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Scaling Up Passive Energy to Suburban Developer Housing

Craig Griffen

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Abstract

Recent reports paint a dire picture of the potential worldwide effects 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 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?

Keywords: Energy, Passive, Solar, Systems, Suburban, Developer, Housing

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 (Figure 1) 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.



Figure 1: Houses Face Street Regardless of Sun Direction

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 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 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 cheaper and efficient to build. Builders have little incentive to take risks, and so follow the adage, “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 argue that the savings in energy bills over time will more than pay for the additional first costs. But speculative builders who sell their houses immediately upon completion are not the future owners/occupants, and therefore 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.

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.⁸ 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.

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.⁹

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.¹⁰ 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. The Village Homes community built in Davis, 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, and none on a similar scale. 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?

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 needed¹¹

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.

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. Recent improvements in technology and affordability in performance standards mean these principles can be applied to most styles of houses including developer housing. This also means that the passive solar heating components of the energy supply systems can be reduced, resulting in less glazing that can lose heat and less reliance on thermal mass. Developer houses typically use small double-hung windows of relatively the same size on all elevations 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 interior and exterior space. The PSDH is a *solar hybrid* model that exists between the Passive House with fewer windows and the passive solar home with excessive glazing that can lose heat easily. This middle ground presents a design opportunity to spatially connect the interior rooms with the exterior spaces on the south without great risk of over or under-heating. It also reduces the amount of required thermal mass which is

harder to achieve with typical wood frame construction common to developer homes.



Figure 2: Charleston House Type

A basic principle of all passive solar-oriented houses is to elongate the floor plan in an east-west direction to expose most occupied rooms to the southern sun. But a substantially glazed facade facing the street or close to neighbors would also reduce privacy. And to correct privacy issues with the daytime use of curtains would negate the solar gain. Therefore, an open south façade works better *if* it can face a private yard space. One solution 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. (Figure 2) While the Charleston house type was mainly created to provide ventilation cooling, (a similar goal of the PSDH) it also works well to promote passive solar heating while maintaining privacy. In the PSDH, the main living spaces are located along the south side overlooking the side yard with service spaces located on the 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, to preserve privacy. A gallery and the deep roof eaves extend out from the wall to provide for shade in the summer while allowing low-angled winter sun to penetrate. The public street-side

entries are best located on the narrow east or west elevations that require smaller windows for sun and also provide privacy from the street. (Figure 3) Renee Chow has already written about how the urban fabric pattern of the Charleston typology can be a sustainable solution for increasing density and reducing suburban sprawl.¹² This same strategy becomes more attractive with the incorporation of passive energy strategies.

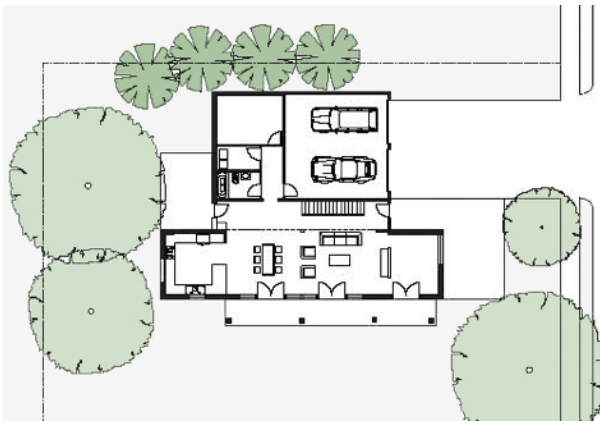


Figure 3: Basic PSDH home plan

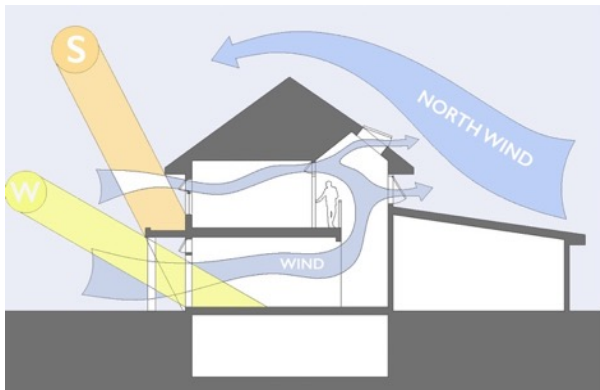


Figure 4: PSDH Section - Passive Energy Diagram

To minimize the need for air conditioning and artificial lighting, the PSDH should make use of other passive energy strategies such as natural ventilation and daylight for their energy-saving, health and psychological benefits. The deep-plan developer house with its closed plan and small windows does not allow for efficient cross ventilation and restricts daylight to only spaces along the perimeter. The linear, open-plan form of the PSDH, allows for an efficient cross breeze by bringing in cooler

air low on the south side and venting warm air out high through the northern clerestory window in the two-story atrium stairway. This clerestory which runs the length of the atrium brings abundant soft northern daylight into the usually dark core of the house to compliment the light already provided by the extensive southern glazing. By stacking two stories on the south and placing one-story service functions on the north, the house forms a wedge shape that deflects cold north winter winds over the house and creates a sheltered, sunny outdoor space on the south. (Figure 4)

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.

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 less 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 *feeling* 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.

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.*¹³

The increased amount of higher-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 needs to 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?*¹⁴

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 ought to utilize Modular and Prefabricated Construction techniques to be competitive. One current solution is the use of heavily-insulated, prefabricated panelized building envelope 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.¹⁵ Another firm, GO Logic, has developed reproducible designs for

prefabricated passive homes they call GO Homes that are in styles similar to what suburban buyers want.¹⁶ (Figure 5) While not expensive one-off designs, these homes are still built one at a time and located on large rural sites. The challenge is to scale up this idea to the level of the developer subdivision to improve affordability.



Figure 5: Passive GO Home Model, GoLogic

GO Homes also uses the *panelization* process to factory assemble complete wall panels up to 30 feet long to make Passive House construction more affordable. (Figure 6)

Below is a chart of GO Home estimated sales pricing in Maine where they are based:

Plan	\$/SqFt	Total
600 sq ft	\$298	\$179,000
1000 sq ft, plan A	\$275	\$275,000
1000 sq ft, plan B	\$276	\$276,000
1100 sq ft	\$268	\$289,200
1400 sq ft	\$244	\$341,600
1500 sq ft	\$243	\$365,000
1600 sq ft	\$241	\$385,400
1700 sq ft	\$241	\$409,000
2300 sq ft	\$229	\$548,400
2500 sq ft	\$227	\$567,000

At Toll Brothers, a major home builder in the US, their average single-family home is about 3,500 square feet and sells for around \$800,000, or \$228 per square foot, similar to GO Home per square foot prices¹⁷ While home construction costs in Maine are generally less than other parts of the country, the price per GO Home is still

relatively expensive because of the increased amount of construction materials and each house is constructed as an individual home. However, the efficiency of scale that developers like Toll Brothers can provide through mass production and factory prefabrication could improve cost efficiency to make pricing more affordable.



Figure 6: GoHome Panelization House Assembly Process

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.”¹⁸

Like all solar-oriented houses, the PSDH needs to be oriented mainly to the south with streets running mostly north-south. Therefore, there is a risk of creating repetitive, monotonous neighborhoods through unrelieved orthogonal street grids. Although the rectilinear grid is a successful urban strategy, it is less desired in suburbs where relentless rectangular 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 a small handful of house designs and a limited palette of materials.

Passive Houses have become so thermally efficient they will still effectively capture enough solar gain if oriented to within 20 degrees to either side of true south.¹⁹ This

40 degree swing creates greater flexibility in house orientation than the stricter direct north-south orientation recommended for passive solar houses. Without the requirement of only straight, north-south oriented streets, roads can be gently curved and angled, which when combined with pocket parks and green spaces, relieves a relentless grid. (Figure 7) PSDH’s energy efficiencies don’t make sense without sustainable land use as well. Typical suburban sprawl master plans often 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 1/4 acre lots. The increase in density can nearly double the number of houses in a subdivision (from 45 to 86 in the site plan 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 could potentially offset increased capital costs with an increase in total home sales.



Figure 7: Subdivision design with PSDH homes

To avoid repetition of house styles, several house models should be designed to accommodate diverse family structures and sizes, as well as models for the small amount of houses that whose public façade faced north or south. These models could use the same basic plan but vary in scale, color, materials and features; making them 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, an architecture firm that works with Ecocor, has already created a portfolio of basic passive house models that can be adapted to each individual client.²⁰ Models vary in size, number of stories, roof shape, exterior material finishes to allow for a wide variety of combinations. (Figure 8) Like with the prefabricated GO Home, the next step would be to scale this idea up to the level of the suburban development which is already well versed in the process of mass customization.



Figure 8: Passive Home Model Option, Pendranti Architects

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 housing developments to increase the positive effect of energy savings through sheer volume. But are we at the point yet where we can make that jump? To test the feasibility of this idea I needed the feedback from someone in the industry who knows the market well. Therefore, I presented 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 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?

Unfortunately, for the 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 of a GO Home 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 2015.²¹ 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 comfortable with smaller, denser housing. The post-war exodus from cities to the suburbs left abandoned houses that became abandoned lots and blocks. A 2001 study of 70 US cities found an average of 15% of urban land was vacant.²² 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.

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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 scale of 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 a prime opportunity to have a demonstrable effect on 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.