities. Like most activities, its relevance closely reflects the technological advances of the day, however because of the skewed relationship between production
and design quality, the construction industry has been unwilling to engage in the fabrication process due to previous missteps.

Nevertheless, as a solution toward a built environment that may be disassembled as easily as it is assembled, prefabrication and modularization have enormous potential. Incidentally, it is also important to recognize that prefab is not a one-size-fits-all solution for housing or every application in the built environment. And yet, by ignoring the opportunities that prefabrication may provide — architects, builders and others in the construction industry risk becoming increasingly irrelevant. Through technology and collaboration, prefab can offer better value, precision, shorter timelines and environmental sustainability. Additionally, by building in a controlled environment, it is possible to create safer working conditions and reduce waste by promoting lean manufacturing. To this end, it is important to understand that prefab is a tool that has yet to be fully realized as a solution in creating sustainable shelter.

A Brief History of Prefabricated and Modular Construction

The earliest recorded case of prefabrication date back to British colonization efforts that took place in 1624. These simple timber framed structures were the first industrialized prefabricated buildings to develop during a time that rapid building was necessary. Following this, iron manufacturing came to prominence as means of building during the British colonial movement. Compartments such as windows, columns, and trusses were manufactured in a foundry then brought to the jobsite and

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5 As the predecessor to modern housing fabrication, it is worth noting that while these components were manufactured in England then shipped to various locations, they were not entirely prefabricated as we have to understand of contemporary offsite production.
assembled into various structures. During the Gold Rush of the mid-1800s, the influx of people searching for prosperity in San Francisco created an urgent demand for housing. In response, entrepreneurs on the East Coast used the latest in iron technology to create simple metal shelters during this era. This was beginning of the “Kit Home”. It wasn’t until the early 1900s that prefabrication as we know it today emerged. In 1920, the prefabricated house allowed innovative architects all over the world to develop concepts for homes that could be produced in an assembly line.

The Industrial Revolution in the United States allowed companies such as Aladdin Homes and Sears Roebuck and Co. to begin marketing prefabricated houses through mail-order catalogs. According to Gössel (2014):

- cut-to-measure wooden beams as well as façade and roofing elements, were offered for houses built using the balloon frame widely accepted in the New World; customers could also opt for plumbing and heating, while the nails and paint are even included. (p. 12)

The first homes — roughly 65,000 houses — that were sold in this fashion were the Readi-Cut house by Aladdin Homes which offered a total of 450 different models. Despite this, it was Sears Roebuck and Co., that had the greatest sales success. Between 1908 and 1940, the company was able to sell nearly 100,000 houses through its catalog and sales offices. These houses offered a wide range of models that included precision-built components that were packed and delivered by freight rail along with assembly instructions. Gössel (2014) points out that “this enabled [customers] to select a model, clarify the question of financing, and decide whether
they wanted to order furniture from the Sears Roebuck catalog all at the same time” (p. 12). Without knowing it, Sears Roebuck and Co. shaped the future of prefabricated architecture through variety, affordability, and marketing. Following this, advances in prefabrication developed in response to new technologies that allowed mass production. Specifically, because of processes made famous by Henry Ford's Model T, standardization allowed prefabricated homes to be made in a variety of quantities and scales. This created all new possibilities for the building industry.
As a result, prefabrication as a discipline began to attract young craftsmen such as Frank Lloyd Wright and Walter Gropius. These men believed that prefab was not only a lifestyle, but a solution to important social questions. In 1911 Wright designed “Ready Cut” kit houses for Real estate developer Arthur L. Richards as a way to provide aesthetically pleasing yet affordable homes to the public. Gössel (2014) explained that “Wright believed that every American was entitled to own a house that fulfilled high aesthetic standards, but was still affordable” (p. 14). Unfortunately, the First World War stalled this momentum as materials were diverted to the war effort. Nevertheless, after the First World War, homebuilding increased to meet the demands of post-war housing.

Similarly, as World War II was coming to an end, returning soldiers again increased the demand for affordable housing. In response, the United States
government passed the Veterans Emergency Housing Act (VEHA) of 1946, which mandated the production of 850,000 prefab houses in just two years. This spurred numerous initiatives for post-war “pre-packaged” designs, and architects and engineers like Gropius, Mies Van der Rohe, and Le Corbusier pioneered innovations in housing craft, material, and quality. Likewise, the Japanese Metabolist, developed modular systems that plugged into service cores or structures. By doing this, it was believed that modules could be easily extracted when tenants moved or required updating. This was short-lived however, as the relationship between architecture and prefab changed in the second half of the 20th century.

![Figure 4. Frank Lloyd Wright’s American System-Built Homes, early 1900s. Source: dwell.com.](image)

![Figure 5. Le Corbusier’s Citrohan House, 1920-1930. Source: Smith (2010).](image)

In the 1970s, as attitudes about materials and the natural landscape change, the futuristic designs inspired by space travel were rejected in favor of buildings in harmony with nature. What is more, the development of prefab elements as an answer to high-density “emergency” shelter exacerbated opinions about prefab housing.
Hence, Gössel (2014) wrote “prefabricated building now came to be associated with the aesthetic and social failure of the de-individualized, megalomaniac, prefabricated slab housing blocks clustered on the periphery of large cities” (p. 25). It wasn’t until the 1990s that prefab began to separate itself from its cheap, mass produced image. This was mainly due to the introduction of computer-aided design (CAD) programs that allowed the creation, modification, and analysis of design.

Today, the prefabricated housing industry is experiencing a resurgence. Because of the precision offered by the computer-controlled production of building components, designers and architects have an opportunity to create standardized, yet flexible housing components to meet a variety of needs. Even more, it is important to recognize that like most technological innovations, the history of prefab has been an evolutionary process. From British colonization to post-war housing, each success and failure has allowed a greater understanding of what does and doesn’t work. What is key after all, is what the construction industry chooses to do with this information in the future.

**Prefabricated/Modular Construction Technology**

Dieter Rams once said: “Good design is innovative”. Specifically, Rams (n.d.) said: “the possibilities for innovation are not, by any means, exhausted. Technological development is always offering new opportunities for innovative design. But innovative design always develops in tandem with innovative technology, and can never be an end in itself”. It is for this reason that the process of prefabrication must be viewed in
concert with design as well as the development of technology. Prefabrication does not
solely consist of beautiful designs, but of detailed connections that come together in
unique ways. While it easy to blame technological advances for the negative aspects of
the environment, it is much more likely that the people behind the deployment of such
technologies are to blame. While most consider the construction industry to be
technologically advanced, the reality is that in general, this industry is extremely
delineate responsibilities with much elaboration on the consequences of failure. These
contracts reinforce risk-abating behavior, causing projects teams not to engage in
integrated practice models, much to the disadvantage of all stakeholders” (p. 53).
Instead of gaining value on projects, owners lose money and architects do not see an
increase in design quality. Similarly, contractors bear a great deal of risk and financial
burden due to financial litigation. As a result, the construction industry has spent little
time investing in technology or training professionals for prefabrication.

In 2006, Pritzker Prize-winner Thom Mayne stated: “if you want to survive,
you’re going to change; if you don’t you’re going to perish” (as cited in Smith, 2010, p.
66). In his statement, Mayne was talking about using digital tools as an advantage in
providing opportunities for increased fabrication capabilities. Today, this tool comes in
the form of CAD and more recently, Building Information Modeling (BIM).

BIM, is the creation and management of digital representations of the physical
and functional characteristics of places. It allows for better informed design decisions,
and buildings that are more efficient and cost-effective; and perhaps more importantly,
it reduces waste and increases profit margins by helping industry professionals plan ahead, produce faster results, and finish projects on budget. Consequently, the use of this technology is on the rise and is expected to drive higher levels of prefabrication over the next few years. In 2011, McGraw-Hill Construction research found that:

currently, 71% of prefabrication and modular construction users are doing model-driven prefabrication on some projects. However, this activity is expected to grow to 91% by 2013—with a quarter of users (25%) doing model-driven prefabrication on more than 50% of their projects.

![Use of Model-Driven (BIM) Prefabrication](image)

*Figure 6. Use of Model-Driven (BIM) prefabrication by percent. Source: McGraw Hill Construction (2011).*

Aside from the benefits of reducing waste, off-site work could decrease habitat disturbance, and offer flexibility in contributing to the development of adaptive buildings. Not only does this contribute to greater control, but many also believe that the use of prefabrication/modularization can help projects achieve LEED credits under
the U.S. Green Building Council’s LEED green building certification program, thus leading to greater environmental sustainability. Again, because the impact of construction on the environment is significant, the use of prefabrication/modularization could contribute to greener construction practices. In the end, the greatest benefit of BIM is in potential productivity gains. As new advances in technology offer more possibility and cost savings when compared to stick build construction, prefabrication/modularization will emerged as an important building option for industry professionals.

Prefab/Modular Construction Uses

While prefab/modular construction can not yet be used for every project, the extent and integration of its increased use depends on the context in which those in the industry come together. In practice, prefab and modular construction can be used for a variety of projects in the commercial and residential building process. Yet its greatest potential lies in its ability to provide affordable, “green” housing.
Since housing will always be a basic human need for populations that are growing, it may be an important tool in providing housing for millions of American Millennials. Because increasing homeownership has been a long-standing policy in the United States, focusing on innovations that support and increase the supply of affordable homes available for purchase is very important. Traditionally, homes have been site-built with certain types of construction materials creating a construction process that is relatively costly and unable to produce units that are affordable to lower income individuals and families. On the other hand, prefab/modular construction methods can produce housing units more cheaply and thus increase the supply of affordable homes available to a generation of cash-strapped individuals. And still, this type of construction only represents a small percent of the housing starts in the United States. According to a report by the U.S. Department of Housing and Urban Development (HUD):

factory-built housing, which includes modular, panelized, and manufactured homes, increasingly allows homebuilders to provide consumers with homes that are less expensive than site-built housing without sacrificing a home’s quality or aesthetic appeal. Yet, such homes represent only 21 percent of housing starts in the United States. (p. v)

This presents an opportunity for homebuilders to provide consumers, specifically Millennials, with homes that are less expensive without sacrificing quality or aesthetic appeal. Above all, prefab/modular construction can be used to: save time, lower costs,
improve energy efficiency, lessen environmental impact, and meet market demands, especially for Millennials.

**Lifecycle Building and the Importance of Prefabricated/Modular Building**

In the United States, many cities are experiencing an “urban renewal”. When compared to urban cores in European cities, which have stood for centuries, the U.S. consumption pattern has had a detrimental effect on the quality and longevity of buildings. Smith (2010) notes that this practice stems from the real estate market’s “concept of product obsolescence, … [when] products become outdated [they] must be renewed in order to improve their technology and usefulness to society” (p. 220). This model of consumptive development has become the standard practice in the United States requiring older buildings to be demolished then replaced by new buildings over and over again. Again, Smith (2010) explained that “the sheer amount of material required to do this continues to remove raw materials from the earth, and pollutes our streams, rivers, and air. In addition, treating buildings as consumptive products is not viably economical” (p. 221). Incidentally, the economic recession of 2008 spurred a new understanding of how businesses should invest in long-term goals rather than short-term profits. This being the case, an investment in durable, long-lasting methods that produce architecture that can be disassembled, reused or even reassembled can offer balance between initial and lifecycle costs. Figure 9 lists do’s and don’ts for reuse.
The idea that prefab/modular construction can assist in the process of recycling may seem like an idyllic notion, but one of the greatest opportunities that off-site fabrication can provide is the ability to identify materials that have the capacity to be recycled. Nevertheless, the importance of prefab/modular construction is not so much in its ability to be recycled, but perhaps its ability to be designed for flexibility.

**Prefab as a Viable Option for Growing and Changing Populations**

In the United States, it is estimated that the population grows by approximately 2.1 million people per year⁶. This means that by 2060, the total U.S. population is projected to increase by 98.1 million people. As a result, cities will have to figure out where all these new people will live and work. This will undoubtedly have an effect on

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⁶As reported in the U.S. Census Bureau's *Projections of the Size and Composition of the U.S. Population: 2014 to 2060* report.
land consumption as land will be expected to be developed at an increased rate. For Millennials and the generations that follow, sustainable, smart growth that can support people in all income groups with housing through all phases of life is critical.

While trying to accommodate for the future needs of society is fraught with uncertainty, in order to gain true sustainability, these needs must be theoretically considered, and designed for change. Smith (2010) argued that “volatility in housing may include changes in lifestyle over a life from young without children … to retired … [while] other changes may occur because of philosophical shifts, changes due to life circumstance, financial or otherwise” (p. 229). This idea of designing for adaptability and flexibility could allow the Millennial generation and future generations to choose their destinations and aid in the social and economic aspects of sustainability.

Figure 10. Diagrams for prefabricated interior partitions for residential architecture. Pieces can be manipulated for change through various stages of life. Source: Smith (2010).

Incidentally, another important function that prefab may provide is the assistance of disaster relief for those who have experienced natural or man-made
disasters due to climate change. Again, Smith (2010) acknowledges that “many [disaster relief shelter] proposals have made it to market … [and are] fabricated in a factory and deployed quickly” (p. 229). This represents a desire and ability to provide temporary and durable housing solutions for those struck by devastation.

Is Prefabrication and Modularization Really “Green”?

As previously mentioned, one of the opportunities that off-site fabrication can provide is its ability to be environmentally-friendly. Although the composition of buildings typically consist of raw materials, prefab may play a role in the extraction, recycling and processing of specific renewable materials. In terms of energy consumption, a building typically has two lifecycle phases: construction and operation. During the construction process all of the energy is embodied in the materials, and the process of building or renovating a facility. During operation however, all of the energy is embodied in the maintenance required to operate the building throughout its lifecycle. Therefore, considering both the initial energy consumed prior to operation and the energy used during operation is equally important. In this respect, prefab offers great promise in the construction and operation of buildings as this allows for more control over materials and energy efficiency.

Besides this, prefab may allow nature-inspired solutions in the built environment through biomimicry. While still relatively new, “biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature’s time-tested patterns and strategies” (as described on biomimicry.org, n.d.). As an
applied science, the widespread and practical application of biomimicry as a design method remains unrealized. But even so, architects such as Michael Pawlyn are advocates for environmentally sustainable projects that take their inspiration from nature. In his 2010 Ted Talk, Pawlyn gives a sense of what biomimicry can offer, he states:

if we could learn to make things and do things the way nature does, we could achieve factor 10⁷, factor 100, maybe even factor 1,000 savings in resource and energy use. And if we’re to make progress with the sustainability revolution, I believe there are three really big changes we need to bring about. Firstly, radical increases in resource efficiency. Secondly, shifting from a linear, wasteful, polluting way of using resources to a closed-loop model. And thirdly, changing from a fossil fuel economy to a solar economy. And for all three of these, I believe, biomimicry has a lot of the solutions that we’re going to need. (Pawlyn, 2010).

Therefore, if one looks at nature like a million-year research and development project, solutions to global challenges can be found all around us.

Additionally, prefab allows for Lifecycle Assessments (LCA) in which a Lifecycle Inventory (LCI) is compiled. By conducting this assessment, resources used for construction can be quantified to include raw and recycled materials while also considering carbon emissions, and energy, and water resource use. In a similar manner, industry professionals can strategize water conservation efforts to meet water

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⁷Factor 10 is the idea that humanity must reduce resource turnover by 90% on a global scale within the next 30 to 50 years to achieve dematerialization. Thus, factor 10 proposes that within the next generation, human energy use must decrease by a factor of 10, and resource productivity and efficiency must increase by a factor of 10.
reduction or catchment goals — and high-performance components can be created in a factory controlled setting to ensure that modules are joined to increase energy-efficiency. The LCA also includes an economic and cultural cost benefit analysis. Despite this, there are drawbacks to this type of assessment as location and context specificity may be issues since each location or company may have different production or transportation processes.

Another major obstacle in performing an LCA analysis is in the time and resources required to perform the study, therefore tracking the path of material flow is difficult to justify in smaller projects. According to Smith (2010), “although offsite fabricators should have more knowledge and control of the products used in their assemblies, most also do not have resources to spend on full lifecycle research either” (p. 235). As a consequence, there is reason to question the reliability of the data. In any event, it is also important to remember that completely data-driven design does not allow room for experimentation, or for the designer to look at a problem qualitatively or intuitively in order to manipulate the context of an environment. In addition, data is only as good as the algorithms that drive them and since these methods are built using small-scale studies there is potential for the algorithms to improve. An example of this can be seen in measuring methods from Leadership in Energy and Environmental Design (LEED). In their article, Armpriest and Haglund (2006) cite a Seattle Post-Intelligencer article from 2005 which proclaimed that “Seattle’s new City Hall is an energy hog” (p. 140). While the building was not prefabricated, it was designed to LEED standards, but data from utilities indicated that energy costs increased 15 to 50
percent when compared with the building it replaced. Granted, there are various reasons as to why this occurred, however, it is likely that the lack of quantitative measures means that designers are not necessarily creating better-performing buildings. Perhaps the lesson to be learned is that there is still room for LEED and various other rating systems to develop qualitative improvements. In the end, there are many factors that influence environmental sustainability, but prefabrication’s ability for quality control while also keeping costs down is an ideal method of greener construction per unit of cost.

Off-site Construction Perceptions

Although it is necessary to develop more precise methods for evaluating green buildings and sustainability in general, whether or not buildings are more sustainable when prefabricated is not entirely the issue. If prefab is to be used to provide affordable housing and accomplish sustainability, then consumers must be educated and perceptions must be changed. Many associate prefabricated/modular construction with “manufactured” trailer homes. Yet, factory-built housing, which includes modular, panelized, and pre-manufactured homes can offer homebuyers and renters with options that are less expensive and attractive.

In 2007, HUD published a report called, *Factory-Built Construction and the American Homebuyer: Perceptions and Opportunities*. According to the report, the goal was to identify “what public perception barriers there [were toward] more widespread adoption of these more affordable construction techniques and what education and
marketing strategies could be used to overcome any identified barriers” (p. v). A key finding of the report was that typically, respondents are simply more familiar with whatever type of home they already live in. That is to say, if respondents lived in panelized housing, then they were more likely to be aware of this type of home and view it favorably. On the other hand, the report suggests that those who have a negative view of factory-built housing do so because they do not identify factory-built homes as investments that will bring future social or financial rewards. As a result, these perceptions limit the prefab industry’s market potential. In response to these perceptions, one thing that the industry can do is participate in marketing efforts that educate the public on the benefits of factory-built homes.

In order for prefabricated or modular homes to gain recognition, industry-wide marketing strategies must be developed to reduce purchasing complications and coordination. In addition, architects and developers must do a better job of designing projects that utilize prefabrication technologies. In their 2011 report, McGraw-Hill Construction research found that “46% of non-users report not using prefabrication/modularization because the architect did not design it into the project” (p. 31). Moreover, believing that prefab is not applicable to a project, and not being familiar with the process of prefabrication/modularization ranks second highest with 34% of non-users. Given these points, evidence suggests that while the cost benefits of prefabrication/modularization are known, there is still a need for an understanding of the processes and the wider applicability of prefabrication and modularization.
AFFORDABLE HOUSING

Affordable Housing in the Twenty-First Century

The U.S. Department of Housing and Urban Development (HUD) was established during the Baby Boomer generation, and as a result, this generation has had a significant impact on patterns of housing growth and development in the United States. Today, many Baby Boomers are parents to America’s largest generation, Millennials. As a group with the potential to reshape the urban form, Millennials have come of age during a time of rapid demographic change and increasing diversity. Their choices on where and how to live, transportation patterns, and cultural activities have played a large role in shaping the country today. Unfortunately, many of the policies aimed at supporting housing opportunity have constrained this generation, making it difficult for millions of young Americans to move through various stages of adulthood. After watching millions of Americans lose their homes due to the Great Recession, this group has been slow to transition into the role of head of household. But, as the economy slowly recovers, questions remain as to what choices Millennials will have in regard to affordable housing as many in this group have already been priced out of important metropolitan markets.

During the 1950s and 1960s, the Brooke Amendment to the 1969 Housing Act capped public housing rents at 25 percent of income. In 1981, this was increased to 30 percent and is considered the general standard for affordability. And yet, today many Americans, both young and old are spending 50\(^8\) percent or more of their income on

\(^8\)As reported by U.S. Department of Housing and Urban Development (HUD).
housing. For Millennials, the implications are many. Will they follow in their parents' footsteps and move to the suburbs? Or, will they demand different types of housing options that support their preferences for the sharing economy, social interaction and urban cores? More importantly, as homeownership remains unattainable for this generation, will high rents add to the longstanding issue of affordability? Considering that rental market was already on the rise prior to the Great Recession, the share of renters paying more than 30 percent of income for housing has put an enormous strain on America’s largest labor force. For Millennial individuals and families who are unable to find affordable housing, the consequences are dire indeed. According to a report called *America’s Rental Housing—Evolving Markets and Needs* (2013), the Joint Center for Housing Studies of Harvard University explains that:

> with little else in their already tight budgets to cut, these renters spend about $130 less on food—a reduction of nearly 40 percent relative to those without burdens… [and] spend significantly less on health care and retirement savings, with direct implications for their current and future well-being. But even those lower-income households that manage to secure affordable housing face difficult tradeoffs, often living in inadequate conditions or spending more on transportation. (p. 6)

So, the question is: what can be done to supply low-cost housing that meets a variety of needs without forcing millions of Americans to choose between basic human needs?
The Challenge of Supplying Affordable Housing

While there are many advantages to renting, the surge in demand in rental markets has pushed the number of households paying excessive shares of their income for housing to record levels. For Millennials this is a complex situation. As a group that stands out as the most educated generation, they are also the first modern generation to have record levels of education debt, unemployment, and stagnant wages. This being the case, one of the fundamental problems in providing affordable housing is that typically, the cost of providing decent housing exceeds what low-income, and evenmore, middle-income renters or homebuyers can afford to pay. For example, in order for an individual with an annual income of $45,000 who lives in New York, to meet 30 percent of the income affordability standard, they would have to find housing that costs no more than $1,125 a month. When compared with the median rental rate of $3,340⁹ in New York however, an individual would have to triple their income in order to afford to live in one of the most popular cities in the United States. Given this disparity, it is no surprise that the gap between the cost of affordable housing and the supply of affordable units continues to grow.

To make progress on the nation’s goal of providing affordable homes for all those who require it means a new approach. For some, part of the solution is to persist in efforts to reduce the barriers that prevent innovative approaches to constructing homes in general. Because expanding the supply helps to reduce rent inflation and provide affordable homebuying options for all households, efforts to develop low-cost housing deserve particular attention. One such effort involves rethinking how policymakers view factory-built or prefabricated housing. As previously discussed, not only are prefabricated homes well-designed to today’s standards, but they can offer new perspectives to a major source of low-cost housing. Genz (2001) argues that:

when the housing market speaks, advocates need to listen. If we listen carefully enough, we might figure out where to intervene effectively to improve housing for people with low incomes, little wealth, and not much power. When it comes
to manufactured housing, the market is not just speaking, it is shouting. Yet the huge popularity of manufactured housing has prompted only a shrug, and in some cases a cold shoulder, from those who promote housing opportunities. (p. 303)

Thus, in order to truly meet the demands of America’s largest generation, there needs to be a greater understanding of the dynamics of the prefabricated/modular housing industry. By doing this, advocates skilled in finance, development, and policy can help do what HUD has been trying to do since its inception — respond to housing and urban issues — especially in the context of modern America.

RECOMMENDATIONS AND NEXT STEPS

Home ownership has been an important part of the “American Dream” for several decades, however, as homeownership rates fall — the reality of what it means to own a home has forced many to abandon this dream — no longer considering it a path to wealth or success. Today, this thinking has led many to view housing in a different way. Historically, owning a home has been considered an important part of transitioning into adulthood, but for a large part of the population, specifically Millennials, this process has been altered. Student loans and high unemployment prevent many Millennials from moving toward traditional paths of adulthood. Instead, Millennials are choosing to live in urban cores that foster environments that are socially diverse — but have higher price tags. At the same time, Millennials value mobility and flexibility so the idea of owning a home is unappealing. Still, many believe that as
Millennials age, they will choose paths similar to their parents, however, tighter lending environments have forced this generation out of homeownership and into rental markets with higher rates and less supply. To combat this, ambitious but achievable housing plans must be developed to bridge the gap between science, technology and design — while also lessening the impact of socioeconomic shifts on society.

**Technology**

As affordability continues to be a major challenge for Millennials, developing and administering improvements that support holistic and proactive housing needs is vital to sustainability. Moreover, innovations at the federal, state, and local level may be able to identify ways that more people can attain affordable housing. In particular, Smith (2010) explains that “for prefabrication to thrive as a building production, an understanding and implementation [of technology] by architects and construction professionals … is necessary in the process of technology transfer” (p. 335). Technology must be harnessed to remake the housing and construction industry in the same way that other industries have appropriated technology to solve complex problems which are better suited for a sustainable future. This approach may motivate the construction industry to engage in pro-environmental behaviors like alternative construction as a way of providing low-cost housing options for the growing number of young American Millennials.

Currently, there are no specific federal policies aimed at developing construction technologies. However, there several policy initiatives that may encourage green
building innovations. Specifically, the Office of Science and Technology (OSTP)\textsuperscript{10} works to advance a wide range of programs and projects that use the power of science, technology, and innovation for the benefit of Americans and people around the world. Because technology allows for the transfer of knowledge and capability from one party to another, the OSTP can work with public and private agencies to increase their investment in advanced fabrication research and development in prefabricated/modular building. The OSTP notes that:

- to bridge the gap between basic research and product development in areas …
- [it is important] to identify advanced manufacturing technologies that are ripe for expanded investment and collaboration between government, industry, and academia. (“Spurring Innovation”, n.d.)

Thus, the transfer of technology between government, industry, and university may lead to further research and development of fabrication techniques that allow a wider use of prefabrication and modularization in both the public and private sectors. In addition, the National Economic Council (NEC) and OSTP’s \textit{Strategy for American Innovation} aims to identify and pursue goals that use science and technology to invest in and fuel innovation. This suggests that an exploration of building technologies would easily allow an ongoing exchange of process and technology to aid in the design of just about anything, especially housing, for the benefit of all.

Alternatively, federal green building standards should be revised to better advance the objectives of prefabrication and modularization. In 2006, the Federal Leadership in High Performance and Sustainable Buildings Memorandum of

\textsuperscript{10} This organization advises the President on science and technology in regard to domestic and international affairs.
Understanding (MOU) was signed by the Department of Energy and several other agencies. It established a set of guidelines toward the implementation of: integrated design principles, optimized energy performance, the protection and conservation of water, enhanced indoor air quality, and the reduction of environmental impacts of materials.

According to the DOE, the overall goal of the memorandum was to “commit to implementing common strategies for planning, acquiring, siting, designing, building, operating, and maintaining HPSB” (p.1). Ultimately, the adherence of these goals aim to:

- reduce the total ownership cost of facilities and the life-cycle cost of facilities’ environmental and energy attributes; improve energy efficiency and water conservation and utilize renewable energy; provide safe, healthy, and productive building environments; and promote environmental stewardship through responsible land use and material procurement. (p. 1)

This being the case, it is easy to see how the use of integrated design and prefabrication could meet all of the MOU goals by reducing total project costs and providing healthy buildings that also reduce material waste. Admittedly, when the DOE developed these standards, it is likely that prefabrication was never considered, thus, in order to facilitate the utilization of newer building technologies, the DOE simply needs to include prefabrication or modularization in its HPSB standards when considering new construction, major renovations, leases, and existing buildings under federal management, as this may create opportunities for the advancement of
prefabrication/modularization. In the end, in order for the technology associated with prefabrication and modularization to reach a wider audience, those in the construction industry need to view prefabrication as a tool that allows all the players in the market to fully integrate these building practices into the larger fabric of the construction industry.

**Financing**

If prefabricated building is to be considered in the affordable housing market, then advocates must do more to assist in the financing of factory-built housing. For many, factory-built, prefabricated housing is an important part of the affordable housing industry. However, despite the U.S. House of Representatives’ recognition of the third week of June as Manufactured Housing Week, the government has done little to support the manufactured housing market. In a paper called, *Bringing Manufactured Housing into the Real Estate Finance System*, Burkhart (2010) highlights that:

> despite its importance, the government has done relatively little to assist the manufactured housing market as it struggles to recover from a devastating meltdown while the government spends hundreds of billions of dollars to strengthen the mortgage market and to prevent home foreclosures. (p. 428)

The issue here is that while the government’s attention has been focused on financing traditional mortgages, manufactured homes are not usually included in these efforts. More importantly, a lack of distinction between more modern manufactured homes and those known as mobile homes has made it difficult for those seeking affordable housing solutions to receive better financing options. HUD and NAHB note that
“financing procedures for most manufactured housing sold today are holdovers from the origin of a manufactured home as a mobile vehicle of trailer” (as cited by Genz, 2001, p. 401). And, because a limited number of companies finance this kind of specialized lending, buyers end up paying anywhere from two to five percent more in interest than with conventional home loans. Therefore, a simple solution in the financing of manufactured or prefabricated homes is a recognition that these types of homes are indeed real property similar to conventionally built homes. The challenge then, is how to encourage lenders to recognize prefabricated/modular homes as real property since the traditional method of categorizing these homes as personal property puts them outside of the realm of traditional housing financing systems.

Coincidentally, another challenge to financing prefabrication concerns risk. Typically, any deviation from the standard construction process elicits fears about potential financial vulnerability. Despite this, the reality is that many prefab projects tend to be more secure than traditional construction because of the ability to anticipate changes ahead of time. Thus, an unwillingness to use prefab has more to do with not wanting the deal with issues of initial design and financing. Smith (2010) notes “in residential construction, prefabrication methods continue to have a negative image, associating it with temporary or HUD code portable construction. As such, lending institutions may be more reluctant to provide funding” (p. 92). When financing custom residential construction, funding through traditional construction loans may present problems. On the other hand, prefabrication has a greater potential to offer variable loans or leasing options that make homeownership more attainable. As a final point,
unlike traditional construction, prefab/modular elements could potentially provide higher a return on investment when compared with traditional buildings that primarily derive value from the land on which they sit. This is due to modular construction’s ability to be more flexible and adaptive.

Eventually, if the housing market is to be sustained under the current economic climate then those responsible for financing the “American Dream” must consider how alternative building methods may diversify the housing market with low-cost, factory-built homes. Again, if advocates of manufactured housing are to make any difference, then they must promote financing programs that view manufactured homes as real property in order to overcome the existing practice of financing manufactured homes as personal or HUD property. Thus, informed consumers, supporters of prefabrication, and innovative lending institutions must step up in order to influence change in the financial sector.

Collaboration and Influence in the Private Sector

As previously discussed, one of the drivers in the adoption of widespread use of prefabricated and modularized building is the sharing of technology through collaboration within the private sector. If this building process is to be implemented on a scale similar to conventional building, then all those who participate in the development of prefabrication technologies must share information. Since technology is often transferred from one party to another, there is an opportunity to transfer various models of collaboration across the architectural field.
Fortunately, architects have the ability to participate in all phases of technological development which may greatly influence the market. In addition, Smith (2010) emphasizes that:

architects need to also develop component knowledge, or an understanding of the role that each player contributes to the team, using a joining effort to innovate on a project. The advantages to sharing one’s specific knowledge in a building team are obvious. (p. 337)

Instead of assuming that tools and theory will trickle down, professionals should seek out and focus on key players and how they might integrate learned practices into collaborative building. One such player is the subcontractor. Smith (2014) again points out that “subcontractors are increasingly becoming more innovative and advanced as tools for manufacture are more accessible. By collaborating with manufacturing, architects have an increased chance to deliver more efficient and innovative products, assemblies, and buildings” (p. 337).

Eventually, greater integration requires reworking the discipline of architecture to include cross-disciplinary learning in architecture, engineering and construction. This may allow students to prepare for the future by collaborating with industry mentors to make decisions that will affect innovation in the construction field. Nevertheless, the future of prefabricated building is a process that must combine the full range of capabilities in the manufacturing industry while transferring it to architecture and construction professionals. All in all, if prefabrication is to move forward, then better
solutions must be found as prefab is an improvement that can increase productivity and quality.

**Design, Sales and Installation Processes**

When it comes to shopping for and choosing a factory-built home, there are several choices. This is both good and bad. Because of reasons mentioned previously, a lack of collaboration can lead to confusion when it comes to choosing which company to use for design, sales and installation. Thankfully, most prefab designers and builders have the ability to guide consumers through the process. Since there is very little education or understanding of prefabrication processes, most buyers must figure out this out on their own. To overcome this, information about various designs and models must be widely and readily available. Collaboration across the field can improve sales processes and reduce confusion. On the local level, permitting and zoning procedures that allow prefab to exist in a similar manner to traditional building will also help. Rather than creating ordinances that cluster “manufactured” homes to trailer parks, local codes could create a distinction by defining various zoning conditions based on more modern types of factory-built housing. For example, older zoning ordinances restrict the locating of manufactured/mobile homes to specific areas, however, today the use of modular construction is more widely accepted as an alternative to traditional building while also adhering to conventional zoning practices. In the end, the installation of prefab/modular homes is a critical step that needs special
regulation until it is more widely recognized as being on the same level as more conventional building processes.

CASE STUDIES

While prefabrication in the twenty-first century is still evolving, there have been several successful cases throughout the industry. The following will review some notable projects and how each company facilitated these projects.

Cubicco

Cubicco is a modular housing company — based in both Miami, Florida and the Netherlands — that specializes in a mix of contemporary communities designed around people’s health and well-being. According to Cubicco, the company “aims to create cost efficient, safe, healthy and comfortable homes within well designed communities in a closed sustainable life cycle” (p. 5). Each community is developed in concert with long-term conservation of natural resources. Buildings are energy-efficient and promote pedestrian-friendly urban design standards. This is achieved through state of the art technological practices that allow flexible modular building solutions that are designed with precision and extreme natural conditions in mind. In particular, all of Cubicco’s units are designed to meet, and in some cases exceed Florida’s high velocity hurricane building code requirements.

As with most prefabricated or modular housing, Cubicco’s units are designed for assembly in virtually any location. In addition, a combination of materials and
finishes make each structure low maintenance and long lasting. When maintenance is required, Cubicco will provide expertise and prompt service. Above all, Cubicco provides affordable housing options with prices starting at $115,300 through $167,300.

\[\text{Figure 12. Cubicco Exploded Axonometric – Typical Module + Options. Source: Cubicco.}\]

\[\text{All prices include freight on board for Miami and are based on estimates non-contractual. Costs are subject to country and region specifics.}\]
Perhaps the most important aspect of Cubicco’s practice is their ability to also provide master planning services which seek to promote sustainability and the enhancement of a community’s social structure. The company explains:

we design our communities around the needs and comfort of the pedestrian and not the automobile. We try to encourage walkable mixed use neighborhood design as opposed to single isolated uses while at the same time enhancing the connection the user has with nature and the beauty of their surroundings.

(“Master Planning”, n.d.)
Figure 14. Cubicco master plan concept 1. Source: Cubicco.

Figure 15. Cubicco master plan concept 2. Source: Cubicco.
That being the case, Cubicco’s greatest strength may come in its ability to design and plan communities that use land in an efficient manner to promote healthy NetZero community living.

The Stack, NYC by Gluck+

In 2013, over the course of 19 days, New York City’s first, entirely modular building went up in the northern part of Manhattan. On a site 50-foot-wide, 150-foot-deep, 56 modules were stacked into two seven-story structures with one unified facade that surround a central courtyard.

Within The Stack there are 22 apartments ranging from studios starting at $1,755, one-bedrooms from $2,400, two-bedrooms from $2,850, and three-bedrooms from
$3,990. Included in this are six affordable apartments that were given out via a lottery. Three, two-bedrooms were priced at $1,060 and three, one-bedrooms were priced at $909. The one-bedrooms were available to families of up to two people making less than $40,320 combined, while the two-bedrooms were reserved for families of four earning less than $50,340.

In addition, through the NYC Housing Partnership, Manhattan Community Board 12 residents, along with people who have visual, motor or hearing impairments had their applications processed before general applicants thus providing easier access to those who truly required housing assistance.

On the whole, this project was an opportunity to create an exciting design for living while enjoying the benefits and efficiencies of a controlled factory setting. In terms of future building and development, the method used to construct these units
will surely allow a greater understanding of application processes for a multitude of other projects.

**Michelle Kaufmann Studio**

Michelle Kaufmann created her company, mkDesigns in the early 2000s as a way of finding better, more sustainable housing. Kaufmann’s first house was for herself, and originally took 14 months to work through the prefab process onsite. Later, Kaufmann would build the same house, but it would take only 4 months and cost 20 percent less because it would be produced entirely in a factory.

More recently, Kaufmann has partnered with other companies such as Studio 101 Designs and Blazer Industries to create modular homes throughout California. With skillful design, Kaufmann and her team were able to build a space that felt larger through the use of open spaces, high ceilings and high clerestory windows. In addition, the home produces its own energy through PV panels and was designed with efficient systems to reduce the amount of energy and water used. According to Kaufmann’s website, one home in particular “went through an exhaustive evaluation as a part of the California Solar Initiative’s New Solar Homes Partnership (NSHP) program which helps create a self-sustaining solar market by ensuring high levels of energy efficiency in projects seeking solar system rebates” (“Northern CA 2”, n.d.). What is more, the floor was made of woven bamboo, the cabinetry is FSC certified and the interior finishes are low VOCs. On average, Kaufmann’s houses range from $250 to $300 per sq. ft., while factory production costs average $200 per sq. ft.
Figure 19. Michelle Kaufmann and Studio 101 modular house, exterior 1. Source: Michelle Kaufmann Studio.

Figure 20. Michelle Kaufmann and Studio 101 modular house, exterior 2. Source: Michelle Kaufmann Studio.

Figure 21. Michelle Kaufman and Studio 101 modular house, walkway 1. Source: Michelle Kaufmann Studio.

Figure 22. Michelle Kaufman and Studio 101 modular house, walkway 2. Source: Michelle Kaufmann Studio.
Resolution: 4 Architecture’s Modern Modular

Developed by Joe Tanney in 1990, Res4 developed spatial modules to create urban domestic spaces. In 2003, the firm won Dwell Magazine’s prefab housing competition and since then has designed dozens of houses across the United States. According to Smith (2010), “Res4 developed a comprehensive knowledge of the modular industry and the efficiencies and deficiencies of such” (p. 258). The company’s designs provide hundreds of configurations that build on lean manufacturing and assembly line principles. Furthermore, Res4 works with manufacturers to develop standard methods for detailing, lighting and mechanical integration. To date, Res4 has designed and built homes from Maine to Hawaii. Houses average $250 per sq. ft. and include necessary site improvements. Soft costs like architectural fees are a little more at 15 percent, but this is due to the high level of coordination needed to produce units in a factory while creating added value or the customer. Designs are usually bid out to several modular providers and a general contractor works to prepare the site, foundation and utilities.

Figure 23. Resolution: 4 modular system configurations. Source: Resolution: 4 Architecture.
In short, the goals of Resolution: 4 are to build better homes while collaborating with manufacturers to find more affordable ways of delivering quality housing that is sustainable. In the long-term, Tanney aims to build communities with higher densities as well as infill housing in urban cores. This includes mixed-use structures with commercial on the bottom and residential above. The potential of these projects is their ability to combine visionary ideas with research-based practices.

Table 1. Case Study Comparison

<table>
<thead>
<tr>
<th>Prefab Builder</th>
<th>Cost</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubicco</td>
<td>$165/sq. ft.¹</td>
<td>Least expensive (homebuying)</td>
<td>NA</td>
</tr>
<tr>
<td>The Stack, NYC by Gluck+</td>
<td>$36 - 50/sq. ft.²</td>
<td>Rental units/High density potential</td>
<td>NA</td>
</tr>
<tr>
<td>Michelle Kaufmann Studio</td>
<td>$250 - 300/sq. ft. (plus factory costs of $200/sq/ ft.)</td>
<td>Custom builder</td>
<td>Costly/Comparable to some traditional builds</td>
</tr>
<tr>
<td>Resolution: 4 Architecture</td>
<td>$250/ sq. ft.</td>
<td>Flexibility/High density potential</td>
<td>Factory/architect fees</td>
</tr>
</tbody>
</table>

Note. Overall comparison of case study builders. ¹Prices start from. ²Indicates rental rate ranges ($36 per ft² avg, $2,469 avg price, $50 per ft² avg, $1,895 avg price). Traditional construction costs start at $150, but does not include all necessary fees or overages. Source: Cubicco, Gluck+, Michelle Kaufamann Studio, and Resolution: 4 Architecture.

Overall, while the prefabricated and modular construction industry has made significant advances in implementing materials and processes that build and deliver sophisticated and complex buildings, there is still more work to be done. Prices, locations and techniques vary from fabricator to fabricator — thus architects and builders still need to develop an understanding of how each prefab project contributes to the underlying goal of the industry. With that in mind, the most viable builders from the above case study are Cubicco and Gluck+. The reason for this is simple. Both builders offer low prices at higher densities, and may be able to offer the greatest flexibility when it comes to building in more urban, high density locations. In addition, these builders appear to have developed standards which allow for faster builds with the least possible environmental impact. Therefore, Cubicco and Gluck+ offer the most appropriate type of housing based on characteristics of the Millennial generation.
CONCLUSION

Innovation and productivity have been, and will continue to be critical to the well-being of the American economy and its people. Competition from new and existing industries plays an important role in fostering advancement and growth. Specifically, the commercialization of new ideas and products in the construction industry will allow the creation of incentives that encourage transformation and reduced costs in the housing and rental markets. At the same time, there needs to be a greater recognition of alternative building processes as they may provide benefits that lessen environmental and economic impacts on the built environment for current and future generations. And, since green construction practices like prefabrication are still viewed as new phenomena, oftentimes the problem with prefab is that those who are unfamiliar with 21st century fabrication processes fail to recognize the differences and opportunities of factory-built projects. Specifically, there are dozens of potential ideas, processes, and practices that may have a significant impact on the construction industry’s efficiency and productivity if implemented widespread throughout the construction sector. These activities could significantly advance construction innovation and improve quality, timelines, cost-effectiveness, and the sustainability of construction projects since buildings, and housing in particular have a huge impact on the environment. Therefore, through processes employed by various assembly line products, fabrication and modularization can provide integrated housing solutions for what is now the largest part of the American population.
As the largest cohort, Millennials continue to challenge market and cultural traditions. Instead of settling down in their early twenties, this group chooses to remain unmarried and mobile — and although highly educated, also faces harsh economic challenges such as high student loan debt. What is more, because of choices about education, Millennials chose to cluster in urban cores that provide greater opportunity. However, an unintended consequence is that these choices have forced Millennial adults into markets with extremely high rental rates, while also shutting Millennials out of the homebuying market because of tighter lending environments. This marks a significant shift from previous generations. And since, housing will always be a requirement for populations that are growing and changing, greater emphasis must be put on innovative strategies and processes that not only house people affordably, but provide sustainability, as this is vital to the health and stability of cities. With this in mind, it is important to note that before prefabrication or modularization can be implemented on a wide scale, several things need to happen.

First, technologies and research must be shared among industry professionals, and among governmental regulators on the Federal, state and local level. In addition, widespread deployment and use of technological applications such as Building Information Modeling (BIM) must be used to improved job-site efficiency through more effective interfacing of people with materials, equipment, and information that increases the use of prefabrication and modularization through off-site fabrication techniques and processes.
By doing this, a process of standardization can be achieved similar to what typically happens on traditional construction projects — which would allow a greater understanding of performance and measurements that support innovation. Second — consumers, developers, and homebuyers need to be educated on all aspects of twenty-first century factory-built housing. This includes dispelling notions that manufactured housing in the modern context is the same as a mobile home or a trailer. Third, financing instruments for factory built housing need to create a distinction between what is considered real vs. personal property. Doing this will encourage lending processes that fund new housing solutions like prefabrication and modularization that meet the demands of population and demographic changes. And finally, state and local officials should develop practices that seek out, and promote smart growth patterns that can be supported by prefabricated building. Incidentally, while there is still more to learn about prefabrication and modularization, the urban ecosystem can certainly benefit from those who advocate for the integration of a wide array of technologies that can evolve while maintaining energy efficiency and renewable materials. The Federal government can certainly help to ensure that technologies for urban applications such as affordable housing are coordinated through research and development activities that support a number of sustainable community initiatives aimed at providing decent, reasonably priced housing.

In the end, there are still breakthrough opportunities yet to be developed in the prefabricated and modular building industry. Perhaps the largest breakthrough to come is how to provide low cost housing at high densities to those who desperately need it.
Nevertheless, gathering information from various builders such as Cubbico and Gluck+ promotes the facilitation of information and resources that has allowed other countries to build prefabricated houses for decades. These companies prove that there are different and affordable ways to build while also creating sustainable spaces. And, if one has learned anything from the past few of years during the Great Recession, it is that American consumers desperately need and want affordable housing options. Thus, if given the choice and ample information, consumers, especially Millennials would flock to better-built, lower cost housing alternatives instead what is currently being offered on the market. So, for the sake of society’s need for affordable housing and for the sake of the future of the construction industry, leaders and officials must do better to provide a more superior and efficient way to build.
References


