The untapped potential of passive energy housing developments

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ABSTRACT: Recent reports paint a dire picture of the potential worldwide effects of climate change. Since our buildings' energy consumption plays a significant role in the production of greenhouse gases, many more energy-efficient buildings could affect a major reduction in carbon production. Single-family developer housing represents a high percentage of US construction at close to a million starts per year. Yet, the typical subdivision is designed with little to no regard for orientation to sun, wind and thermal envelope efficiency. Since single-family homes consume around 80% of residential energy use, a million *passive energy* house starts per year could have profound effects on our energy use but most architects appear uninterested in suburban housing design. This segment of the market is prime opportunity for applying passive energy strategies on a massive scale. So with the looming specter of climate change, why do most architects and builders seem apathetic to the suburbs and continue to disregard this opportunity despite the potentially catastrophic results? This research/design project questioned: if passive solar houses have been around for decades, why are there few passive single-family housing communities, and why haven't they made the leap in scale? The research component investigates the historical reasons for the disconnect between architects, large housing developments and passive energy. Based on the findings, the design component proposes a variety of model house types, based on the Charleston House typology, and subdivision designs, both in the suburbs and as urban infill, as potential present-day strategies for extending the strategy to the massive scale. The research produced two governing questions that informed the design solutions: 1. How do we apply passive energy strategies to the pre-manufactured developer house? And, 2. How do we make passive houses marketable in a well-established industry?

Figure 1. Typical Suburban Housing Layout

Figure 2. Houses Face Street Disregarding Sun Orientation

INTRODUCTION

Most scientists agree, if not already too late, that to slow the effects of climate change will require enormous changes to the way we produce and use clean energy. In our built environment, to achieve measurable success in integrating sustainable energy systems into buildings will likewise require application on a sizeable scale. However, wind and solar sources supply only a small percentage of power for building energy systems that still rely heavily on fossil fuels. In terms of construction volume, single-family developer housing starts account for a huge percentage of construction each year. (US Census Bureau reports levels

of over one million starts per year for the past several years)[1] And more recently, suburban style developments have been constructed on large tracks of vacant land in large cities. With the vast majority of new house construction produced by these large housing development companies, this segment of the market is prime for applying passive strategies on a scale great enough to have a significant impact on energy use. Yet developers typically build entire subdivisions with little to no regard to orientation to sun and wind and most architects appear uninterested in becoming involved with suburban housing design. The increase in quantity of passive house construction is laudable, but at the current small volume it will not have a measurable effect on our environment. However, a million *passive* house starts a year could have profound effects on our ecosystems. With the looming specter of climate change and the potentially catastrophic impact, can architects ethically continue to ignore the problem as it grows into a major environmental concern? This design/research paper investigates the reasons for this disconnect between architects, large housing developments and sustainable energy, and then identifies potential design strategies for improvement.

1.0. THE LACK OF DEMAND FOR SUSTAINABLE SUBURBAN HOUSE CONSTRUCTION

> Rethinking suburban design is an enormous challenge because many suburban neighborhoods have been designed, developed and managed precisely to avoid change and limit uncertainty. …the issues remain just as relevant, except the houses have gotten bigger and more wasteful and the environmental imperatives more urgent 2

Why have developers stayed out of the passive energy housing market and what would it take to convince them of the feasibility of sustainable single-family housing? At the same time, while there is a high demand for single-family homes, why is there is not a strong demand among buyers for sustainable suburban housing? Two major fears among both developers and clients are resistant to change and cost. The construction industry (at least in the US) is notorious for using the same construction techniques again and again with little desire for innovation. This is especially true in the suburban house market. “Is there anything made in America that’s less innovative than the single-family home? While we obsess over the new in terms of what we keep in our houses...we’re incredibly undemanding of the houses themselves.”[3] Change is a financial risk to developers because the new techniques have not proven themselves through repetition and are more vulnerable to unseen cost fluctuations. Lightweight wood-frame designs are replicated across the country, regardless of location and climate, because they are cheap and efficient to build. Following an “if it ain’t broke, don’t fix it” attitude, builders have little incentive to take risks so “If the buyer wants it, give it to him.”[4]

Proponents of energy efficient housing agree that initial costs of showcase “green” houses are more expensive but there is strong evidence that the savings in energy bills over time will more than pay off for additional first costs. But speculative builders who sell their houses immediately upon completion are not the future owners/occupants, so are less concerned with future operational costs. Unfortunately, seeking the bottom-line and suspicion of new techniques make reducing initial costs and maximizing profit the main goal. “Initial cost will always be important and many of the showcase projects have a short-term flaw in that it has generally been perceived by the wider construction industry that there must be a monetary penalty when demonstration developments are transferred, in a somewhat diluted form, into the more affordable mass market”.[5] So the wariness is understandable.

A harder question to answer is why don’t more home buyers demand higher energy efficient houses? In a recent on-line article titled *Ask The Agent: What Home Features Are Most In Demand When Buying Or Selling*?[6], many real estate agents across the country gave a predictable reply that the focus was on location and luxury amenities: “I noticed that buyers really love when properties are move-in ready with the decked out kitchens, bathrooms and hardwoods floors.” However, several agents did mention that in addition to those desires, there is a newer demand for energy efficiency: “Buyers and sellers are starting to demand amenities that are energy-efficient, low emission and cost-effective like tankless water heaters,

solar panels, Nest-type thermostats, low-water toilets and the like." So the demand for energy efficiency may be increasing among home buyers, albeit slowly.

In addition to developers and buyers, our legal environmental energy codes in this country are not very demanding. With a few exceptions, most municipalities follow the far-from-stringent ASHRAE 90.1 or similar minimum level of energy efficiency. So if "...neither building codes nor buyers demand that homes be energy efficient. And given the lack of incentives to go green, most builders prefer to do what they know, rather than master new — and more demanding — building techniques and materials."[7] Until the public demands it or the government requires it, builders will have little incentive to change.

1.1. Architects' apathy towards the suburbs

> With blithe inconsistency, architects and architectural scholars point to the seemingly undesigned sprawl of suburbia and say, "Don't blame us, we had nothing to do with it." This avoidance is precisely the problem.[8]

Another question is why aren't architects, who are some of our best sustainable construction advocates, more involved in suburban housing? There are many well-trained professionals who could lend their expertise in passive systems but many architects have washed their hands of developer housing seeing it as beyond hope or beneath their status. The "…the bias against suburbia remains strong among designers and critics, whether it manifests as tirades against sprawl or utter indifference. Unless they're wooed by an Apple or a Facebook, top-tier architects rarely work in the 'burbs."[9] Suburban development accounts for approximately 75% of all new construction in recent decades so therefore presents great opportunities on a very large scale, yet it is still shunned by most architects.[10] Suburbia seems to have an image problem among architects. In 1950's post-war America, the suburbs were seen as a land of opportunity for design and planning, but no longer. PAU architect's current website includes a list titled "What We Do" to describe their scope of services, as well as another, less typical one: "What We Don't Do," which identifies *"Single-Family Suburban Homes; Suburban Subdivisions, Malls, and Office Parks; Work for Autocratic/Dictatorial Nations; Work for Nations or Corporations with Unacceptable Labor or Environmental Practices; Correctional Facilities; Casinos/Facilities for Slot-Machine Gambling; Facilities that Manufacture Arms."*[11] To place suburban homes and subdivisions in the company of tyrants, weapons, gambling and prisons, speaks volumes about their reputation in the eyes of some architects.

To be fair, many architects have addressed the problems of suburbia. Most of that work has centered on increasing density, promoting mass transit and reducing the immense waste of land and infrastructure through planning means like zoning code and land-use reform. In *Retrofitting Suburbia*, Dunham-Jones and Williamson provide many methods and potential solutions for redeveloping suburban environments into denser more urban sustainable places.[12] Compact developments address sustainability well at the macro level by reducing carbon emission through less road and utility construction, decreasing car use, promoting walking, using mass transit, etc. But the individual suburban house has received less consideration.

> The big-picture ideas and national movements are by now well-known—transit-oriented development, New Urbanism, Smart Growth, and so on. And yet the suburban reformers, focusing almost always on the scale of systems, have rarely paid sustained attention to suburbia's essential component, its irreducible unit — the freestanding single-family house.[13]

Increasing density is a critical move, but could we continue that line of thought to focus on the energy consumed/ wasted by each individual house. Some architects argue that single-family homes are not a sustainable use of land and resources; preferring multi-unit housing as a better approach. But single-family homes consume around 80% of residential energy use.[14] To affect change on a massive scale requires a willingness to confront the big issue. Although unpleasant to many architects, the continual demand for detached single-family suburban housing is an issue that needs greater attention to investigate how to make this enormous number of homes energy sustainable. To continue to ignore the issue is an ethically questionable decision.

1.2. The solar suburban house and subdivision – a (very) brief history

> During and right after the war, hundreds of solar houses were built across the United States, most using passive radiation to reduce heating load. Typically these designs featured a narrow plan and an all-glass façade, in order to allow solar rays to penetrate deep into the house in the winter, and also a carefully designed overhang, in order to deflect the summer heat.[15]

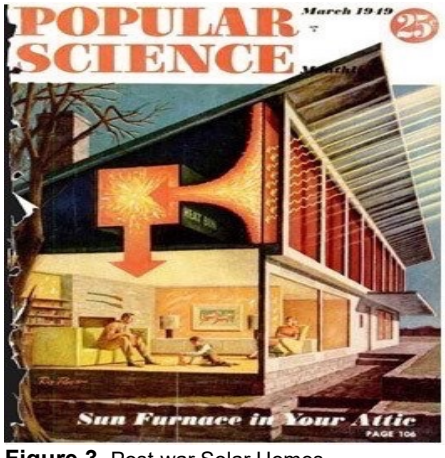

Figure 3. Post-war Solar Homes

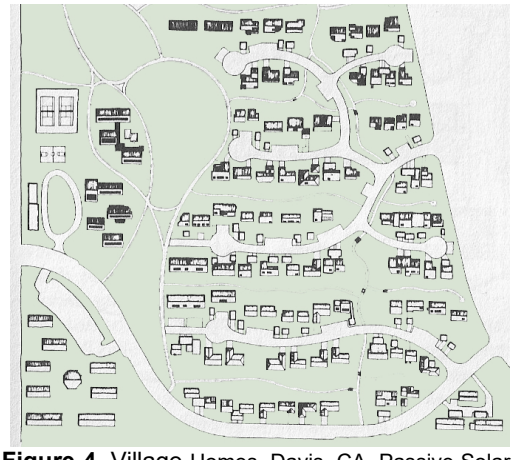

Figure 4. Village Homes, Davis, CA, Passive Solar Community

Although rare, the passive solar suburban house is not a recent development. While there was much experimentation in the 1960's and 70's, the origins are earlier. After World War 2, oil was in short supply so there was a search for new forms of energy including solar. However, these solar houses were not very effective and required continual maintenance which, when combined with newly discovered oil, doomed this first generation of solar houses.16 So while passive solar houses have been around for decades, more extensively in Europe, they exist only as individual cases or in small groups. Few large passive single-family housing communities exist, and none close to the scale of a suburban development containing hundreds of houses. Davis Homes community built in California in the early 1970's is one of the truly rare examples of a passive solar oriented subdivision but very few followed their lead. This paper explores why passive energy systems are not part of US suburban developer housing and which issues might be preventing the leap in scale. These ideas were then tested through potential design solutions on the scale of both an individual prototype Passive Suburban Developer House (PSDH) model and a community master plan. Out of the research grew two major questions. First, how do we apply passive energy strategies to the pre-manufactured suburban house, and second, how do we make passive houses marketable in a well-established industry?

2.0. THE CHALLENGE OF MAKING DEVELOPER HOUSES PASSIVE

> Not so long ago homes were designed to make the most of their surrounding climate and terrain. Vernacular forms like the shotgun, in places like New Orleans, served a purpose that went far beyond aesthetics — they encouraged natural cooling by improving cross-ventilation. ... Houses were sited and windows placed to maximize or minimize sun exposure as needed [17]

With the advent of central heating, air-conditioning and electric lighting, houses could ignore the sun and wind conditions of a site and depend on solely mechanical means for thermal comfort. Current developer housing is designed and sited with little to no relation to the direct solar gain, wind movement or daylight. Streets of a typical subdivision are often laid out in a pattern of gently curving drives and dead-end cul-du-sacs with the houses oriented towards the street regardless of which cardinal direction they face. A prime challenge is how to adapt

and site these non-directional houses to maximize natural passive environmental benefits. To also take advantage of the sun and wind requires orienting the house in a specific direction.

2.1. Orientation towards sun and wind

The first step to make a house energy efficient is to use *Passive House* thermal performance principles of continuous well-insulated walls, an airtight envelope, and high-performance windows. Since most of these requirements deal with material performance standards, they can be applied to most styles of houses including developer housing. Developer houses typically use small double-hung windows of relatively the same size on all sides that do not adjust for the varying solar demands on the four faces. While this reduced glass area is good for minimizing heat loss (same for the Passive House) it also limits direct sunlight, restricts views and separates inside and outside space. Therefore, the PSDH model varies slightly from the Passive House by opening up more window area towards the sun and the exterior on the south side.

Figure 5. Charleston House Type

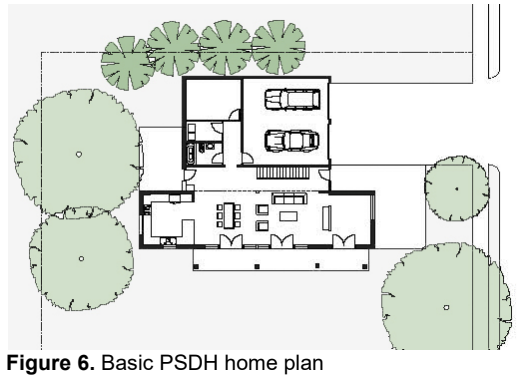

Figure 6. Basic PSDH home plan

A passive solar house wants to stretch out in a long east-west direction to expose many rooms to the southern sun. But a heavily glazed facade facing the street or close to neighbors would be detrimental to privacy and the use of curtains would negate the solar gain. An open south façade works better *if* it can face a private yard space. The result is to exchange the large front and back yards of a standard subdivision house for one big side yard, a house type similar to the Charleston House of a long, side-yard facing building with a gallery along the south wall. In the PSDH, main living spaces are located along the sunny south side overlooking the side yard with service spaces located on north with few windows. Since all houses are oriented the same general direction, the heavily glazed south walls look across a landscaped yard at the predominantly solid north wall of the neighbor, thereby maintaining privacy. A gallery and the deep roof eaves extend out from the wall to provide for shade in the summer. The public street-side entries are best located on the narrow east or west elevations that require fewer windows and therefore provide greater privacy. Renee Chow has already demonstrated how the urban fabric pattern of the Charleston typology can be a sustainable solution for increasing density and reducing suburban sprawl.[18] This strategy becomes more attractive with the addition of passive energy strategies.

To minimize the need for air conditioning and artificial lighting, the PSDH should make use of natural ventilation and daylight for their health and psychological benefits. The deep-plan developer house with its closed rooms and small windows does not allow for efficient cross ventilation and greatly restricts daylight to only spaces along the perimeter. The linear, open-plan form of the PSDH, allows for an efficient cross breeze and a two-story stairway with northern clerestory windows vents warm air out high. The clerestory which runs the length of the atrium brings abundant soft northern daylight into the core of the house to compliment that already provided by the extensive southern glazing. With two stories on the south and one-story service functions on the north, the house forms a wedge shape that deflects cold winter winds over the house and creates a protected outdoor space on the south.

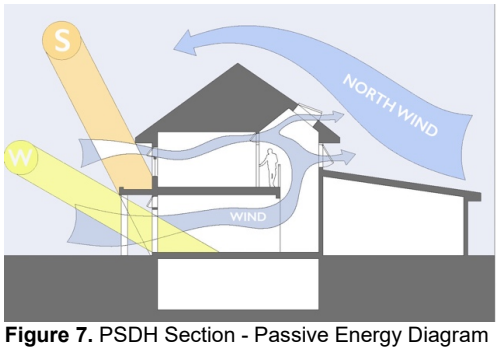

Figure 7. PSDH Section - Passive Energy Diagram

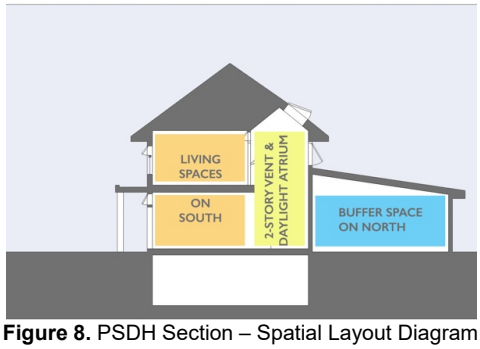

Figure 8. PSDH Section – Spatial Layout Diagram

3.0. THE CHALLENGE OF MAKING PASSIVE HOUSES DEVELOPABLE

Passive Suburban Houses can't have an effect on the environment if they don't sell in great numbers so they need to be attractive to a broad spectrum of buyers. The typical developer house presents a nostalgic image of the traditional house as a symbol of *home*. Developers aren't pushing one style over the other. They say they will build whatever style sells; that they are only giving the client what they want. So, any design for passive suburban developments must be financially feasible and aesthetically marketable to a massive audience.

3.1. Conveying the image of 'home'

A Passive House whose only goal is to maximize energy efficiency is at risk of becoming a data-driven machine that while efficient, will have little appeal to the public as a cherished family home. The image of house as home is deeply imbedded in the public psyche as evidenced by the long-time popularity of the historical pseudo-colonial style house. The challenge is how to retain this image of home without resorting to outdated historical pastiche; something architects understandably detest. But the modern house that appeals to designers is not as appreciated by the developer house-buying public. Looking at the traditional styles of developer homes that are purchased today, it becomes evident there are certain common defining characteristics that are desired by buyers. While the counterfeit historic language of false gables, pasted on brick, and screwed-on plastic shutters are less appropriate, incorporating structural sloped roofs and sustainable building materials make it possible to convey the image of home in a more authentic way.

3.2. Making it cost effective

> Many of these radical homes can be characterized as showcase developments, which employ all manner of state-of-the-art techniques, as well as sound, basic passive solar principles, to produce often expensive, prestige homes designed to demonstrate what is possible. The theory is that money will be saved over the lifecycle of the building.[19]

The better performing building materials needed to create passive house envelopes also drives up their initial cost. Since developers shy away from increased initial expenses, passive house construction should be cost effective to be adopted and marketable. There are many examples of high-end architect-designed custom sustainable houses that are very efficient in terms of energy use but not in terms of construction cost. Their one-off design makes them too expensive for the developer market. As Allison Arieff asks,

> Devoting this much R&D and software development to so few homes feels akin to installing a $250,000 solar array on a garden shed. Why not devote that energy to transforming cookie-cutter developer homes?[20]

The developer housing industry has developed successful methods for pre-packaging building elements to reduce labor and material costs. This strategy can be extended to passive houses. To be economically feasible, these houses should not be site-built, but should utilize Modular and Prefabricated Construction techniques to be competitive. One current solution is the use of prefabricated panelized building components such as those manufactured in the US by the Ecocor company, that are shipped to the site and erected by cranes to shorten construction time and save material and labor costs.[21] Another firm, Go Logic, has developed reproducible

designs for prefabricated passive Go Homes that are in styles similar to what suburban buyers want.[22] While these examples show that passive homes don't need to be expensive one-off designs, they are all located on large rural sites so the next challenge is to apply this idea to the developer subdivision.

Figure 9. Go Logic Home

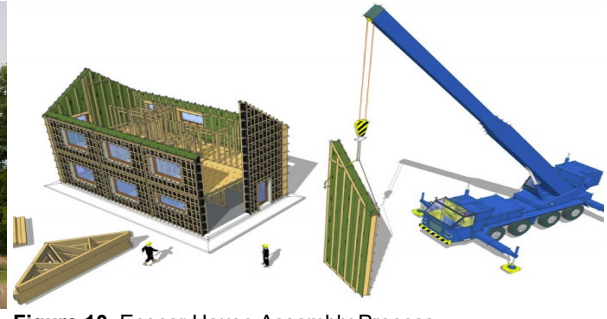

Figure 10. Ecocor House Assembly Process

3.3. Planning passive neighborhoods

> "In general, the planning profession is not concerned with or particularly well trained in the physical performance of buildings, yet decisions made at this stage can radically affect the performance of passive solar designs*".*[23]

Since passive solar houses generally need to be oriented the same way, there is a risk of creating repetitive, monotonous neighborhoods if all houses face the same direction south. A street grid oriented to the cardinal points with mostly north-south running streets, is the most efficient. Although the grid is a successful urban strategy it is less desired in suburbs where relentless grids can create look-alike neighborhoods that lack a sense of identity and place. Therefore, initial planning is critical. Likewise, there is a need to avoid repetitive house styles. Developer housing subdivisions are often created using only 2-3 house designs and a small palette of materials.

Passive Houses have become so thermally efficient with their insulation they will still effectively capture enough solar gain if oriented to within 20 degrees to either side of true south.[24] This 40 degree swing creates enough flexibility in house siting from a strict north-south orientation to allow for gently curved and angled streets, which when combined with pocket parks and green spaces, relieves a relentless grid. PSDH's don't make sense without sustainable land use as well. Typical suburban sprawl master plans use large half-acre lots; more land than usually needed by the owners. The Charleston House model, with its large side yard, allows for smaller 1/6 to ¼ acre lots. The increase in density can nearly double the number of houses in a subdivision (from 45 to 86 in the site analysis shown) while maintaining the same overall amount of public green space and creating walkable, livable neighborhoods. With more houses to sell per acre the developer can offset any increased capital costs with an increase in total home sales. To avoid repetition of house styles, several house models should be designed to accommodate diverse family structures and sizes. These models would use the same basic plan but very in scale, color, materials and features; excellent candidates for mass customization. A large number of combinations would help provide initial variety and owner modifications over the ensuing years would provide additional character and neighborhood identity. Richard Pendranti Architects, who works with Ecocor, has already created a portfolio of basic passive house models that can be adapted to the individual client[25]. Like with the prefabricated Go Home, the next step is to jump up to the scale of the subdivision.

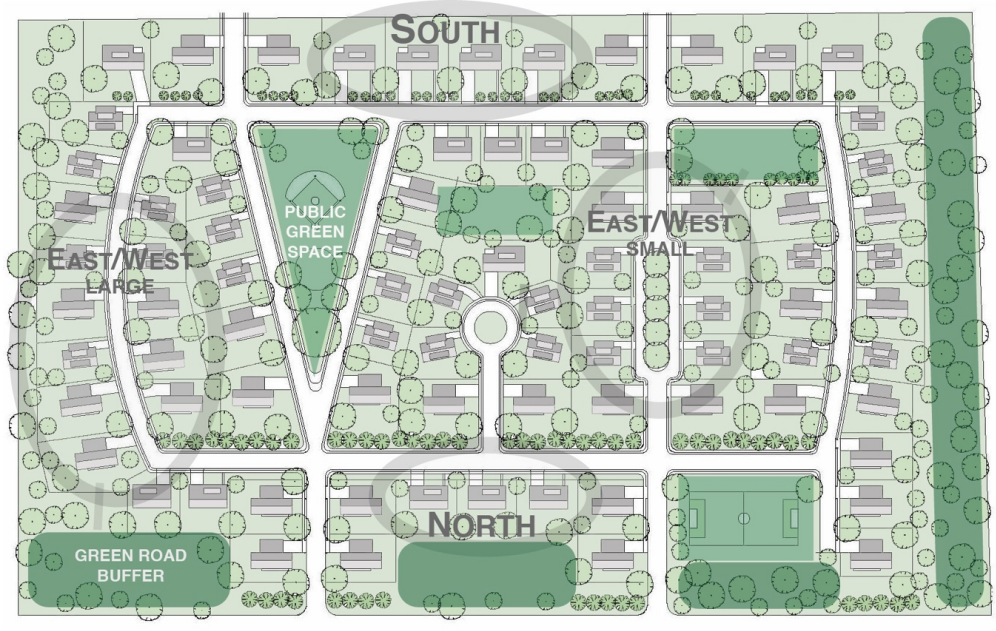

Figure 11. New PSDH Subdivision Design Showing Different House Types – 86 Homes replace Current 45

CONCLUSION, AND NEXT STEPS

Passive houses already exist that are attractive, affordable and non-repetitive so the next challenge is how to make the jump in scale to large suburban and urban housing developments to increase the positive effect of energy savings. But are we at the point yet where we can make that jump? To test the feasibility of these ideas I needed the feedback from someone in the industry who knows the market well. Therefore, I submitted my house and subdivision designs to Tim Gehman, an architectural executive for a national Fortune 500 homebuilder, for review and comment. While he was personally supportive of the idea, he felt there would still be many hurdles in changing the very imbedded status quo of suburban home buyers. First is the legal problem of in increasing density. Many zoning boards are reluctant to change codes to allow additional lots per acre as it could overburden roads, schools, infrastructure, traffic, etc. But the biggest challenge may be that suburban home buyers still don't demand energy efficient housing. As he states:

> "Real-estate is valued by location, square footage and bedroom/bath count. Attractiveness matters as an opener, but doesn't drive a yes or no, and annual maintenance and energy usage are an afterthought at best for most buyers. That's a systemic long-term behavior, how do you change it?"

For the great majority of today's buyers, bottom-line cost and lot location still far outweigh issues of requests for energy efficiency and until they do, builders will have no incentive to change. There are a growing number of buyers who are concerned with the sustainability of our environment and would prefer an energy efficient house, but they are mostly younger first-time buyers who can not afford the price for their first purchase. But the increasingly palpable effects of climate change are causing a corresponding increase in the public's acceptance and concern. Sixty-two percent of the public now understands that global warming is caused mostly by human activities, an increase of 10 points since 2015.[26] As climate change worsens and affects more people, we may see an increasing demand for more efficient homes as well.

In the meantime, I have refocused attention inward to the cities where there is greater potential for a clientele that highly values sustainability and is accustomed to smaller, denser housing. The post-war exodus from cities to the suburbs left abandoned houses that became

abandoned lots. A 2001 study of 70 US cities found an average of 15% of urban land was vacant.[27] Since this land comes with an existing infrastructure of utilities, streets, and public services, it provides prime opportunity for housing development. Government housing authorities in cities like Philadelphia have taken advantage of this vacant land to construct multi-block neighborhoods, but the houses designed there look nothing like the row homes they replaced. Instead, pseudo-suburban style homes set back from the street incorporate gable roofs, driveways, lawns and other suburban elements that feel out of place in the city fabric. It appears the American Dream of the gabled suburban house is as powerful in the city as outside it. But the grid form of urban streets is a favorable geometry for transferring passive subdivisions strategies to the city. If a city's grid is oriented within 20° of south (11° off in Philadelphia) it can serve as a prime planning layout for passive solar houses. The Charleston House Type, being an urban form itself that fronts on the street, works well here. When arranged in a staggered pattern, it can provide secure side yards and off street parking while maintaining a density level more in tune with an urban environment than the current homes on the site. Redeveloping vacant urban neighborhoods to their former density may never be economically feasible, or even desirable, but filling these sites with passive houses rather than inefficient suburban style houses could attract a wider audience back into the city while conserving energy.

If we could apply passive energy strategies to the vast developer housing market, whether in the suburbs or the city, over time the magnitude of the effects at the macro scale could have significant environmental impacts. Architects alone cannot have a major effect on the environment by designing passive houses one at a time, but the massive scale of developer housing presents one of their best opportunities for change to the larger ecosystem. The potentially devastating effects of climate change make it even more important that developers and architects find a way to create passive developments on a scale large enough to produce profound results.

ENDNOTES

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