INCREASING THE APPEAL OF SUSTAINABLE HOUSING

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Housing is a large source of energy consumption worldwide. Many houses currently on the market are not energy efficient and lack that due to the high upfront costs of sustainable technologies (D'Agostino et al, 2020, para. 58). The topic being discussed for the technical project involves attempting to create a net-zero house, a house that produces more energy than it consumes. The project will also involve trying to keep costs relatively low. The technical portion is advised by Professor Harsha Cheliah from the University of Virginia's Department of Mechanical and Aerospace Engineering. Twelve undergraduate 4th year Mechanical Engineering students working on this project are Luke Anderson, Lucas Daugherty, Alex Davis, Jillian Doyle, Max Gerber, Amelia Kokernak, Kara Koopman, Isaac Mulford, Cathryn Palmer, Jack Pazin, Noah Plues, and Joshua Starr. The original house was built by the University of Virginia School of Architecture back in 2010 but is being modified in this project by adding higher quality insulation, a ground source heat pump with a custom heat exchanger, and solar panels that follow the sun. The team was divided into three groups and each group is working on one system.

The Science Technology and Society (STS) portion of the project aims to improve the appeal of sustainable housing to the public. Sustainable housing in this project will capture net-zero houses and other energy efficient homes. The project primarily focuses on finding ways to reduce the costs of sustainable homes since reducing the costs of environmentally friendly technologies tends to increase the willingness for people to adopt them (Chiu et al, 2014, p. 9). The technical and STS portions are tightly coupled since both portions are tackling issues with sustainable housing. The technical portion addresses issues relating to improving the energy efficiency of homes while the STS portion focuses on finding options for more affordable and appealing sustainable housing. Interest in sustainable was sparked by the numerous news reports in recent years about climate change and the housing market crisis. It was further sparked due to having a background in topics such as thermodynamics and heat transfer since thermodynamics and heat transfer are both applicable to energy efficient housing. The research question being answered is how can sustainable homes become more affordable and appealing to the public. The question will be answered through Actor Network Theory (Latour, 1992, p. 14) (Callon, 1986, p. 9). Actor Network Theory will be used to discuss faults in rating systems, shared equity housing, and subsidies as ways to improve the affordability and desirability of sustainable housing.

EMISSIONS CAUSED BY HOUSING

Housing is a large source of CO_2 emissions. The global residential energy sector accounts for 25% of all energy consumption and 17% of greenhouse gas emissions (Aram et al, 2020, para. 1). In the US, residential buildings account for 22.4% of all energy consumption (*U.S. Energy System Factsheet*, *2021*, para. 2). The average American's energy consumption while at home is 12.1 kWh and includes consuming over 2 gallons of oil, almost 8 pounds of coal, and over 250 cubic feet of natural gas (para. 2). Buildings in Europe are also large contributors to CO_2 emissions. They account for 36% of all CO_2 emissions in Europe (D'Agostino et al, 2020, para. 1)

USE OF ACTOR NETWORK THEORY

Actor Network Theory is a model that provides an understanding on how decisions made by people affected by a technology (actors) intertwine with the physical attributes of a technology (Cressman, 2009, p. 3). The use of Actor Network Theory in this project will analyze how different actors affect the availability, affordability, and desirability of sustainable housing.

Actors being considered will include construction companies, lawmakers, homebuyers, engineers, rating systems, environmental regulations, and shared equity housing companies. These actors all play roles regarding sustainable housing and interact with each other as shown in Figure 1. One example of an actor affecting sustainable housing would be lawmakers providing rebated to those who add solar panels to their roofs. This example would increase the affordability of sustainable housing by reducing the costs of installing solar panels and would make sustainable housing more desirable by making it more affordable.

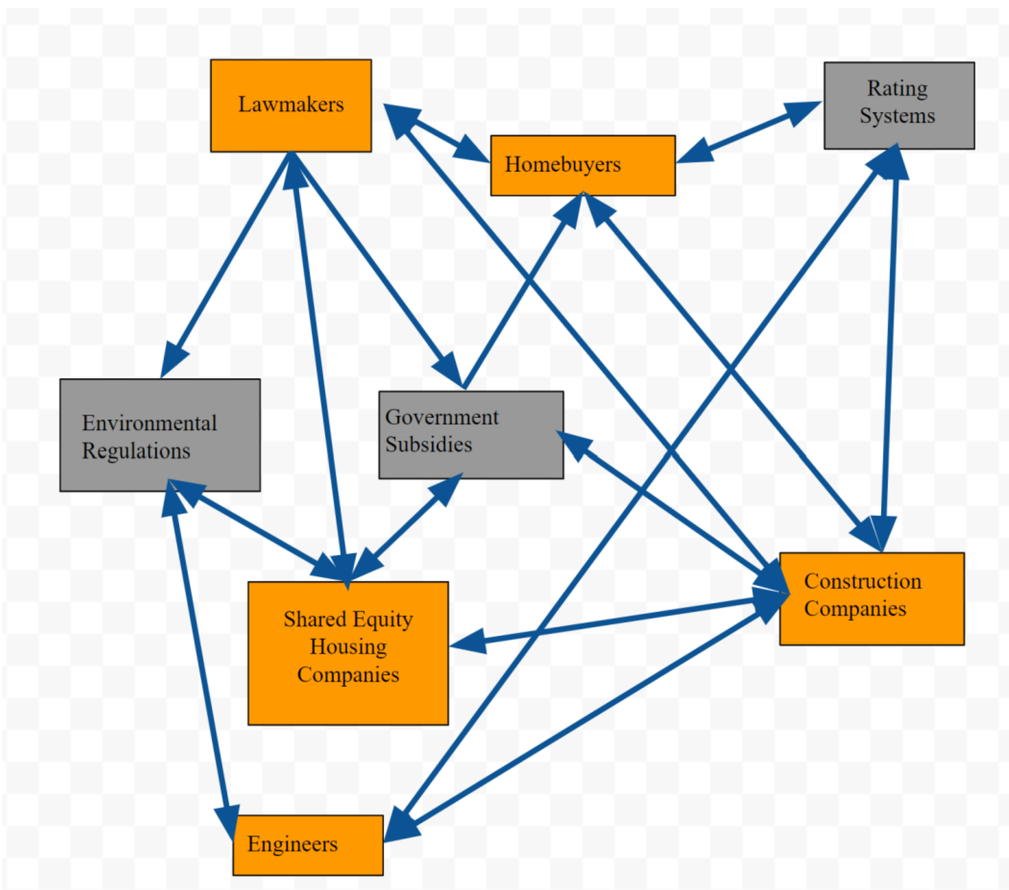

Figure 1: How different actors affect the affordability of sustainable housing. This figure shows the interactions between different actors and how they affect the affordability of sustainable housing. Orange icons represent actors while gray icons represent actants. (Pazin, 2022)

FAULTS IN EVALUATION SYSTEMS

Leadership in Energy and Environmental Design for Neighborhood Development (LEED®ND) is a rating system developed by the US Green Building Council (USGBC) and has become a readily accepted benchmark for designating buildings as environmentally friendly (Cidell, 2009, p. 1). The LEED®ND system is built on 3 pillars: equity, economy, and environment (Szibbo, 2016, para. 5). LEED®ND rated communities can score up to 110 points are there are 4 categories that can be attained based on the community's score (para. 12). A bronze rating requires of a score of at least 40 points but less than 50 points, a silver rating requires a score of at least 50 points but less than 60 points, a gold rating requires a score of at least 60 points but less than 80 points, and a platinum rating requires a score of at least 80 points (para. 12). The table for the maximum number of points awarded for each general category is shown below in Figure 2.

	Maximum Possible Points	Percentage of Total Points
Smart Location & Linkage	28	25.45
Neighborhood Pattern & Design	41	37.27
Green Infrastructure & Buildings	31	28.18
Innovation & Design Process	6	5.45
Regional Priority Credits	4	3.63
Total	110	100

Figure 2: LEED®ND score breakdown. This figure shows how the LEED®ND scoring system's main categories are weighted. (Adapted by Jack Pazin (2022) from *Checklist: LEED v4 for Neighborhood Development* 2014).

Within the Neighborhood Pattern & Design category, a maximum of 7 possible points can be attained for having a variety of housing types and affordable housing (para. 13). Other criteria in such as walkable streets, compact development, and having a connected and open community are all required for any level of LEED®ND certification regardless of score (para. 25). However, the 7 possible points awarded for affordability and diversity of housing stock are not required to be considered even though LEED®ND-certified neighborhoods need to fulfill other outright requirements such as avoiding construction on floodplains and making sure streets are walkable (*Checklist: LEED v4 for Neighborhood Development*, n.p.). A neighborhood could theoretically completely ignore the housing diversity and affordability subcategories and still achieve a platinum rating since getting a perfect score on every other category would still result in a total score of 103, well above the 80 points required for a platinum rating. This lack of emphasis on affordability and diversity often leads home developers to either deprioritize affordable housing stock or neglect it altogether (Szibbo, 2016, para. 9).

Currently, the 7 points given for affordability and diversity of housing stock consist of up to 3 points for affordability and up to 3 points for providing a range of housing options. An extra point for maxing out both of the above categories brings the highest possible score in this category to 7 points out of the 110 total points (*Checklist: LEED v4 for Neighborhood Developmen*, n.p.). Points can be awarded for any combination of the thresholds met in Figure 3 for at most 3 points. Housing diversity is measured by using the Simpson Diversity Index. This index calculates the percent chance that 2 randomly selected homes will be of different types. For example, an index of 0.9 indicates that 2 randomly selected homes within a neighborhood will have a 90% chance of being different types. This index is calculated using the equation $Score = 1 - \sum \left(\frac{n}{N}\right)^2$ where *n* is the number of homes in a single category and *N* is the total number of homes in the entire neighborhood (*Housing types and affordability*, para. 2). A score of at least 0.7 awards 3 points, a score of at least 0.6 but less than 0.7 awards 2 points, and a score greater than 0.5 but less than 0.6 awards 1 point. No points are awarded for scores of 0.5 or below (para. 3).

Rental Units				For-Sale Units			
Priced up to 60% AMI		Priced up to 80% AMI		Priced up to 100% AMI		Priced up to 120% AMI	
Percentage of Rental Units	Points	Percentage of Rental Units	Points	Percentage of For-Sale Units	Points	Percentage of For-Sale Units	Points
5	1	10	1	5	1	8	1
10	2	15	2	10	2	12	2
15	3	25	3	15	3	-	-

Figure 3: Scoring system for affordability. AMI stands for Area Median Income. For example, houses selling at 60% AMI would be purchasable for those earning 60% of the median income in that area. (Adapted by Jack Pazin (2022) from *Housing types and affordability* n.d.).

Although potential faults in the LEED®ND may unintentionally steer developers into neglecting affordable sustainable housing, various solutions have been proposed. Several solutions were suggested by Nicola Szibbo, an affiliate faculty member at the University of Hawaii-Manoa who studies comprehensive planning and sustainable communities. Proposed solutions involve increasing the importance of considering the affordability and diversity of each neighborhood during LEED®ND certification process (Szibbo, 2016, para. 1). These potential solutions include awarding more possible points for affordability as well as requiring a minimum percentage of units in a neighborhood to be affordable for LEED®ND certification to even be considered (para. 25). A survey of 114 LEED®ND accredited professionals found that 47% believe LEED®ND fails to support social equity, 63% believed the affordable housing scorecard could be improved, 23% would increase the weight of the affordability score, and 13.5% would mandate the affordable housing component for all LEED®ND candidates (para. 31). Mandating the affordability component for LEED®ND certification would likely help increase affordable sustainable housing since adding affordable housing tends to run counter to the motives of developers. Developers are often hesitant to add affordable housing to neighborhoods awaiting LEED®ND certification due to lower profits and 63% of LEED®ND accredited professionals suspect that the lack of affordable housing in such projects can be traced to these lower profit margins (para. 80). Therefore, mandating a certain amount of affordable housing for LEED®ND certification provides a much stronger incentive for developers to add affordable sustainable housing.

SHARED EQUITY HOUSING

Although editing rating systems such as LEED®ND may bring down the cost of sustainable housing due to pressuring homebuilders to make their developments affordable in order to achieve LEED®ND certification, other options that have been used to lower home prices in traditional homes are worth attempting. One such strategy for improving the affordability of sustainable housing is the use of shared equity housing. Shared equity housing involves a one-time public investment that allows for a subsidized purchase price below market value. Although the homeowner owns the home, they have to face restrictions regarding the home's resale value to make sure the home stays affordable for future homebuyers (Greer et al, 2013, para. 6). Homeowners in these programs can usually make between $2000 to $43000 when selling their homes and resale profits mainly depend on the area's cost of living and the generosity of the formulas used for resale restrictions (Price et al, 2013, p.3). Shared equity housing has been tested in the US, England, Scotland, Belgium, Kenya, Honduras, Australia, France, and Canada (Greer et al, 2013, para. 8). Limited studies on shared equity housing in the US show positive results (para. 9). Analyses across 7 US-based shared equity programs found that homebuyers had lower foreclosure rates and many were able to eventually sell their homes and buy new ones at market rate (Price et al, 2013, para. 1). People living in shared equity housing did not feel locked in place and moved to new homes at rates comparable to those of the national average (para. 1). Over 90% of low-income homeowners participating in shared equity housing were still homeowners 5 years later while about half of low-income homeowners buying homes at market value faced foreclosure (para. 4) (para. 9). Additionally, 68-78% of shared equity homeowners were able to buy homes at market rate after moving (para. 9). Based on these early findings, shared equity housing allows more people to afford homes and provides a path for upward mobility. Financial help from programs such as shared equity housing may be even more beneficial for the sale of affordable sustainable homes due to the higher upfront costs of manufacturing such homes (Lorinc, 2020, para. 16).

Due to the higher upfront costs of sustainable technologies, sustainable homes generally cost more to build and would consequently sell at higher prices (Proskiw & Parekh, 2010, p. 1). These higher upfront costs would result in lower-income people being even less likely to own environmentally friendly homes. Using upfront subsidies on new sustainable homes as a way to sell them as shared equity homes would lower the financial barrier required for people to own sustainable homes. Lowering the financial barrier to sustainable housing could make it even more attractive than traditional homes since utility costs are often lower (Reagan, 1983, p.11). Additionally, nonprofit homebuilders who built low-income housing that meets LEED®ND standards often found that residents paid about half as much in utilities when compared to residents in low-income housing that did not meet the criteria (Szibbo, 2016, para. 85). These lower utility costs combined with the lower upfront costs could make sustainable shared equity housing an attractive path to homeownership while reducing greenhouse gas emissions.

Although shared equity housing is a promising model for increasing homeownership opportunities in low-income populations and has plenty of demand from those who cannot afford homes at market-value, implementation has not been widespread due to various supply constraints (para. 87-88). One constraint that lowers the supply of shared equity housing is that many lenders are reluctant to invest in shared equity mortgage products (para. 89). This reluctance from lenders often subsides once lenders learn more about the time investments required for shared equity housing. Lenders often become eager about shared equity housing after hearing that the loans are usually paid back successfully (para. 89). Due to these concerns, the importance of educating lenders about shared equity housing is imperative since their opinions often become more favorable. Another way to improve access to shared equity housing is to improve how the US Department of Housing and Urban Development (HUD) allocated funding for affordable housing (para. 90). Currently, HUD funding for shared equity housing is often limited for reasons such as concerns about feasibility and paying more attention to short-term results (para. 90). However, HUD staff are becoming increasingly receptive to supporting shared equity housing programs and are considering increasing the amount of funding towards them (para. 90). Also, the funding of HUD programs has traditionally not been structured in a way that works for shared equity housing programs. Reasons for this include higher administrative costs and failing to account for cost savings over future generations (para. 90).

These cost savings come from the fact that shared equity programs create a permanent supply of affordable homes (para. 85).

SUBSIDIES, REBATES, AND INCENTIVES

Another way to improve access to sustainable housing is to use subsidies and rebates. Subsidies and rebates are helpful since people are much more willing to pay for sustainable products that provide direct financial benefits (Chiu et al, 2014, p. 9). For example, a survey of 150 people in Macau found that people were more willing to pay for energy-efficient LED lighting and water-saving shower heads than sustainably sourced wood (p. 8). Due to the high upfront costs of many energy-efficient technologies, incentives such as tax breaks and lower down payments (Reagan, 1983, p. 11). The idea of a allowing a lower down payment for sustainable homes makes sense due to the high upfront costs combined with lower utility costs (p. 11). In theory, the lower utility costs would allow for people to pay more each month in mortgage payments and therefore pay less upfront. Consumer appeal would increase due to this since most people consider financial decisions from a short-term perspective (p. 11). For example, many people would be more willing to buy appliances that are cheaper upfront but more expensive and energy-intensive in the long run even when they know that the more expensive device will pay itself off over time. When people are facing unemployment or other forms of economic hardship, the effect of buying the item with the cheapest upfront cost intensifies (p. 11). Therefore, tax breaks and lower down payments would increase the likelihood of people buying sustainable housing due to reducing the upfront costs.

Reducing the construction costs of sustainable housing also allows for sustainable homes to become more affordable. In Toronto, the city sells 99-year leases to developers while providing financial incentives such as reduced development charges but they have to follow several conditions. The developers who lease the land must guarantee affordable rents for a century and satisfy the stringent benchmarks written in the 2018 Toronto Green Standard (Lorinc, 2020, para. 4-5). These standards include high-quality insulation, fewer windows, and improved heating and ventilation (para. 5). These programs lead to an increase of about 3.5% to construction costs but are financially attractive some developers due to very low operating and maintenance costs (para. 15). Toronto's plan for increasing affordable sustainable housing is derived from the Vienna model, a model that allows for affordable apartments to be built on public land at prices determined by the city (para. 3-4). Many other European cities use this model but Toronto took it a step further and added strings attached to incentivize the development of affordable sustainable apartments.

Rebates are another way to incentivize affordable sustainable housing. A common example of rebates being used to make sustainable housing more affordable are rebates for solar energy. One such rebate program is the California Solar Initiative. They provide rebates for residential and commercial use of solar energy (Hughes & Podolefsky, 2015, p. 2). Current predictions show that 53% fewer people would have installed solar panels and that increasing rebates from $5600 to $6070 would increase installations by a further 10% due to lowering the upfront costs of solar energy (p. 1). Over the last 20 years, emissions in California were estimated to be reduced by 2.3-3.4 million metric tons of carbon dioxide due to the current subsidies (p. 1). Correlations were taken between rebate rates and installation rates within California and it was found that there was a statistically significant relation between increasing the amount of money earned per Watt of solar power and the rate of solar panel installation (p. 21). It was also estimated that increasing rebate rates from $1.46 per Watt to $1.56 per Watt, the daily installation rate would increase by 10% (p. 21). Just like other methods of reducing costs (especially upfront costs), the use of rebates increases the adoption of sustainable technologies in homes by making them more affordable.

ACTUAL TESTING NEEDS TO BE DONE

In summary, improving environmental rating systems, expanding shared equity housing programs, and increasing rebates are good steps for improving the affordability of sustainable housing. Mandating the affordability and diversity of housing stock section for LEED®ND certification would increase the amount of pressure for developers to build affordable sustainable housing. Expanding shared equity housing would increase the affordability of sustainable homes for multiple generations with a single upfront investment and would increase the rate at which low-income people attain and sustain homeownership (Greer et al, 2013, para. 9). Finally, subsidies and rebates can further make sustainable homes more affordable by lowering the high upfront costs through rebates. Subsidies can also be awarded on a per-unit basis for solar energy, further lowering the cost of owning a sustainable home.

Although new ideas were proposed, they have not been tested. For example, shared equity housing has been implemented in the US at a small scale but there is currently no plan to incorporate sustainable housing within shared equity housing programs. Future work also needs to be done to edit the LEED®ND standards and wait for neighborhoods to be developed to the future standards. After waiting for more neighborhoods to be developed, studies would have to be done to see if neighborhoods built to future LEED®ND standards would improve affordability. In conclusion, sustainable housing needs to be made more affordable and desirable through means such as fixing rating systems, offering subsidies, and using shared equity housing.

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