Innovation and the Big Builders: Barriers to Integrating Sustainable Design and Construction Practices into the Production Homebuilding Industry, The Case of Pulte Homes

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ABSTRACT
The homebuilding industry has held a dominant presence in the U.S. economy over the past century. It has been a source of profit, shelter and jobs for countless Americans. In order to meet the needs of an ever-burgeoning population, the industry itself has grown into a complex and vast linkage of developers, designers, contractors and regulatory officials whose job it is to build the houses that most Americans live in. Yet the growth and success of the homebuilding industry in America has not come without repercussions. Today, more than ever, we are cognizant of the environmental impacts that the homebuilding industry is having on our physical landscape and our natural resources. As a response to this cognizance, there has been a growing movement towards less environmentally harmful methods of design and construction. Many, if not most, of these methods require substantial changes to the way the industry currently builds homes. In this sense, they are considered *innovations*.

This thesis will provide an illustration of the process of innovation and how it diffuses throughout an existing industry in addition to recapping historical arguments for why the U.S. homebuilding industry has long been characterized as resistant to change. The industry, however, is currently witnessing several trends which begin to refute the notion that homebuilding is change-resistant. These trends and the effects that they are having on large scale production homebuilders, what I will refer to as *mega-production builders*, are leading to a period in which this ever-growing segment of the industry will be ripe for more innovative practices. To test this hypothesis, I have undertaken a case study of two divisions of America's second largest homebuilder, Pulte Homes. The Las Vegas Division, through their partnership with the Department of Energy's Building America Program, is building more energy efficient homes largely through incremental product and process-based technologies. The Washington D.C. Division is pursuing more radical and systemic innovations through component manufacturing processes entirely independent of any government or third-party partnerships.

This thesis finds that while both divisions have been largely successful to date, the potential for growth lies in the more systemic innovations being pursued in the Washington D.C. Division of Pulte because these innovations are more strongly tied to Pulte's national agenda for expansion and can be improved upon more easily than the more incremental innovations pursued by Las Vegas. Furthermore, this thesis finds that the disconnect between design and engineering currently exhibited by most large production builders is a detriment to the adoption of more innovative practices and, finally, that government programs designed to foster innovation in homebuilding should focus more on small regional builders, corporate decision makers and product manufacturers as opposed to the independent operating divisions of large production builders.

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Introduction

Housing has long been recognized as a vital component of this nation's economy. The bundle of goods and services which go into producing and maintaining our housing stock typically accounts for 20% or our gross domestic product.[1] There are close to 120 million homes in our stock of housing and that number is projected to grow, on average, by about 2 million every year for the next ten years.[2] While the housing industry often falls victim to the cyclical nature of the economy, America's growing population, now augmented by tremendous increases in immigration, is expected to fuel a growth industry for years to come. This strong industry provides a wide array of jobs for a list of trades which is too broad and diverse to list here, but includes architects, planners, contractors, subcontractors, building material manufacturers, and developers. As housing production continues to grow, it benefits all of these professional endeavors.

Yet, the contemporary homebuilding industry is a cause of concern for many in this country. Depleted natural resources, rising energy costs, the adverse health effects of toxic building materials and a loss of open space have caused some to raise a watchful eye on an industry which is clearly having an increasingly negative impact as measured by a host of environmental indicators. In their drive to increase profits and survive in a ferociously competitive industry, most homebuilders don't account for the environmentally deleterious impacts of both their construction processes and their finished products.

These concerns have given rise to a wide constituency of advocates for more environmentally sound building practices. Their efforts have been felt from the highest reaches of the federal government to local city councils in small towns all across America. They make strong arguments for such things as the construction of *energy efficient homes*, the use of *renewable resources* in homebuilding, improved *indoor air quality* and the recycling and reuse of *construction waste*; and while there is growing acceptance for sustainable design and construction practices in the homebuilding industry, the integration of such practices is still far from widespread.

The strategies for decreasing the environmental impact of the homebuilding industry can be broken down into the four main categories mentioned above: *energy efficiency*, *resource and* *material efficiency*, *construction waste minimization* and *indoor air quality*. *Energy efficiency* is one of the primary concerns for homebuilders and consumers today. The increased amount of electronic equipment and climate control technologies in our homes has correspondingly increased the energy consumption of those structures. Taking measures to improve energy efficiency in a home and its appliances could greatly reduce the lifecycle impact of those home's operations. *Resource and material efficiency* have also become primary concerns as we have increasingly recognized the finite limitations on many of the raw materials which go into constructing and operating most American homes. Analogous to resource efficiency is the implementation of *construction waste* minimization practices. The modern residential construction site produces exorbitant amounts of waste, much of which is recyclable but ends up in landfills none-the-less. Finally, *indoor air quality* has become a growing concern, as the use of toxic materials in poorly ventilated structures is causing adverse health impacts for a growing number of residential homeowners.

There are multiple reasons for why more sustainable practices in each of these categories have not been widely adopted, first and foremost among them would be the fact that to build in a more environmentally sensitive manner requires a substantial number of trades in a historically change-resistant industry to adopt "ideas, practices or objects that are perceived as new by an individual or other unit of adoption."[3] It requires, in essence, the process of innovation and the diffusion of innovation throughout the industry and it is this process which is largely the crux of the dilemma. This thesis will deal directly with that issue.

Hypothesis and Questions

The hypothesis of this thesis is that there are particular structural trends in the American Homebuilding industry today which are leading to a period in which the industry, itself, will be bifurcated into *mega-production builders* and, smaller, regional and local entities. While the smaller homebuilders will continue to exhibit many of the traits which have led researchers to characterize the industry as resistant to change, the *mega-production builders* are entering a period in which they will be ripe for more innovative practices. Corollary to these concepts is the fact that the U.S. government continues to dedicate tremendous resources to fostering innovation in homebuilding and that many of its programs are wholly geared towards addressing those very traits which have made American homebuilders resistant to change.

This thesis proposes that mega-production builders are, indeed, adopting more innovative technolgies which stand to remediate the environmental impacts of their practices and that the aforementioned government programs, while entirely successful to date, will need to either adapt to the new dynamics of the industry or shift their focus to the smaller local and regional builders which will continue to occupy a sizable portion of the U.S. Homebuilding industry. Therefore, my questions are as follows:

> *Are current trends in the production homebuilding industry creating an environment in which large production builders are "ripe" for more innovative practices which could lessen the environmental impact of their products and processes and what might some of the remaining obstacles to innovation be for these builders?*
>
> *Are contemporary government programs, designed to foster innovation in homebuilding, going to be successful in dealing with the two different segments of the homebuilding industry - the mega-production builders and the smaller regional and local entities- as they continue to evolve?*

To answer these questions I have researched two divisions of one of America's largest homebuilding corporations, Pulte Homes. The divisions which I have chosen to study have both made efforts to incorporate innovative practices and technologies into their operations and in both of the case studies these innovations and technologies have lessened the environmental impact of the homebuilding process and the homes themselves. That said, the case studies are very different in nature. One is extremely localized, heavily dependent on the assistance of government programs and strives to improve upon existing building practices without calling into question the fundamental manner in which homes are built. The other is a more centralized effort being propagated by Pulte's national headquarters and has led to systemic changes to traditional homebuilding practices by utilizing more industrialized technologies to build the shell of a home in a factory setting.

Pulte Homes was chosen as the builder for this case study for two primary reasons. First of all, they appear to be the most active of the large production builders in the Department of Energy's *Building America Program*, having used the public/private partnership (which will be explained in more detail later in this thesis) to improve the energy efficiency of homes in several of their divisions across the country. Secondly, the company has aggressively pursued more industrialized manufacturing techniques through the development of the *Pulte Home*

Science division (which will also be explained in more detail later in this thesis). The fact that both of these practices are being pursued by one builder allowed me to work with a single entity to study two very different approaches to homebuilding which greatly eased my ability to conduct the interviews upon which a large portion of my case studies are built. While focusing on a single builder makes it difficult to extrapolate conclusions to the industry at large, it will allow a glimpse into some of the evolving dynamics of this particular sector of the production homebuilding industry. The chapters of this thesis will be organized as follows.

Chapter Outline

The first chapter of this thesis will provide an overview of innovation and the process through which it is diffused in an existing industry. This chapter will illustrate a theoretical framework for a subsequent investigation into why sustainable design and construction practices have yet to achieve widespread acceptance. It will be important to provide a variety of definitions in addition to explaining both historical models of innovation and more contemporary adaptations of those models which are better suited to deal with the complexities of contemporary production industries like homebuilding. This chapter will also illustrate key differences between the concepts of *sustaining* and *disruptive* technologies and how such technologies interact with existing industry structures.[4]

The second chapter of this thesis will take the theoretical foundation of the first chapter and apply it to the homebuilding industry. It will provide an overview of the few studies which have attempted to quantitatively address the diffusion of innovation in the homebuilding industry in addition to addressing the numerous studies which have illustrated traits specific to the industry which have led it to be characterized as "backwards" and "change-resistant." Having illustrated some of the obstacles to innovative practices posed by the industry structure, the chapter will then illustrate past government efforts toward fostering innovation and its diffusion in homebuilding. The Federal Government has a long and storied history in its relationship with the homebuilding industry, and this chapter will not attempt to recount that history in its entirety.[5] Instead, it will deal directly with those programs designed to foster and promote innovative practices in the industry through public/private partnerships, specifically: *Operation Breakthrough* and the *Building America Program*.

The third chapter of this thesis will focus on the contemporary production homebuilding industry, paying specific attention to the increasing presence of what I will call the *mega-production builder*, those large publicly traded corporations which are producing well in excess of 25,000 houses a year and operating in real estate markets all across the country. It is here that I will illustrate several trends which discredit previously accepted notions as to the "backwardness" of the production homebuilding industry in addition to presenting the argument that the homebuilding industry is entering a period in which *mega-production builders* will have a distinct competitive advantage in the market place and will be "ripe" for the types of systemic innovations which have traditionally eluded it.

The fourth chapter will deal specifically with my case study of two divisions of the second largest homebuilder in America, Pulte Homes: the Las Vegas division and the Washington D.C. division. These divisions are illustrative of two very different approaches to innovation in the production homebuilding industry, one which may be considered *incremental* in nature and the other which is clearly *systemic*. In Las Vegas, Pulte is an active partner in the *Building America* program, whose ultimate goal is to reduce energy consumption in residential construction by upwards of 60%. It should be noted that, of the *mega-production builders*, Pulte has been the most aggressive with the Building America Program, utilizing the public/private partnership to increase the efficiency of 24 subdivisions in Las Vegas alone by making subtle alterations to the way "stick-framed" houses are built.[6] In a very different, and more systemic approach, in the Virginian suburbs of Washington D.C., Pulte has created a specific arm of their company referred to as *Pulte Home Sciences* which has constructed a factory and is now prefabricating foundations, floors, interior and exterior wall systems for assembly in four subdivisions in the Washington D.C. metropolitan market. The case studies will rely most heavily on industry trade journals in addition to interviews with individuals directly and peripherally involved with both divisions in an attempt to illustrate the successes and failures of both approaches.

Based on the findings of these case studies, the final chapter of this thesis will evaluate the successes and failures of these two different approaches to innovation and to gauge what the long term obstacles towards widespread adoption of either approach might be. It is important to bear in mind not only the current accomplishments of each approach but also the ability of either process to grow and further reduce the environmental impacts of homebuilding. Some of these findings include:

1. *Current trends in homebuilding are, indeed, creating a bifurcated industry with two distinct sectors- the mega production builders and smaller regional and local firms.*

2. *Some of these trends, including code consolidation, increased size & profitability and vertical integration are creating an environment in which the mega-production builders have a distinct competitive advantage and will be ripe for more innovative practices in the years ahead.*

3. *Private sector partnerships, like some of those illustrated in this thesis, which create value for builders, product suppliers and homebuyers can be a strong catalyst for more innovative practices designed to lessen the environmental impact of the homebuilding industry.*

4. *The disconnect between design, engineering and construction which typifies most large production homebuilding operations is still a large barrier towards the adoption of more innovative practices.*

5. *Quality control means more to production homebuilders than sustainability or energy efficiency and construction evaluation and post-construction testing is an important means of helping builders adopt more innovative practices by tying them to quality control measure.*

6. *Consumer perceptions of change and innovation are still large barriers to the adoption of more innovative practices, but can largely be addressed by more sophisticated and well organized marketing approaches.*

In addition to these findings, I will provide a series of recommendations for public and private intervention in the production homebuilding industry by assessing the success of the *Building America* efforts in Las Vegas and the potential for more systemic innovations based on the analysis of the Pulte Home Science projects in Virginia. I will also make recommendations for how industry participants could evolve to be more effective in adopting innovative building practices and technologies.

[1] Hassell, et al, Building Better Homes: Government Strategies for Innovation in Housing (Santa Monica, RAND Science and Technology Policy Institute, 2003) xiii.
[2] Joint Center for Housing Studies at Harvard University, The State of the Nations Housing, 2004 (Cambridge, Joint Center for Housing, 2004) 2.
[3] Definition of innovation provided by:
Rogers, Everett M. Diffusion of Innovations (New York: The Free Press, 1995) 11.
[4] Christensen, Clayton M. The Innovators Dilemma (New York: Harpers Business, 2003)
[5] Those interested in the dynamics of this relationship should refer to Keneth Jackson's *Crabgrass Frontier*; Marc A. Weis' *The Rise of the Community Builders;* and Dolores Hayden's *Building Suburbia* as excellent introductory works on the topic.
[6] The Las Vegas Division of Pulte Homes is not the only division of this large homebuilder which is partnering with the Building America Program, but was one of the earliest and is considered to be the most aggressive in terms of energy efficiency and widespread adoption of the lessons learned through the partnership.

Chapter 1: Innovation

Theoretical Models

In order to understand why sustainable design and construction practices have not been widely adopted in the homebuilding industry, one first needs to have a broader understanding of the complexities of the innovation process and the methods through which successful innovations are diffused in organizational structures. There is enough literature on innovation to fill an entire library and the purpose of this section is not to review that literature in its entirety, but rather to introduce the reader to some of the key concepts surrounding the topic.

Everett M. Rogers, one of America's leading theorists on innovation and the process through which it is diffused, has defined an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption."[1] This simple definition would lead the reader to believe that innovation is a process which can be easily modeled and explained, yet after decades of analyzing complex business, social and political organizations, most theorists have come to the conclusion that innovation is far more complex than can be explained by any single process model.

Yet models of innovation abound, and the most widely recognized model is known as the "linear model" which characterizes the process as a straight line trajectory of four key elements:

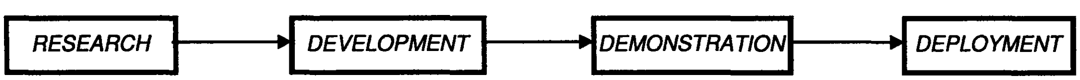

Figure 1.1: The Linear Model of Innovation

One of the key problems with the linear model is that it fails to account for any sort of information feedback loop. Inevitably, most innovations go through several phases of each process indicated here, often moving forward into demonstration only to find that there were gross miscalculations in the development phase, or worse yet, the development phase was based on flawed research much earlier in the process.[2]

Furthermore, several studies have pointed to other shortcomings in the linear model. A recent report written for the U.S. Department of Housing and Urban Development by the RAND Science & Technology Policy Institute has illustrated several of these flaws. First, scientific research is rarely a launch pad for most innovations; rather the process is regularly built upon a wide body of existing knowledge and experience. More often than not, innovations are simply a reconfiguration of existing applications and materials which have been repositioned in different ways to produce a new process or product. Innovation does not entail a rigorous theoretical understanding of the underlying science behind each invention.[3]

Finally, the linear model does not account for the fact that a lack of technological "know-how" or adequate research may not be the primary obstacles which prevent an innovation from moving into its deployment phase. Issues of cost and market demand are just as often barriers towards the implementation of a technically feasible innovation, yet remain conspicuously absent from the linear model.[4] Recognition of these shortcomings has led to a variety of new models of the innovation process and one, in particular, is worth noting.

The "chain-linked" model of innovation was developed by Stephen J. Kline & Nathan Rosenberg. It attempts to account for the complexities of the innovation process by providing us with a more comprehensive model.

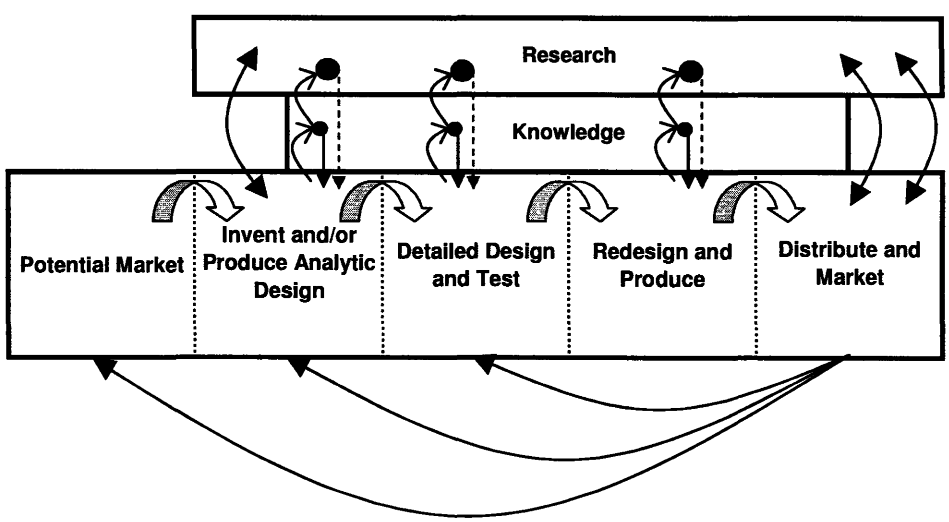

Figure 1.2: The Chain-Linked Model of Innovation

One of the key differences between the two models is that the four primary elements of the linear model have been replaced by the seven elements illustrated above: identifying a *potential market* or need, *producing an analytic design*, *detailed design and testing*, *redesign and production* and, finally, *distribution and marketing*, all of which is "chain-linked" to an existing *knowledge* base and the potential for scientific *research*. There are many readily apparent differences between the two models and two of these differences are worth noting.

First, *design* has replaced *science* as the foundational component of the innovation process.[5] While it is not rare to depend on scientific research as the basis for a new innovation, it is often the case that science is treated as a complement to a vast base of existing knowledge, and sometimes science may not be used at all in the creation of a new product or process. Design lends the model much greater flexibility in its treatment of science.

The second important differentiating element is the presence of an existing knowledge base. Note that, in the smaller feedback arrows which link the design process through to knowledge and research, knowledge is the first line of defense. Drawing on existing knowledge as a solution to problems encountered during the design, testing and production phases of innovation is easy enough, as is the recognition that new scientific research may be needed. However, as indicated by the dashed lines in the model, to return to an existing design process ensuing the creation of new scientific knowledge is a rather difficult process; creating new science often entails beginning the innovation process anew.

Consider, for instance, two building material innovations developed over the past one hundred years: the structurally insulated panel (SIP) and the photovoltaic (PV) panel. The SIP was a combination of two existing materials: particle board or plywood and rigid foam insulation. The products were bound together with readily available adhesives and the structural properties of the panel were tested via the existing knowledge base of lateral and vertical structural forces. While there were multiple tests and variations on materials, the innovation was entirely dependent on the presence of an existing knowledge base.

The conversion of sunlight into direct energy, however, involved a number of scientific achievements dating back to the discovery of photoconductivity in the element selenium

(1873) through to the 1954 "accidental" discovery at Bell Labs, while researching semiconductors, that discovered silicon "doped" with impurities was extremely sensitive to light. Experiments with the silicon eventually led to the first solar modules in the late fifties. Scientific discovery was an integral part of the process, and without it, we would not have the modern photovoltaic panel.

Diffusion

Thus far, we have explained innovation as a singular entity, but for innovations to have the far-reaching financial, social or environmental effects which, it is assumed, their propagators wish them to have, there must be a process of diffusion throughout the industries in which they occur. The process of diffusions is typically modeled as a classic "S" curve, illustrating a relatively small number of adopters in its early stages followed by an industry-wide rapid adoption and then a relative flattening of the curve when only the late adopters or "laggards" complete the transformation.[6]

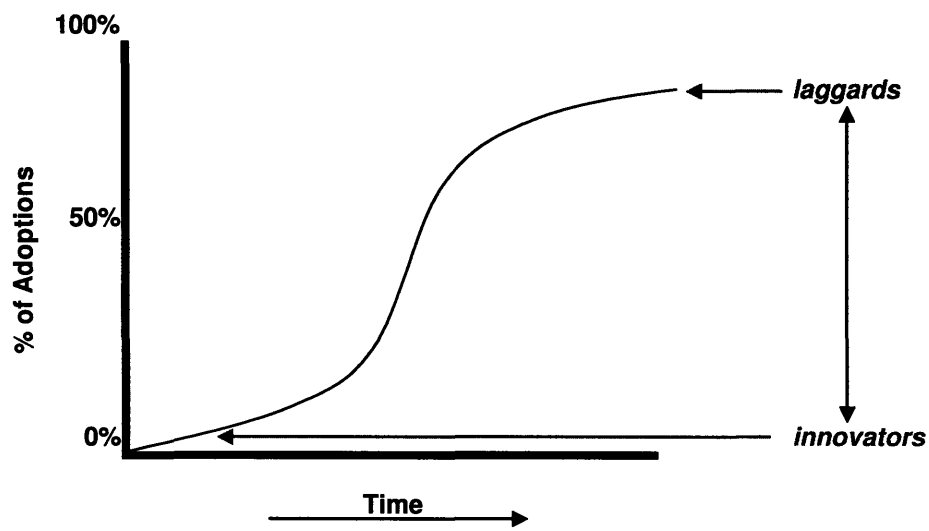

Figure 1.3: The "S" curve of innovation diffusion

The process of diffusion has been defined as having four key elements: the *innovation* itself, a *communication channel*, *time* and a *social system*.[7] I will draw on Roger's definitions to briefly describe them here.

Rogers has defined the *innovation* element as having 5 distinct characteristics, which will be important to keep in mind when we begin to look more closely at the homebuilding industry:

- *Relative Advantage: the degree to which an innovation is perceived as superior to the idea it supercedes.*
- *Compatibility: the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters.*
- *Complexity: the degree to which an innovation is perceived as difficult to understand and use.*
- *Trialability: the degree to which experimentation may be experimented with on a limited basis.*
- *Observability: the degree to which the results of an innovation are observable to others.*

Theodore Koebel has added to this list the characteristic of *certainty and timing* to account for the fact that the benefits of any given innovation may be reaped over the lifespan of that innovation, while the cost will have to be paid up front. This lends the importance of certainty to the innovation. To what extent can the end user be sure that this innovation will provide given paybacks over a stated amount of time? The notion of certainty and timing are particularly important with regards to innovations related to sustainability, whose higher up-front costs must often be accounted for by decreased lifecycle costs.[8] Thus, Successful innovations must provide the end user with greater certainty, relative advantage, compatibility, trialability and observability, while also having less complexity.

The second element of innovation diffusion is a *communication channel.* This is the mode by which an innovation, or the experience of an innovation, is transferred from one adopter to another potential adopter. The channel can take several different forms ranging from interpersonal communications to the use of mass media. Some industries, homebuilding among them, have been described as having extremely weak communication channels which have stood as barriers to the diffusion of innovative practices.

The third element of diffusion is time. The "Rate of Adoption" is the speed with which any given innovation is adopted by members of a society. Adopter categories are essentially defined based on their rate of adoption with the "innovators" being the very first to adopt and the "laggards" being the last (see Figure 1.2). Industries with poor communication channels can expect to have slower rates of adoption as would be indicated by a flatter diffusion curve.

The fourth, and final, element of diffusion is a *social system.* A social system is defined as being a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal.[9] Knowledge and understanding of this system is a key element to our particular problem of the production homebuilding industry, as the "structure" of this industry is perceived as one of the primary barriers towards the adoption of more innovative practices. Koebel (1999) has argued that it is the structure of the industry, not its lack of knowledge or research capabilities which have led to its current "backwardness" and change-resistance. In his words, "engineering is only half the solution," and we need to develop a deeper understanding of the complex social networks which constitute the homebuilding industry in order to better understand how innovative practices can be adopted.[10] Any discussion of the homebuilding industry's social structure will need to bear in mind the concept of "network embeddedness."

Network Embeddedness

Network Embeddedness has been defined as the quality of the ties between a focal firm and its transaction partners (buyers, sellers, service providers, as well as competitors with whom the firm cooperates in the context of research and development projects).[11] The notion of embeddedness provides an important link between the fields of sociology and economics in that it accounts for the extent to which social relationships shape economic action.[12] Traditional literature on economics has tended to marginalize the relationship between social ties and economic behavior.

Individuals and organizations whose activities are embedded in a larger organizational structure or social system will tend to consider the benefits and consequences of their own actions, and those around them, in the context of how it will affect not only themselves, but also the collectives in which they operate.[13] The extent to which such considerations affect firm level decision making processes is an important component of any business model and will tend to have significant impacts on a firms willingness to pursue more innovative or technologically advanced processes.

Sustaining V. Disruptive Technologies

Business theorist Clayton Christensen has written extensively on the nature of technological change and the manner in which such changes affect the industries into which they are introduced. Christensen has defined two separate types of technologies: sustaining and disruptive. Sustaining technologies are those that make incremental improvements to products which are assumed to be desired by the mainstream users of those particular products. Disruptive technologies, on the other hand, are more radical in nature and will often tend to under-perform other products in the marketplace in the short term, but may have particular characteristics which make them appealing to a small group of consumers. Over time, the added benefits of these new technologies become appreciated by mainstream users, in that they fill a role in the new market that the older technologies could not fill- either through price, quality or usability.

Sustaining and disruptive technologies can be classified as incremental, moderate or radical. It is important to consider that the different degrees of technological change implied by these labels need not necessarily apply to the "character" of the change at hand but rather the rate at which those innovations take place with regards to time or engineering inputs. While it will certainly be more common for disruptive technologies to be classified as radical, sustaining technologies can typically fall under any one of the above classifications.

Disruptive technologies can be further divided into two types: architectural and intrinsic. Architectural disruptions, as the name implies, typically involve the putting together of existing technologies in new and different ways to create a new product. Intrinsic disruptions, however, typically require new scientific research and development in order to achieve the creation of a new product. The case of hybrid engines and fuel cell engines are good examples of each. The hybrid engines depend on electrically charged batteries combined with the traditional internal combustion engine to create a new highly efficient vehicle. Fuel cells, however, utilize liquid or gaseous hydrogen to create electrical charges which can power a car without harmful emissions. The fuel cell technology, unlike the batteries or internal combustion engine, required extensive research, testing and development before it could be adapted to suite automotive needs.

It is also important to consider what aspect of the industry will be affected by the change at hand. The change can affect the final *product*, the *process* used to arrive at that product, or the entire *system* (i.e.- the inputs, the process and the product). Systemic changes are typically radical in nature though they need not be disruptive in that systemic changes may be used to modify an existing product with a loyal consumer base.

It is often the case that the terms technology and innovation are used interchangeably, yet it is important to distinguish between the two. Technology, as defined by Christensen, is the "processes by which an organization transforms labor, capital, materials, and information into products and services of greater value."[14] An innovation, however, is a change in technology and the impact of an innovation can be far-reaching in that it can often affect the entirety of the social system surrounding the product at hand. Figure 1.4 summarizes the concepts surrounding technological change and innovation.

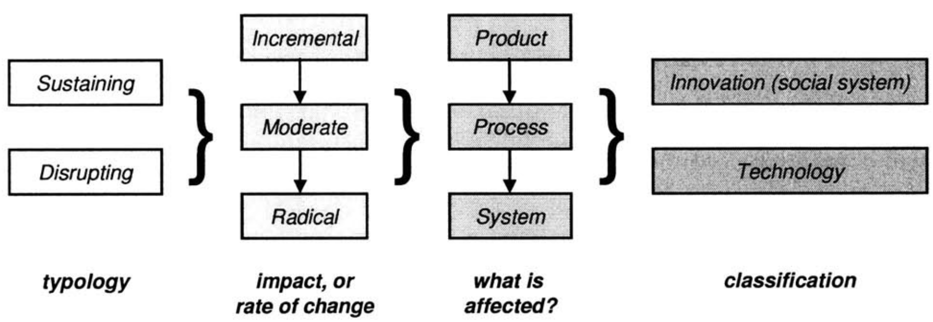

Figure 1.4: Technological Change and Innovation Components

Mobile homes provide us with a good example of a disruptive technology. Largely spurred by government investment during World War II as a means of housing defense workers in a time of extreme building material supply shortages, manufactured housing techniques failed to gain a large share of the market in the years following the war despite extensive private sector experimentation and investment. However, in the sixties, manufactured homes in the form of trailers and mobile homes became a fixture in the American Landscape as primary residences, possibly as a reaction to the inflationary environment of the seventies and the increasing cost of housing production and ownership. The homes lacked many of the amenities and special qualities of site-built structures, but were far more affordable and had the added benefit of being transportable to new and different sites. By the early 70's, one mobile home was being built for every three site built homes and by 1978, the government finally regulated the industry through the establishment of a National Building Code for manufactured housing. Today, some of the HUD-Code housing manufacturing techniques are being adopted by the builders who traditionally utilized site-built methodologies, and the jury is still out as to whether or not the industry as a whole will adapt to these more industrialized building approaches. We can use the model developed in Figure 1.4 to more clearly illustrate the nature of the changes embodied by HUD-Code Housing:

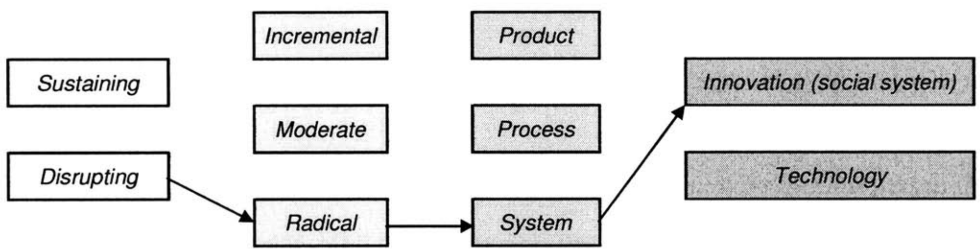

Figure 1.5: Mobile Homes

Mobile homes were cheaper, smaller, easier to build and less adaptive to structural changes & design alterations and therefore may be classified as *disruptive*. The shift to mobile homes did not entail incremental or moderate changes to a single component of the house, but rather radical deviations from traditional construction and design methods. The new way of building homes affected both the final product and the process used to create that product, in this sense, they were "systemic" in that they reached well beyond any single trade and changed the way multiple parties interacted in order to construct the product.

The proliferation of mobile homes (i.e., HUD-code housing) shook the entire social system of the homebuilding industry. The sales were not performed by traditional real estate agents, but rather by a hybrid cross between a car dealer and a home sales office. The regulatory agencies completely shifted both the way they inspected houses and the people used to perform those inspections. Homes were now checked by special HUD-code inspectors before leaving the factory. Upon being shipped to the site, traditional building inspectors would verify the labels on the home and ensure that the structure was adequately connected to the site-poured foundation. Most of the contracting used to build the new structures was internal to the housing manufacturer as opposed to being subcontracted to independent trades. Specially designed transportation devices were developed and highway regulations which mandated the maximum width of loads on the U.S. Interstate Highway System had a greater affect on the size of one's living room than the structural capability a the 2x8 ceiling rafter used to frame that room's roof. HUD-code housing affected much more than "the processes by which an organization transforms labor, capital, materials, and information into products and services of greater value." It changed the way the entire social system surrounding housing development interacted with each other and with the product at hand; it can, therefore, be considered an innovation.

In this chapter, I have laid the basic groundwork for a deeper understanding of the process of innovation by presenting the long accepted *Linear* model of innovation and by illustrating contemporary critiques of that model and it's over-simplification of the innovation process. Out of these critiques has arisen a new model, known as the *Chain-Linked* model of innovation. This model attempts to account for the complexities of the innovation process and the extent to which it is both a process of design and fundamentally dependent on a wide body of existing knowledge as opposed to scientific research. Once an innovation is accepted, the extent to which it succeeds is dependent on its ability to diffuse throughout the industry in which it exists. The diffusion of innovation has been identified as having four key elements: the *innovation* itself, industry *communication channels*, *time* and a *social network*. Social networks are a vital part of the diffusion process and the extent to which an individual or organization is *embedded* in a larger organizational structure should also be considered to have an affect on the extent to which innovations diffuse throughout an existing industry. Finally, I outlined a basic model for identifying different types of technologies and innovations within an industry by introducing the concepts of *sustaining* and *disruptive* technologies in addition to a series of supporting concepts which will be applicable to the case studies which will be introduced in Chapter 4. But first, it is important to look more specifically at how the structure of the homebuilding industry has traditionally affected the process of innovation and its diffusion.

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[1] Rogers, Everett M. Diffusion of Innovations, (New York: The Free Press, 1995) p.11.
[2] Kline, Stephen J. and Rosenberg, Nathan, *An Overview of Innovation*, The Positive Sum Strategy, ed. Ralph Landau and Nathan Rosenberg (Washington D.C.: National Academy Press, 1986) p.286
[3] Hassell, et al, Building Better Homes: Government Strategies for Innovation in Housing (Santa Monica, RAND Science and Technology Policy Institute, 2003) p.13.
[4] ibid, p.14
[5] Kline & Rosenberg (1986) p.286. For the purposes of this discussion, I am using the terms "science" and "research" interchangeably, as they are treated in the Kline & Rosenberg text.
[6] Rogers (1995) 23.
[7] Rogers (1995) p.35.
[8] Koebel, Theodore C., *Sustaining Sustainability: Innovation in Housing and the Built Environment*, The Journal of Urban Technology Vol. 6 Num. 3 (1999) p.81.
[9] Rogers (1995) p.23.
[10] Koebel (1999) p.93.
[11] Beugelsdijk, Sjoerd et al, *Organizational Culture and Network Embeddedness*, Discussion Paper, Tilburg University, Department of Organization and Strategy, October 2002, 4.
[12] Uzzi, Brian, *The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect*, American Sociological Review, Vol. 61 No. 4, Aug. 1996, p.674.
[13] ibid, 693.
[14] Christensen, Clayton M. The Innovator's Dilemma, (New York: Harper Business, 2003) xvi.

Chapter 2: Innovation in Homebuilding

Barriers

The fact that the homebuilding industry has been historically characterized as "change-resistant" or "backwards" has been a source of great consternation for researches and builders alike. Numerous studies have attempted to illustrate the fundamental structural elements of the industry which have led it to be characterized as such. Many of the conclusions drawn by independent researchers and industry organizations, such as the National Association of Homebuilders (NAHB) and its affiliate the National Association of Homebuilders Research Center (NAHBRC) bring to light themes which can be categorized to illustrate the common threads running between them.

Below is a table illustrating some of the major studies conducted over the past thirty years on the topic of the barriers towards innovation posed by the industry's structure:

Field & Rivkin (1975)	Oster & Qugley (1977)	NAHBRC (1989)	NAHBRC (1998)	RAND Corp. (2003)	Koebel, et al (2004)*
fluctuations in residential construction cycles	*fluctuating demand*	*cyclical nature of construction*	*cyclical nature of construction*	*boom-bust cycles*	*high cost of deployment*
firms are specialized and small	*small scale of firms*	*dominance of small firms*	*fragmented industry structure*	*small & medium sized firm dominance*	*inadequate capital for deployment*
consumer resistance to new technology	*Fragmented industry*	*lack of integration (reliance on subs)*	*building code & product approval systems*	*fragmentation (slows information Sharing)*	*low impact of tech. on profits*
autonomous regulatory agencies in every market	*Fragmented regulatory codes*	*diversity of building codes*	*need for education and training*	*competitive nature/ risk minimization*	*high discount rates*
	difficulty in the evaluation of innovations due to the complexity of buidings	*lack of product approval system*	*lack of access to information*	*construction done in the open, innovators can't protect innovations*	*poor info flow within industry*
		lack of access to information about new products	*limited funding for nonproprietary research*		*lack of govt. support*
		inadequate education	*exposure to liability*		*no means for moving tech. from govt.& universities to field testing*
		exposure to liability	*market resistance*		
		req'd acceptence by finance & insurance industry			*poor links btwn construction & universities*
		limited research funding			*adversarial relationship btwn design & const.*
		homebuyer resistance to innovation			*management ingenuity*
					change in ownership of bldgs over lifespan

**Koebel acknowledges the presence of the NAHBRC 1989 barriers as still being present in 2004 and proposes his list as a compliment to those barriers. The entire list of 19 was not duplicated.*

Table 2.1: Historical Research on Structural Barriers to Innovation in the Homebuilding Industry

Undoubtedly, the most striking characteristic of the above chart is the extensive overlap between the different studies over a substantial period of time. Entire industries have been spawned and ceased to exist in the time during which the homebuilding industry has exhibited the same flawed traits which have made it resistant towards innovation. While the most recent study by Koebel attempts to categorize a new set of traits, careful consideration of these traits leads to the conclusion that these new structural barriers are outgrowths of those that preceded them.[1] For instance, the first four traits listed under Koebel (the high cost of deployment, inadequate capital for deployment, low impact of technology on profits and high discount rates) are all logical outcomes of structural characteristics itemized in the previous five studies- fluctuating capital markets and industry fragmentation.

In fact all of the above traits can be broadly categorized into the following six categories:

fluctuating financial markets/ costs of innovation
firm size & industry fragmentation
regulatory barriers/ code fragmentation
lack of communication & research
risk/liability
market/demand side resistance

Table 2.2: Categories of Structural Barriers

The power of fluctuating financial markets and the costs of innovations has been one of the more consistent themes permeating diffusion research in the homebuilding industry. The strength of the homebuilding industry is largely dependent on such things as interest rates, unemployment rates and land values; all of which are clearly beyond the control of the industry itself. The fact that a large percentage of housing is financed on debt means that the fluctuating patterns of housing starts in the United States are a function of the ability to, and the cost of, borrowing money. Thus, even the most subtle shifts in interest rates can cause substantial variations in the cost to build and own houses.[2] This has resulted in a very conservative industry with regards to capital investment. When times are good, there remains substantial resistance towards a firm making capital outlays for new equipment and investing in their employee's knowledge base for fear that such investments may detract from a firm's ability to weather impending market corrections.[3] Thus the effects of fluctuating capital markets inevitably ties into the fourth barrier on the list, lack of R & D.

Firm size and industry fragmentation has also been a predominant theme in the study of innovation diffusion in homebuilding. Historically, the industry has been made up of small to mid-size construction or development firms who have been both vertically and horizontally fragmented. In 1997, firms with four our fewer employees constituted 93% of all construction firms in America.[4] While much of the innovation literature argues that small firms are the most likely to adopt innovative practices, the competitive nature of the industry, the high costs of innovations, the low profit margins and inadequate communication channels have combined to make this not the case in homebuilding.

The minimal profits to be realized in homebuilding (as compared to other industries) when compared to the substantial costs & risk involved in the process of housing development, have led most firms to cut costs by subcontracting out as many tasks as possible in order to minimize the amount of overhead they must carry, thus resulting in a highly fragmented industry. This means that housing developers often have little control over contractors, subcontractors, architects and engineers who largely determine the successful integration of innovative practices in homebuilding. Overcoming this barrier, while maintaining the existing industry fragmentation, would be largely dependent on the development of strong communication channels within the industry, channels which simply do not exist or could be considered entirely ineffective.[5]

Regulatory barriers and the fragmentary nature of American building codes have also been cited as a tremendous barrier to innovation in homebuilding. Traditionally, no unified national code existed and the structure and requirements of each different jurisdiction would vary widely.[6] This was an extremely difficult hurdle for small builders, who typically worked within the bounds of single code jurisdiction. While this may seem counter-intuitive, the reason for this is that large builders, working in multiple code jurisdictions, were likely to find a region whose code officials and code documents were less restrictive than others and may be less adversarial to the innovation at hand.[7] However, this only accounts for the implementation of a pilot innovation, and the fragmentary nature of the codes would greatly contribute to the inability to diffuse any such innovations throughout the industry as a whole- small and large builders alike. As an adjunct to the code issue, Oster and Quigley's 1977 study of innovation diffusion found that the educational level of the chief building inspector had a tremendous effect on the diffusion of four different building technologies in several regions across the country.[8]

Poor communication channels and inadequate research programs have also contributed greatly to the lack of innovation in homebuilding. Recent efforts to improve communication between builders and more rapidly diffuse innovative practices can be credited to the National Association of Homebuilders Research Center and multiple government programs whose educational websites and numerous publications are easily accessible.[9] However, the success of these third party (trade organizations & governmental) programs is questionable, and it may be posited that a more pro-active program of going into communities and actively engaging builders could be what is needed. Recent studies have indicated that builders predominately get their advice on new technologies and practices from manufacturer representatives, subcontractors, trade publications, trade shows and homebuyers. Governmental technology transfer programs and the internet ranked very low as valuable communication channels.[10]

Furthermore, the incredibly competitive structure of the industry coupled with the non-proprietary nature of its innovations may cause innovative builders to resist sharing their latest discovery through whatever channels do exist.[11] The inability to protect proprietary innovations, a noted problem in construction, is further exacerbated by the fact that construction is typically done in the open and innovative practices are readily visible to any passer-by; be they friend or foe.[12]

With regard to research, there is a rich history of government intervention to encourage innovation in the homebuilding industry (as will be discussed later in this chapter), yet by and large these efforts have been ineffective. Japan, on the other hand, which has a fairly progressive and technologically advanced construction industry, mandates that its six largest builders invest .5% of their annual turnover into R & D programs. This has resulted in extensive advances in modular housing technology, floor jacking systems for tight urban construction sites and the use of robotics in the construction process.[13] European nations have also invested in new building technologies, focusing more heavily on information technologies and object oriented CAD systems.[14]

The fifth barrier on this list, risk & liability, has also been noted to substantially impact innovative practices in homebuilding. Homebuilding has become an extremely litigious industry, and the seeming lack of quality control measures has led to a rash of call-back and warranty issues in addition to spawning several class action and independent lawsuits all across the country. This is not a new phenomenon. Architects, contractors, engineers, product manufacturers and developers have always been concerned about their assumed liability on a project. Reading an architectural specification or the product warranty on a water-proofing membrane has become akin to reading a tome of lengthily and dry legal jargon. It is not uncommon to find that following the introduction of a new material, product manufacturers may find it difficult, or impossible, to obtain product liability insurance for that given product.[15]

The sixth and final category of barriers is listed as market or demand-side resistance. A home is, more often than not, the largest investment an individual or family will ever make. The thought that something may go wrong in that investment is, to the investor, a frightening concept. Consumers are historically averse to supposedly "untested" materials or methodologies- they tend towards the tried and true methods of building. This is particularly the case if product or system changes alter the physical appearance of the component or house.[16] Builders, who do not invest heavily in educating buyers as to the benefits and safety of the innovation, may not be able to market their innovations successfully.[17]

Quantitative Studies on Innovation Diffusion

There have been few efforts to quantitatively measure the diffusion of innovation in the residential construction industry. The findings of two studies are worth noting: Blackley & Shepard's 1992 study and Koebel, et al's, 2004 study.

In 1992, Dixie Blackley and Edward Shepard, III, studied the diffusion of ten different building technologies by analyzing data collected by NAHB as part of that organization's 1987 Member's Profile Survey. The innovations included:

- Plumbing provisions of the 1986 CABO one and two family dwelling code (incremental, process)
- 24-Inch stud spacing (incremental, process)
- Two-stud corners (incremental, process)
- In-line off-center spliced joists (incremental, process)
- Composite wood I-beams (incremental, product)
- Open wall panels (incremental, process)
- Closed wall panels (moderate, process)
- Foam structural panels (moderate, product/process)
- Condensing furnaces (incremental, product)
- Solar-assisted water heaters (moderate product/process)

The study utilized regression analysis to gauge what factors or firm characteristics may have influenced the firm's decision to innovate. The results indicated several traits in firms which adopted innovations. Using the "value of construction" as the moniker for firm size, as opposed to number of employees or houses completed, the study found that larger firms were clearly more likely to adopt innovative practices. Analogous to size, the study found that builders working in multiple regions were also more likely to innovate. The study also attempted to quantify vertical and horizontal fragmentation by segregating firms by the amount of work subcontracted (horizontal fragmentation) and the amount of non-construction activity pursued (lending, sales, design- vertical fragmentation). In this regard, the study found industry fragmentation to have an insignificant effect on innovation. Additionally, one of the more interesting findings in this study was that as the price of a home increased (i.e., the further it deviated from the average home price in the survey) the less likely it was to adopt innovative practices- thus theorizing that builders focusing on high-end residential construction are less likely to pursue innovative practices.

Another study, undertaken by Theodore Koebel and his colleagues at Virginia Tech for the Department of Housing and Urban Development, was conducted in 2004. This study looked at the diffusion of eight different building technologies, which included:

- Pre-cast concrete foundation walls (radical, systemic)
- Wood/plastic composite exterior trim/molding (incremental, product)
- Fiber cement exterior trim materials (incremental, product)
- Heat pumps with integral water heating (e.g. desuperheater) (moderate, product)
- Laminate flooring (incremental, product)
- Wood I-joists as roof rafters (incremental, product)
- Fiber cement flooring underlayment (incremental, product)
- Wood I-joist structural floors (incremental, product)

The Koebel study is interesting in that it seems to refute some of the arguments made in the previous study. For one, it argues that custom homebuilders are more innovative than single family production builders- potentially refuting the argument that the high end market is less prone towards innovative practices. Furthermore, the study found no direct relationship between a firm's size and the tendency to innovate. However, it should be noted that, unlike the previous study, Koebel used the number of houses completed and the number of firm employees as his measure of size. Somewhat paradoxically, the argument is made that national firms and firms serving multiple markets are more likely to adopt innovative practices, but it is unclear how this relates to the previous findings, due to the fact that these would be the firms with the largest number of employees and housing completions. Unlike Blackly and Shephard, Koebel found that union participation and the increased use of subcontractors actually improved a firm's level of innovation.

It is important to bear in mind a few key points about both of these studies. With the possible exception of closed wall panels from the Blackly & Shephard study and pre-cast foundations from the Koebel study, almost every listed technology could be considered *incremental* or *sustaining* (see Chapter 1 for definitions). Furthermore, with the exception of pre-cast foundations from the Koebel study, all of these technologies are essentially material substitutions without significant effects on the building process. It is doubtful that any of these technologies would significantly shake up the industry. As a final point, the Koebel paper chose not to stratify its findings by builder size arguing that "previous research was inconclusive about the relationship between size and innovation in residential construction."[18] It could be argued that the Blackly & Shephard study actually refutes this statement through its findings that firms with higher revenues were more prone to innovations. Furthermore, I think the Koebel study refutes the statement itself in its finding that national and multi-regional builders were also more likely to adopt innovative practices.

Government Partnerships for Innovation

The U.S. Government has long recognized the innovative shortcomings of the American homebuilding industry and, at several points throughout history has made sincere efforts at intervention. Several branches of government have been involved at one point or another, including the Department of Housing and Urban Development, the Department of Energy and the Environmental Protection Agency. In 1999, alone, the federal government spent $236 million directly on R&D related to housing, 65% of which was directed at energy efficiency and energy generation.[19] In large part, this is to make up for the fact that the construction industry typically contributes only .5% of its profits into R&D, compared with other industries in America which spend, on average, 3%.[20] While itemizing all of the different government programs aimed at housing would be an arduous task beyond the scope of this paper, there are two which are particularly relevant to the topics at hand: *Operation Breakthrough* and *The Building America Program.*

Operation Breakthrough

In the late 1960's, two very important commissions convened and presented reports to Congress & the President on the state of the nations housing. The Kaiser Commission, and its 1968 report, entitled "A Decent Home," argued for, among other things, the need for more public/private partnerships to meet the nations growing need for affordable housing. The Douglas Commission (1968) also pointed out severe housing shortages and affordability issues in America and argued for a research program to focus on industrialized housing techniques. Out of these commissions was spawned the *Housing Act of 1968* and from this Act came the impetus for the first major government program to foster innovation in the homebuilding industry, it was known as Operation Breakthrough.[21]

The primary goal of Operation Breakthrough was to promote industrialization and modern production techniques in the residential construction industry. As part of the program, the government would pay for the research and development costs for the construction of housing on nine sites across the country. As partners in the program, HUD selected a broad array of industry representatives ranging from building material and appliance manufacturers like Alcoa and General Electric to traditional production homebuilding firms like Scholz Homes Inc. and the Levitt Technology Corporation.[22] Of the 22 partners, 21 projects were built, only 7% of which were single family detached housing. While the projects were completed on-schedule, they ended up costing 40% more than their fair market value. The projects identified two primary culprits for driving up the costs of the housing: burdensome and inconsistent regulatory barriers and the fragmentation of the housing market.[23]

In retrospect, Operation Breakthrough is largely considered a failure because, while it addressed the technological obstacles to introducing advanced production methodologies in the housing industry it failed to account for the industry characteristics which would create barriers to the diffusion of those innovations, and therefore once the projects were built, the innovations, in large part died.[24]

Building America

The Building America Program grew partially out of a response to the National Construction Goals which were developed in 1995 as part of the National Science and Technology Council's effort to create a more focused effort across the 14 Federal Agencies which were currently spending money on R&D projects related to the construction industry, though it existed in a less formal structure prior to that date.[25] The Program, begun in 1996[26] and directed specifically at the production homebuilding industry, currently aims to:

- *Reduce energy use by 50% and reduce construction time and waste*
- *Improve indoor air quality and comfort*
- *Encourage a systems-engineering approach for design and construction of new homes*
- *Develop system cost/performance tradeoffs that improve housing quality and performance without increasing cost*
- *Conduct cost-shared research to accelerate development and adoption of innovative building systems* [27]

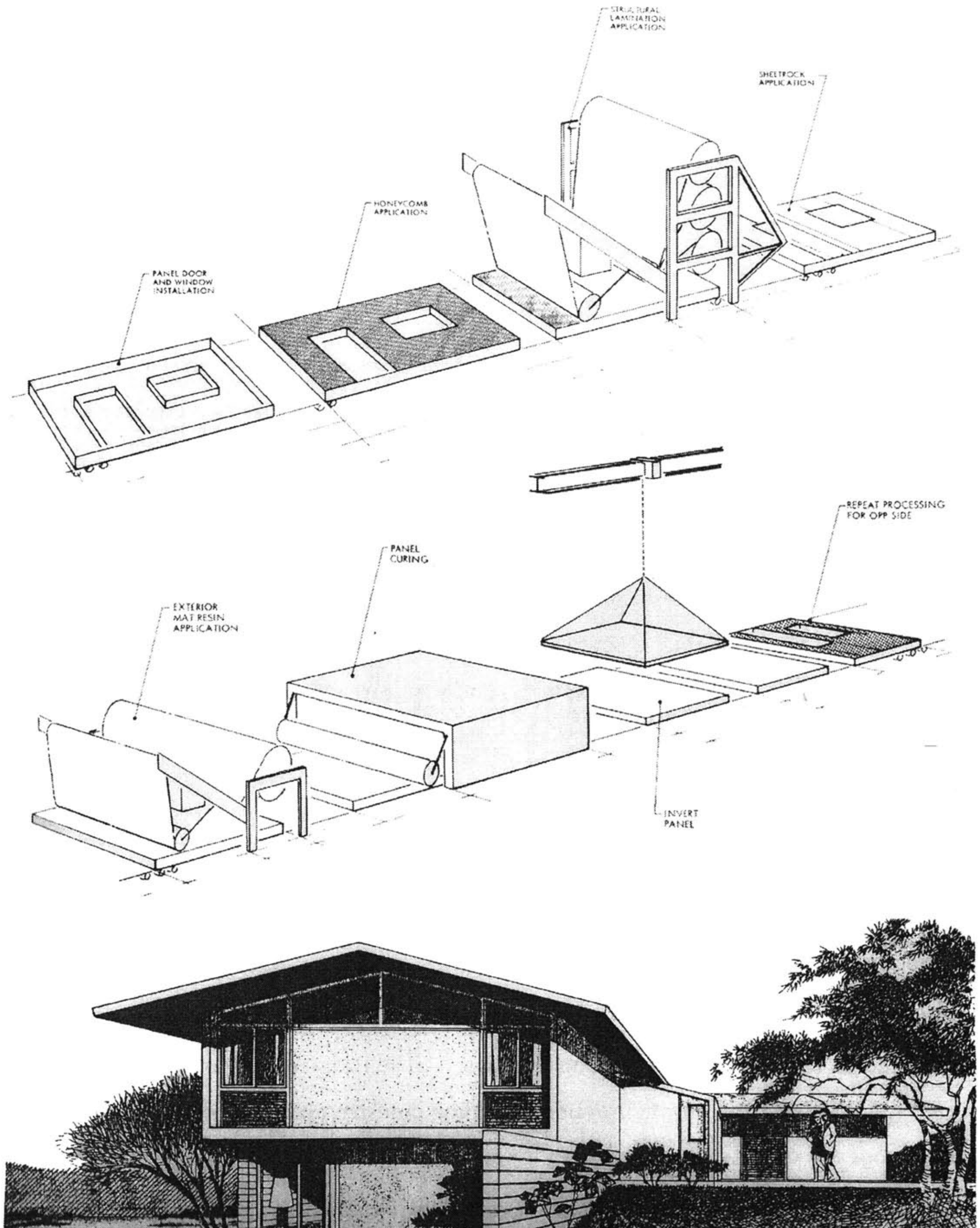


Figure 2.1: Operation Breakthrough Proposal, TRW systems w/ Kaufman and Broad

The work of the program is divided up amongst five Building America teams across the country that provide research & development assistance, technical support and educational seminars to architects, engineers, code officials, contractors, subcontractors, financing organizations, insurers and developers involved in the residential construction industry. An integral part of the program is the "systems engineering" approach to residential construction. No part of the building is viewed in isolation from the whole, thus the program carefully studies how changes to one part of a home's construction may affect the efficiency, cost and constructability of any other part.

Drawing on lessons learned from the Operation Breakthrough program, where regulatory barriers were identified as a key detriment to the program's success, Building America has paid careful attention to educating building officials and inspectors to ensure that the changes made to any building may not encounter regulatory obstacles once under construction.

To date, the program has been largely successful, with numerous building partners and developments across the country accounting for 26,274 completed homes in total. One team estimates, based on the projected build-out of the developments associated with the program, that their Building America projects will generate gas savings of about 40 million Btu's, reduce carbon emissions by approximately 105 million pounds and further reduce SO2 and NOx emissions by 1 million and 1.6 million pounds respectively.[28] However, while the physical numbers are impressive, it is still unclear whether the technical changes made as a result of the program will diffuse throughout the industry at large.

The two programs mentioned here are relevant for several reasons. First and foremost, they build public/private partnerships and make direct investment in the construction of housing as a *means* of research. This investment is something which has separated them from other substantive government programs such as the Partnership for Advanced Technology in Housing (PATH), the Energy Star Program and the Advance Housing Technology Program (AHTP); all of which tend to focus primarily on either pure research or product standard development and marketing. Furthermore, both programs have focused on the capacity of large corporations as catalysts for innovative change in the industry (Building America to a lesser extent than Operation Breakthrough). While over 601 corporations responded to the Operation Breakthrough RFP issued by the Department of Housing and Urban Development in 1969, the 22 chosen clearly represented corporations with the organizational capacity to effect change at the industry level. This could be seen as a possible reaction to previous industry research which indicated that firm size was a major obstacle to the adoption of more innovative practices. It could be said of Building America, that they are primarily focused on dealing directly with large production builders, though the success of the program in recruiting the big nationals has been questionable.

It is also worth pointing out some key differences between the two programs. Operation Breakthrough was clearly more focused on "systemic" innovations. The goal of the program was to industrialize the housing industry by encouraging housing developers to adopt more sophisticated manufacturing and production techniques. It was believed that by pursuing these practices, the industry could improve the affordability of housing and the efficiency through which it was constructed. Building America, on the other hand, seems to have made peace with the fact that housing is not prepared for such radical changes and has invested more of its efforts in promoting and fostering sustaining innovations which are primarily incremental in nature. Most of the homes being built through the program are stick-framed houses, whose systems have been tweaked in such a way as to greatly improve upon their energy efficiency. The program could be considered a reaction to the fact that despite millions of dollars of government investment in more industrialized homebuilding technologies, those practices were never widely adopted by the industry at large.

Community Scale Interventions

It is important to note that high performance buildings are only one component of the larger agenda for sustainable development. The ability to link structures to community scale interventions which can more adequately address larger issues of site impact, transportation and open space preservation is an important concept which has been receiving more attention in recent years. As developments have grown in complexity and scale, it is increasingly the case that the developers of a particular project and the homebuilders involved with that project are separate entities.[29] Recent large scale developments have made notable efforts to create low-impact developments through a variety of measures. One method is for the developer of the community to outline a set of "guiding principles" for development within the community.[30] These principles may include prescriptive (you must do *x, y* or *z*) or performance (the unit installed must meet *x, y* or *z* guidelines) measures with regard to how houses are to be built. These principles may often use one of the previously mentioned government programs as a performance requirement for all homes, i.e. homes must meet Energy Star guidelines. An exciting trend in this regard is the rapid development of "green building guidelines," which are increasingly being used as a framework for the structures in a low impact development. For instance, the Stapleton Redevelopment Project in Denver, Colorado is a New Urbanist community which has paid careful attention to sustainable community development practices like mixed-use, transit-oriented development and walkable neighborhoods. As part of the requirements for winning contracts at Stapleton, homebuilders were required to meet Colorado's Built Green guidelines- a series of environmental requirements which rate homes based on a series of environmental indicators (indoor air quality, minimized use of non-renewable resources, energy efficiency, etc.). While getting large national builders to meet the guidelines was difficult, the project is now held up as model of linking low-impact community scale development to high performance buildings.

The problem with *principles*, however, is that they are not legally binding and can often break down over the extensive time it takes to complete a large scale development project like Stapleton.[31] Other developments have gone another route in attempting to move towards more sustainable development practices by attaching high performance building recommendations to the permitting process, as has been done with the Civano Development in Tucson, Arizona. The developers of Civano wrote a very ambitious set of guidelines for low impact development in their community which included, among other things, a reduction in the use of potable water by 65%, a reduction in internal vehicle miles driven by 40% and the creation of one job on-site for every two residents.[32] To these planning based principles were attached ambitious energy reduction goals for the individual homes. In order to achieve the goals, Civano developed the IMPACT system in partnership with the City of Tucson which essentially created a parallel, and stricter, energy code for the houses being built in the community by inserting addendums to the 1995 Model Energy Code. In order to get their building permits, the homes would have to exceed the Code by 50%, submit construction waste recycling plans and have proper solar orientation in addition to a long list of other sustainable attributes.[33]

Stapleton and Civano are two examples of projects which have tied sustainable construction practices into a larger community vision for low impact development. One utilized market pressures in the form of a development team working to drive demand by mandating the use of a state green building program; the other relied wholly on regulatory measures. To date there has not been enough experimentation with either of these approaches to conclude if one or the other is a better solution- in fact neither of the above mentioned projects is entirely built out. Stapleton is still in phase 1 and Civano is just entering Phases 2 and 3. However, both are driving production homebuilders to higher levels of efficiency and environmental awareness in their building practices.

It is clear from the above examples of community scale interventions and the previous illustrations of government programs that both the private and public sector will need to play a role in pushing the homebuilding industry to adopt more innovative practices. The extent to which either of them succeeds will be largely dependent on many of the structural characteristics which have been outlined in this chapter. These characteristics are well documented over many decades of research. Several common themes can be drawn from these efforts, and these themes are partially confirmed by the few quantitative studies of innovation diffusion in the homebuilding industry which have been presented. It is important to note, however, that there are several trends in the industry which indicate that these structural characteristics may be changing. These trends are the subject of the next chapter.

[1] Koebel, Theodore C., et al, The Diffusion of Innovation in the Residential Building Industry (Washington D.C.: U.S. Department of Housing and Urban Development, 2004).
Note: It is important to note that prior to generating the list included in Table 2.1, Koebel itemized the findings of the 1998 NAHBRC research and confirmed that in 2004 those barriers still existed. Koebel's effort is clearly to expand and build upon existing research on such barriers, not refute the existence of those researches that came before him.
[2] Field, Charles G. and Rivkin, Steven R., The Building Code Burden (Lexington: D.C. Heath & Company, 1975) 11.
[3] Hassell, et al, Building Better Homes: Government Strategies for Innovation in Housing (Santa Monica, RAND Science and Technology Policy Institute, 2003) 42.
[4] ibid.
Note: This statistic, however, includes home remodeling firms. It is generally believed that remodelers constitute 1/3 of the homebuilding industry.
[5] NAHB Research Center Inc., Building Better Homes at Lower Costs: The Industry Implementation Plan for Residential National Construction Goals (Washington D.C.: U.S. Department of Housing and Urban Development, 1998) 7-8.
[6] There has long been a movement afoot to change this, and recent years have seen wide adoption of the new International Building Code (IBC). This code will be discussed in more detail in later chapters.
[7] Missing source
Note: As Blackley & Shepard have pointed out, multi-regional builders are also more insulated from economic downturns.
[8] Quigley, John M. & Oster, Sharon M., Regulatory Barriers to the Diffusion of Innovation: Some Evidence from Building Codes, The Bell Journal of Economics, Vol. 8 No. 2 (1977) 361-367.
Note: The innovations studied included: the use of 2x3 studs for interior partitions, the use of 24" on center framing, pre-assembled drain, waste and vent systems and non-metallic sheathed electrical cable. Based on their regression findings, jurisdictions in which the chief building inspector had a higher level of education had a 2-6% greater chance of adopting the aforementioned innovations. Other conclusions included the findings that unionization, firm size and the affluence of neighborhoods also contributed to the diffusion of innovative building practices.
[9] For instance, all of the following governmental agencies have readily accessible websites with posted research projects: Department of Housing and Urban Development (HUDusers), the Partnership for Advanced Technology in Housing (PATHnet), Department of Energy's Building America Program, National Renewable Energy Laboratory (NREL), Environmental Protection Agency's Energy Star Program.
[10] Koebel (2004) 39.
[11] Kua, Harn Wei et al, Flexible Modular Manufactured Construction. (graduate thesis: MIT, 2003) 20-21.
[12] Hassel, et al (2003) xv
[13] O'Brien, Michael et al, Industrializing the Residential Construction Site (Washington D.C.: U.S. Department of Housing and Urban Development, 2000) p.24.
[14] ibid
[15] NAHB (1998) 8.
[16] ibid
[17] Beck, Dave, National Vice President of Construction, Pulte Homes, personal interview, 3.03.05.
[18] Koebel, et al, (2004) p.32.
[19] Hassel, et al (2003) 69.
[20] Hassel et al (1999), it should be noted, however, that Koebel, et al (2004) refute this argument in that it does not adequately account for the amount of R&D investment conducted by building material manufacturers whose R&D is directly related to the residential construction industry.
[21] Schodek (1975) p.4
[22] Field, Charles G. and Rivkin, Steven R. (1975) p.31
[23] O"Brien, Michael et al (2000) p.23
[24] Koebel, Theodore C. et al (1999) p.85
[25] Hassel et al (2003) p.76
[26] According to George James, the Residential Director of Building America, the program was actually begun well before this date and evolved out of a research project between the Department of Energy and

the Plastics Division of General Electric who tested a pilot program in 1994 to integrate more systems engineering approaches into homebuilding. This evolution will be discussed in more detail in Chapter 4.

[27] Building America Website, www.buildingamerica.gov (2005).

[28] Buidlding Science Consortium, Building America House Totals (2003). www.buildingscience.com/buildingamerica/data/default.htm (similar numbers for other project teams are unavailable as of the writing of this thesis)

[29] Yost, Peter, *Community Scale Evaluation Results*, (Building Science Corporation: on-line posting, 2004) page 1. http://www.buildingscience.com/resources/misc/default.htm

[30] ibid, 7.

[31] ibid, 7.

[32] ibid, 10.

[33] *Civano Impact System: Memorandum of Understanding on Implementation and Monitoring Process*, 6.26.05, online posting, Civano Community Website: http://www.civanoneighbors.com/docs/guiding/revised/Civano_MOU_Dec_8_2003.pdf

Chapter 3: Trends in the Contemporary Production Homebuilding Industry

Having established a theoretical framework for the process of innovation and its diffusion and also having developed an understanding as to what some of the inherent obstacles the structure of the homebuilding industry poses towards that process, it is important to now take a look at some of the trends shaping the contemporary production homebuilding industry. This chapter will illustrate some of these trends, which include: consolidation of homebuilding firms, higher degrees of vertical integration and more centralized supply chain management techniques and the consolidation of building codes. This chapter will conclude by illustrating how these trends are combining to give large production homebuilders a competitive advantage in today's marketplace in addition to making them ripe for more innovative building practices.

Industry Consolidation[1]

As a review of the literature has pointed out, the homebuilding industry has traditionally been characterized, to a large degree, by small firms. In fact, the homebuilding industry has been historically held up as a near-perfect example of a competitive market in which there is a large number of firms, with no firm having enough market power to affect prices, and relatively low barriers to entry and exit.[2] Traditionally, firms tended to operate in geographically distinct areas, and while competition was fierce in those regions, rarely did a single builder establish a dominant national presence.

Over the past two decades, this has been less and less the case, and particularly since the early 1990's the industry has seen the ten largest builders in America increasing in size and gaining market share, while smaller builders have seen declines in these areas. This growth in housing starts for the largest builders has stemmed from two factors: building more houses in their given markets during periods of economic growth (internal expansion) and the buy-out of smaller regional and mid-sized builders (acquisition).

From 1974 to 2002, the market share (as a percentage of new homes sold) of the ten largest builders grew from 4.40% to 19.70%.[3] Viewing the numbers in terms of single builders is slightly less shocking. For instance, in 1992, the largest homebuilder in America (Centex Corporation) built approximately 1.6% of all single family homes sold; and in 2002 the largest homebuilder (D.R. Horton) captured only 3.2% of the market. While this constitutes a 100% increase in the market share for the industry leader, 3.2% is hardly the type of statistic that a market leader would shoot for in other industries. However, as housing economist Elaine Frey has pointed out "if large firms continue to grow at the same rate the market could become very different, with production and sales concentrated in the hands of few enormous firms."[4]

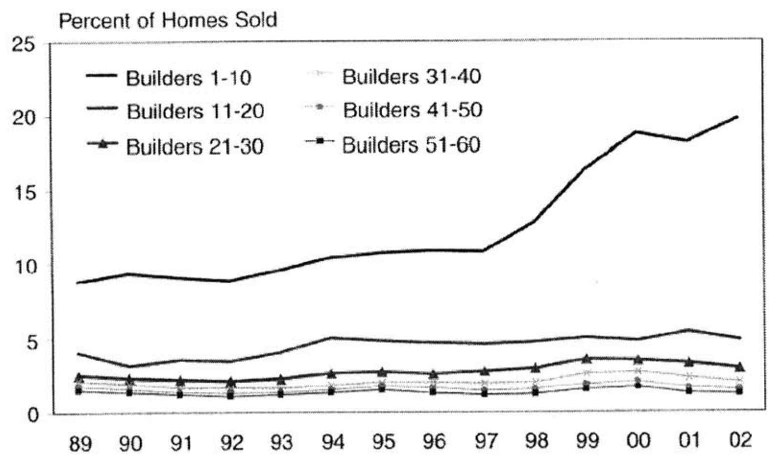


Figure 3.1: Percentage of Homes Sold by Builder Size (source: Housing Economics, May 2002)

Large builders typically use the buyout of smaller firms in order to enter new geographic markets, not to foster internal expansion in the existing markets where they are already established. Smaller firms with profitable operations and large landholdings are likely targets of the big builders. While some firms in the top ten have relied more heavily on internal expansion over the past decade (Ryland Homes, for example, grew internally by 85% and only attributed 15% of its growth to mergers and acquisitions)[5], others have grown predominately through acquisition. For example, D.R. Horton, already cited as America's largest homebuilder, grew from 1,668 closings in 1993 to 22,772 closings in 2001, with roughly 2/3 of this growth stemming from acquisitions. Lennar Homes, the third largest homebuilder in the country, attributes approximately 75% of its growth over the past 10 years to acquisitions. The purchase of smaller firms has clearly played a huge role in boosting the market shares of the ten largest builders. Some firms have even experienced negative internal growth while still pursuing rapid expansion through acquisition. Hovnanian Inc., for instance, increased their closings by 3,120 homes between 93' and 01', yet acquired firms with closings of 3,501 homes, indicating a -12% rate of internal expansion.[6]

***Table 3.1: Homes Closed by America's Largest For Sale Builders** (% indicates market share)*									
	1993	***1994***	***1995***	***1996***	***1997***	***1998***	***1999***	**2000**	**2001**
Top 10	9.20%	9.40%	9.70%	10.30%	10.70%	13.00%	15.20%	16.90%	18.40%
Top 300	30.20%	30.40%	31.20%	32.60%	33.40%	35.50%	38.70%	40.20%	41.50%
Top 11-25	5.10%	5.40%	5.50%	5.40%	6.00%	6.30%	6.40%	6.10%	6.60%
Top 26-50	3.90%	3.70%	4.20%	4.40%	4.40%	4.80%	5.30%	5.50%	5.10%
Top 51-100	4.80%	4.60%	4.80%	4.90%	4.70%	4.70%	4.90%	4.80%	4.50%
Top 101-200	4.90%	4.80%	4.60%	4.90%	4.90%	4.40%	4.30%	4.40%	4.40%
Top 201-300	2.30%	2.40%	2.40%	2.70%	2.60%	2.40%	2.50%	2.50%	2.50%

source: Housing Economics, May 2002

It is also important to consider what has happened with the smaller firms in the industry during this same period. Table 3.1 illustrates the extent to which the growing market share of the top 10 builders is the driving statistic for the industry as a whole. While the market share of the top 300 builders grew by 11.3%, this growth is clearly being accounted for by the top 50 builders (note that builders 51-200 actually experienced negative market share growth during the same period and builders 201-300 experienced fairly minimal growth of .3%).

This growth and consolidation is important to consider for several reasons. First and foremost, is that it begins to refute the notion that the homebuilding industry is plagued by fragmentation. While the current statistics certainly don't make the homebuilding industry analogous to the airline or retail gasoline industries, it is strikingly clear that the trends are pointing in one direction. The big firms are getting bigger and more profitable, and the small firms are grabbing less and less of the homebuilding industry's market share.

The rash of buyouts hasn't negatively affected the profitability of this country's largest homebuilding firms, as might be expected. Pulte homes, for instance, which has conducted three major acquisitions over the period from 2001-2003, accounting for close to 10,000 home closings, managed to increase profitability from $301 million to $625 million over that same period. Furthermore, their debt to capital ratio decreased by more than 6%.[7] This increased profitability coupled with the presence of a more sophisticated and liquid capital market, which is helping to regulate swings in housing demand, is leading to an era in which large production builders may be more prone to making the large capital investments in research and development to which they have traditionally been averse. The era of what I will call the *mega-production builder* is upon us, and the industry will undoubtedly change dramatically in the decades ahead. One of the most intriguing of those changes will be the extent to which these mega-production builders become vertically integrated and manage their supply chains more efficiently.

Vertical Integration/Supply Chain Management

In addition to increasing their size and profits, large national builders have also become highly vertically integrated, often bringing in-house activities which used to be performed by subcontractors and consultants. Large builders now employ their own sales staff, mortgage lenders, title insurers, general contractors, architectural staff and, most importantly, their own in-house project financing arms. Some large builders have even become their own internet and cable television providers in addition to providing termite and pest control services.

In-house financing stands to have a tremendous impact on the residential homebuilding industry. Large lenders have historically been characterized by their aversion to what they consider the risky behavior epitomized by innovative building practices.[8] Large national builders, who finance their own projects, will no longer be subject to the lengthily underwriting criteria of conservative development financiers.

Providing in-house mortgage lending and title insurance services has not only proved lucrative for giving homebuyers a one-stop shopping experience, but has also proved financially beneficial to very large builders. The combined revenue garnered from financial services alone for the top five builders in America totaled over $929 million in 2003.[9] These builders also have large enough blocks of mortgages to sell directly into the secondary mortgage market, thereby realizing a second round of profits through lending activities. In-house lending is now a substantial component of most large production homebuilder's profit margins. Furthermore, having their own mortgage lending arms also allows these builders to internalize the benefits realized by such government programs as energy efficient mortgages, which allow qualified lenders to stretch the debt-to-income ratio of borrowers by several percentage points, thereby opening up a much broader segment of the first-time homebuyer market to builders pursuing energy efficiency in their homes.

Having internal architectural staff is also vital to some of the more process-oriented innovations on the horizon for the homebuilding industry. Experimentation with manufacturing processes requires a much stronger relationship between product designers and project manufacturers. The notion of Design for Manufacturing and Assembly (DFMA) has become widely popularized in the recent dialogue surround homebuilding innovation. During the 1960's, engineering and architectural education in the United States largely divorced itself from the process of making things as illustrated by the dropping of "shop" classes from several of America's major university programs.[10] The separation of design and engineering has subsequently haunted the homebuilding industry in their quest to adopt more innovative manufacturing processes as there is a severe disjunction between the design and manufacturing fields.

Analogous to the DFMA concept in construction is the practice of Value Engineering, in which value is added to the end product through the cutting of costs during the construction phase. The difference between DFMA and Value Engineering is the stage of development in which it occurs, with DFMA occurring in the design phase and accounting for cost reductions through both the substitution of different materials and components *and* the elimination of processes necessary to build them. Value Engineering, on the other hand occurs long after the design process has occurred and only adds value through the removal or substitutions of already designed components thereby greatly decreasing the adaptability of pre-existing product designs.[11]

The shift to DFMA in homebuilding will require two things: stronger ties between project designers and contractors/manufacturers and more industrialized construction process as illustrated by the use of component manufacturing (foundations, walls, roofs) or modularized construction. The ties between design and manufacturing are already being fostered by the large production builders through their internalizing of design and engineering services. Additionally, as these large firms have grown and developed stronger capital reserves, they are also investing heavily in the manufacturing of components in factory settings. These trends, when coupled with tremendous advances in object-oriented CAD systems[12], make large production builders ripe to pursue more DFMA practices.

Supply chain management is another trend occurring with large production homebuilders. Traditionally, subcontractors are shown project plans and specifications, and they, in turn, provide a bid to the developer for both the labor and the materials. Materials are often marked up 10-15% beyond what it costs the subcontractor to purchase them. As homebuilding firms have grown over the past decade, they've come to the realization that this premium on materials is cutting into their profits and many large builders have been making greater efforts to "un-bundle" labor and materials. This is particularly relevant to large production homebuilders who now have national purchasing power. As part of this effort, many large builders are hiring supply chain management experts from outside the building industry to streamline the overall costs of buying, installing and servicing products.[13]

Turnkey operations (those in which the subcontractor provides both the labor and the materials) are still a dominant element in many U.S. housing markets- particularly in the western U.S. where the construction industry is dominated by extremely large trade contractors who are capable of dealing with the volumes required by the production homebuilding industry. Furthermore, profit margins for homebuilders in the west are already extremely high and those builders may tend to be more focused on land and entitlements rather than managing material costs.[14] However, even with turnkey operations, large production builders are attempting to control costs by requiring what is known as "line-item pricing." Builders develop a knowledge base of exactly what a material costs by obtaining pricing information direct from the product manufacturer. Trades will often continue to purchase material, but often with the knowledge that the builder knows how much they're paying for those products and therefore are unable to raise prices on materials in order to bolster their own profits.

For the large builders, like KB homes, Centex, Pulte, Lennar and D.R. Horton, who are successfully unbundling materials and labor, several technological advances have been required. *Just-In-Time* (JIT) delivery methods, a term used to describe the delivery of materials to a construction site, suggests that materials will be brought to their location for final installation and be installed immediately upon arrival without incurring any delay due to storage in a staging area (a physical space at the construction site traditionally allocated for the delivery and storage of materials). The ultimate objective of JIT production is to supply the right materials at the right time and in the right amount at every step in the process.[15] There is no inventory or material storage. This has required production builders to become logistical experts, and many have developed complicated in-house scheduling software in order for materials and delivery times to be simultaneously managed across multiple large-scale production sites. If the material is not there when the trade is scheduled to do the work, the builder will get charged for that trade's time; thus it is vitally important to a firm's profitability for materials flows to match construction schedules.[16]

Other, more sophisticated efforts, have involved the development of third party software manufactures to create supply chain order and delivery interface software. In fact, the boldest of these efforts came in 2001 when the five largest homebuilders in America[17] partnered with Oracle and Encore Venture Partners to create a joint venture called *HomebuildersXchange*, an independent company which plans to offer the first worldwide homebuilding exchange for online commerce, collaboration and supply chain services. The goal of the program was to make the exchange a primary source for direct and indirect procurement of materials and labor for the founding partners, other homebuilders, trade contractors, distributors, wholesalers and manufacturers.[18]

These types of relationships have an incredible impact on a homebuilder's ability to implement widespread adoption of innovative or alternative materials. It is often the case that a new and better material will remain on the periphery of the homebuilding industry due to cost premiums entailed by that material manufacturers inability to achieve certain economies of scale. This has often been the case for a wide array of environmentally responsible building materials. The use of sustainably harvested wood products can be cited as an example.

The reckless use of timber products has often been cited as one of the homebuilding industry's most egregious offences in the realm of environmental impacts. The widespread use of clear-cut lumber and the environmental and social externalities generated through non-sustainable forestry practices have long been derided for the impact those practices have on wildlife habitats and watersheds in addition to creating ecosystem changes which severely hamper the natural environment's efforts to stem the rising tide of global warming. In the early nineties the notion of forest certification became recognized as a best practice to ensure the preservation of forest land while simultaneously allowing for the harvesting of timber for construction and other uses. The certification process mandates that timberland is inspected by third-party representatives who verify that sustainable practices are being pursued in that particular tract of land. After the forest itself is certified, wood harvested from that forest is tracked through "chain of custody" certificates so that the end user is sure of its origins.[19] Currently, certified wood is commanding a cost premium of anywhere from 10-20% above traditionally harvested lumber due to an extremely constrained supply.

In the mid-nineties, environmental organizations like the Natural Resources Defense Council (NRDC) and the Rainforest Action Network (RAN) waged war on homebuilding supply companies like the Home Depot & Lowes, eventually getting them to make long term commitments to the stocking of certified forest products. Having largely won their battle with building material retailers, the environmental groups then focused on large production homebuilders, who, due to their supply chain initiatives, could no longer point their finger at subcontractors and deny responsibility for lumber purchasing decisions.

The lobbying efforts have had significant effects with two of the nation's largest builders. In particular, CTX Builder Supply (the supply chain management arm of Centex, the fourth largest homebuilder in America) made a commitment to integrate a certification screening program into their supply chain's client list, giving preferential treatment to those lumberyards, distributors, and manufacturers that can prove their products are composed of wood harvested from sustainably managed forests.[20] It should also be noted that Centex went one step further and hired Price Waterhouse Cooper to conduct a forensic analysis of the homes it was building in order to find out where the wood that it purchased outside of CTX Builder Supply was coming from and found, surprisingly, that less than half of the wood was coming from non-certified sources.[21]

KB Home, the nation's fifth largest homebuilder, also bowed to the pressure from NRDC and has entered into long term contracts to purchase lumber directly from certified lumber suppliers. The ongoing effects of these large contracts will undoubtedly put pressure on large forestry companies to pursue certification of their timberland. In its 2002 Annual Report, Weyerhaeuser stated that by the end of 2003, all of its American forests would be certified under SFI and that all of its Canadian forests would be CSA certified by the end of 2004.[22] With 2/3 of American lumber being used for residential construction, it is questionable whether such large scale changes could have been accomplished without the more consolidated supply chains of the big national builders.

Code Consolidation

The fragmented nature of America's code system has regularly been cited as one of the primary barriers towards the widespread adoption of innovative practices in the homebuilding industry. Traditionally, the development of building regulations has not been mandated by the Federal Government, but rather has been handed over to the states who, in turn, have often delegated the authority to local jurisdictions. Efforts to regulate the design and construction of residential structures can be divided into two categories: *standards* and *model codes.*

Product standards tend to have more effect on building component and materials manufacturers and not housing developers in particular. Typically, when a manufacturer wants to introduce a new product or material, that manufacturer will request that a "bench standard" be set by a particular testing agency to insure that the health and life safety issues related to the product are met. That testing agency will then verify that the new product is in compliance with the set bench standard. The bench standards and testing methods must be developed under the guidelines of the American National Standards Institute and the various testing agencies include, but are not limited to:[23]

- American Society for Testing and Materials (ASTM)
- American Society of Civil Engineers (ASCE)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
- American Society of Mechanical Engineers (ASME)
- American Society of Sanitary Engineers (ASSE)

- Factory Mutual (FM)
- International Code Council (ICC)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Underwriters Laboratories (UL)

While getting new products approved can often be a lengthily and arduous process, manufacturers have traditionally dealt with a fair level of historical consistency with regards to the regulatory bodies governing product approval. The same can not be said of model building codes.

Model Building Codes are the enforceable regulatory framework by which buildings are deemed safe and habitable. Model Codes are adopted through state statutes or local government ordinance with enforcement being provided by state agencies and local governments having special jurisdiction.[24] The codes may include, among other things, reference to the aforementioned building standards as a means of meeting their goals. A primary obstacle for builders has been the fact that there have traditionally been three model codes/code organizations recognized in America: the Building Officials and Code Administrators International, Inc. (BOCA) and their *National Building Code*, the International Conference of Building Officials (ICBO) and their *Uniform Building Code*, and the Southern Building Code Congress International, Inc. (SBCCI) and their *Standard Building Code*.[25] Each model code was specific to a particular region of the U.S.; BOCA in the east, ICBO in the west and SBCCI in the south. Individual states have often developed their own regulatory framework based upon these three model codes. The regional nature of codes can be attributed to a number of factors including climate, local economy, local building practices and the heterogeneity of natural forces throughout the country (i.e. earthquakes in California and hurricanes in Florida).

The fragmentary nature of the code system has posed a particular obstacle to large homebuilders who increasingly find themselves operating in a variety of different markets across the country. It is not uncommon for a large production builder to have operations in upwards of 30 states. The problems created by the local nature of codes were finally addressed in 1994 through the creation of the International Code Council, which is a nonprofit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes. The ICC was founded by members of the aforementioned regulatory bodies (BOCA, ICBO and SBCCI) and the first edition of the *International Building Code* (IBC) was released in 2000, followed shortly thereafter by a second release in 2003. The ICC has now been adopted by 44 states, as illustrated by the map below.[26]

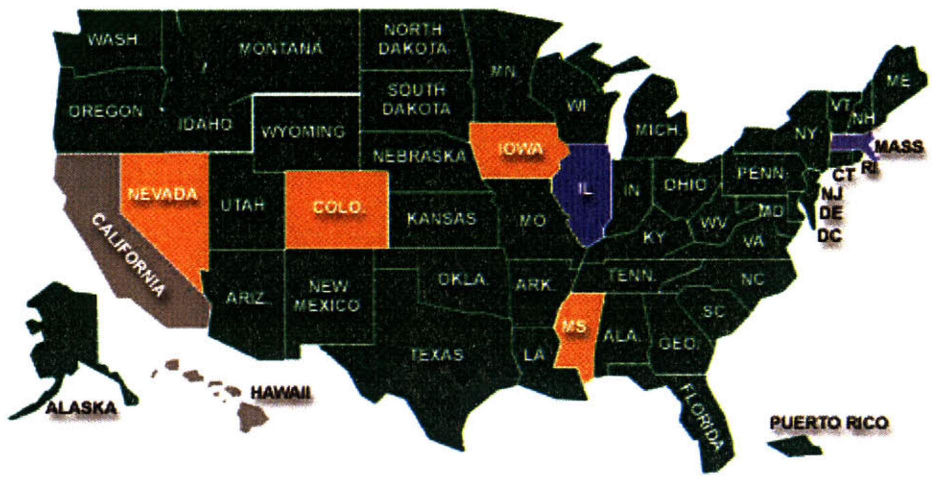


Figure 3.2: Statewide Adoptions of International Building Code (shown in green)
source: ICC website

While the ICC works with localities to encourage the adoption of the code without technical amendments, this has often not been the case- particularly in states with extremely rigid regulatory environments, like California, where the model energy code (Title 24) is the strictest in the nation. However, the importance of a single model code can not be understated and the tremendous effort that went into developing the IBC stands to have a significant affect on the long-term feasibility of large production builders being able to adopt and deploy innovative practices across multiple regions.

The Competitive Advantage & Ripeness for Innovation

Business theorist Michael Porter has argued that the changing structure of the homebuilding industry is now creating a tremendous competitive advantage for large production builders. Porter has pointed to the increasingly high barriers to entry presented by the complexity of large project developments with complicated entitlement issues and the distinct disadvantages smaller builders now have in terms of materials procurement as making it harder for newcomers to enter the industry. Large builders, while financing individual projects internally, have access to corporate bond financing to add vast tracts of land to their pipeline, while small builders only have access to bank debt, which is extremely limited in economic downturns. Porter has also argued that land and location are increasingly the differentiating factors in consumer's decision to buy, rather than the features of the house itself, and it has long been the case that the large production builders typically have access to the better parcels of land that smaller builders can not afford to buy.[27]

The paradoxical nature of increasingly strict land use regulations and "smart growth" legislation, which, through the use of such mechanisms as urban growth boundaries tend to constrict the amount of developable land in any given market, is also fostering the competitive advantage of large builders. It has been observed that growth controls in most markets play to the strengths of larger builders because of these companies' ability to control very large parcels of land for extended periods of time.[28] As Porter has pointed out, more regulation leads to less developable and therefore more costly land, higher fees and exactions and slower processes which, in turn, require a more capital intensive entitlement process- again giving large production builders an advantage in highly regulated markets.

Industry Trends and Innovation

It is also important to consider how these changes may affect the industry's willingness to adopt more innovative practices- or at least that portion of the industry defined by the mega-production builders. In Chapter 2, we categorized traits specific to the homebuilding industry which have limited the deployment and diffusion of more innovative practices. To re-cap, those traits include:

fluctuating financial markets/ costs of innovation
firm size & industry fragmentation
regulatory barriers/ code fragmentation
lack of communication & research
risk/liability
market/demand side resistance

It is important to view these barriers in light of new trends being exhibited in the industry. The first barrier, fluctuating financial markets and the costs of innovations, will, undoubtedly continue to plague the homebuilding industry. However, it is important to note the increasing capacity of large production builders to deal with this obstacle. While profits will undoubtedly ebb and flow with the cyclical movements of the economy in general, the shear size and geographic diversification of the new mega-production builders will allow them to confidently weather these changes, and when times are good, they will undoubtedly be less resistant to investing in technological innovations for fear of when the downturn will arrive.

Firm size & industry fragmentation are also increasingly a thing of the past. While it would be naïve to imply that small builders will disappear from the market, the trend is clearly towards what might be deemed a subtle blend of oligopoly and small firm competition.[29] A small group of large builders will continue to establish a national presence in the industry, targeting particular segments of the market like first-time homebuyers and retirement communities. Small firms will maintain a local or regional presence, but will focus primarily on higher end, move-up or multi-family housing. The small group of national builders, however, will continually increase their market share through buy-outs of mid-sized regional entities. The top ten builders today are all projected to grow even larger in the years ahead and some have estimated that this segment of the industry may hold as much as 40% of the single family market within ten years.[30] With this size has come the de-fragmentation of their supply chains, and their ability to leverage their size and buying power into direct purchasing from manufacturers. These large firms are also just beginning to develop the sophisticated logistical networks necessary to deliver those materials to a regionally diverse set of construction sites.

The regulatory barriers are also being overcome in that we are now seeing the beginnings of a de-fragmented building code system. The widespread adoption of the *International Building Code* has now set the stage for an increasingly predictable regulatory environment in a majority of states across the U.S. While the political, economic and environmental concerns of individual states will continue to drive them towards amending and strengthening the IBC model in areas where there are perceived deficiencies, the fact that these states will increasingly work from the same model code is a good omen for large builders who often face extensive and diverse regulatory barriers when attempting to adopt innovative practices at the national level.

Faulty communication channels are still a major problem in the homebuilding industry. While these channels are being improved upon through government programs like PATH in addition to the extensive efforts of organizations like the National Association of Homebuilders (NAHB) and the NAHB Research Center (NAHBRC), progress certainly needs to be made. The outlook for Research and Development, however, is much better. As firm size has increased, most of the large homebuilders have invested in developing extensive relationships with building science consultants such as the Building Science Corporation (BSC) and Integrated Building and Construction Solutions (IBACOS), and this trend will undoubtedly continue as the mega-production builders get even bigger. Some homebuilding companies have gone one step further by integrating research and development divisions into their own operations.

Risk and liability have traditionally had a tremendous impact on the homebuilding industry's willingness to innovate. Building or system failures can put any homebuilder in the extremely difficult position of having to conduct costly repairs or, worse yet, having to buy back the home in question. While none of the trends itemized in this chapter directly address the issue of liability, it could be argued that as homebuilders develop closer relationships with product and material manufacturers, the opportunity will arise for more extensive product and material testing through the construction of pilot projects. It has further been argued that tort reform limiting the liability of homebuilders for damages would greatly benefit the industry with regards to this issue.[31] Given our current political climate, and the seemingly bi-partisan support for such measures, they may not be far off.

The final barrier, market and demand-side resistance, can largely be addressed through the extensive training of an integrated sales and marketing staff. Consumers often approach innovations with trepidation due to their lack of knowledge of the product at hand. Large builders who have successfully sold innovative practices in the marketplace have been able to do so because their people on the ground knew and believed in what they were selling. Large builders also benefit extensively from their reputations. Whether people like them or not, most would agree that they're didn't get to where they are today by building faulty products. These builders have tremendous leverage with their reputations and most consumers would undoubtedly feel more comfortable purchasing an innovative product from an established market leader rather than a smaller local builder.

It is now becoming clear that trends in the industry are coinciding to create a dynamic in which large production homebuilders clearly have a competitive advantage over other industry participants. These trends are also increasing the likelihood that in several years, the industry may be "ripe" for a period of extensive innovation, whether through building products and materials or through more advanced manufacturing processes. In fact, with some builders it is already clear that these changes are taking affect. In the following chapter I will illustrate one builder in particular which has capitalized on these trends to pursue two very different types of innovations.

[1] Data on the nation's 100 largest homebuilders is annually collected and published by two publications: Professional Builder Magazines *Giants List* and Builder Magazine's *Builder 100.* Unless otherwise cited, all data in this section will have been taken from these sources. Both of these publications base their findings on the SEC filings of homebuilding corporations.

[2] Frey, Elaine F., *Building Industry Consolidation*, Housing Economics, August 2003, p.8.

[3] Ahluwalia, Gopal. *Concentration in Homebuilding.* Housing Economics, December 1998, p.10.

[4] Frey (2003) p.8.

[5] There are flaws in estimating the amount of growth through acquisition. The estimate is based on the number of closings by the acquired firm in the year prior to acquisition. This number is then accounted for as a percentage of the acquiring firm's closings in the following year. Statistics on the performance of acquired firms, post acquisition, are currently unavailable.

[6] Eisenberg, Elliot F. and Benshoof, Mike, *Home Building Industry Concentration*, Housing Economics, May 2002. p.11.

[7] Pulte Home Corporation, Annual Report: 2004, (Bloomfield: Pulte Home Corporation, 2004).

[8] Leinberger, Christopher C., The Need for Alternatives to the Nineteen Standard Real Estate Products, (draft article for Places Magazine taken from authors website, June 2005) 6.

[9] Mortgage origination revenue numbers taken from the 2003 Annual Reports of Centex, KB Homes, D.R. Horton, Pulte and Lennar

[10] O'Brien, Michael et al, Industrializing the Residential Construction Site (Washington D.C.: U.S. Department of Housing and Urban Development, 2000) 36.

[11] ibid

[12] Object Oriented CAD systems replace the traditional approach of two-dimensional architectural and engineering drawings with 3-d depictions of building components linked to information databases which include, among other things, structural properties and cost information.

[13] Kash, Wyatt, *Supply Line Evolution*, Big Builder Magazine, March 2004.

[14] Lurz, Bill. *Purchasing Power Plays.* Professional Builder Magazine, July 1, 2002.

[15] Tommelein, Iris D. and En Yi Li, Annie. *Just-in-Time Concrete Delivery: Mapping Alternatives for Vertical Supply Chain Integration.* Proceedings IGCL-7, July, 1999. As Tommelein & En Yi Li note in this article, JIT is a concept developed by the Japanese who created the Toyota Production System, later translated into English as the lean production system.

[16] Beck, Dave, National Vice President of Construction, Pulte Homes, personal interview, 3.03.05.

[17] At the time of the partnership, the five largest homebuilders in America included Centex, D.R. Horton, Kaufman and Broad, Lennar Corporation and Pulte, while there has been a slight shuffling of their positions within the top five, the same five builders are still present in the top five as of the writing of this thesis.

[18] Centex Investor Relations. *Five Largest Homebuilders, Oracle and Encore Venture Partners to Form Global B2B Exchange* (Centex Investor Relations Website, May 4, 2000). http://ir.centex.com/

[19] It should be noted that of the three currently operating certification programs, the Forest Stewardship Council (FSC), the Sustainable Forest Initiative (SFI) and the Canadian Standards Association (CSA), only FSC & CSA require chain of custody certificates. There is currently a large debate in the homebuilding industry that has arisen out of the rash of "green building guidelines" as to which process is most economically and environmentally suitable for homebuilders. The current LEED Residential Guidelines mandate the use of FSC certified wood whereas the NAHB Green Building Guidelines are more flexible in allowing the use of SFI certified forest products.

[20] Caulfield, John,. *Certified Dilema*, Big Builder Magazine, July 2003.

[21] ibid

[22] Weyerhaeuser Company, Weyerhaeuser Company: Annual Report, 2002 (Washington: Weyerhaeuser, 2002) 17.

[23] National Evaluation Service, Inc., Getting Building Technology Accepted, (Washington D.C.: U.S. Department of Housing and Urban Development, 2002) 11.

[24] Francis, Sam W. and Stone, Jeffrey B., *The International Building Code and Its Impact on Wood-Frame Design and Construction*, Presentation at the ASAE Annual International Meeting, July 12-16, 1998.

[25] Eisenberg, David and Yost, Peter, *Sustainability and Building Codes*, Environmental Building News, September 2001.

[26] International Code Council website: www.iccsafe.org
[27] Porter, Michael E., *The U.S. Homebuilding Industry and the Competitive Position of Large Builders*, Presentation to the Centex Investor Conference. November 18, 2003.
[28] Alexander, Barbara T., *The U.S. Homebuilding Industry: A Half Century of Building the American Dream*, John T. Dunlop Lecture, Harvard University. October 12, 2000.
[29] Scherer, F.M. and Ross, David, Industrial Market Structure and Economic Performance (Boston: Houghton Mifflin, 1990) p.660.
[30] Sichelman, Lew. *Forecast: Largest Builders Will Hold a 40% Market Share in 10 Years.* National Mortgage News, March 8, 2004.
[31] NAHB Research Center Inc., Building Better Homes at Lower Costs: The Industry Implementation Plan for Residential National Construction Goals (Washington D.C.: U.S. Department of Housing and Urban Development, 1998) 8.

Chapter 4: The Case of Pulte Homes

Thus far, I have introduced the concept of innovation and how innovative practices and technologies diffuse throughout industries. I have also reviewed an extensive body of literature on the homebuilding industry which has presented compelling arguments for why its structure has led it to be historically characterized as *change-resistant*. However, even the most recent studies on innovation in homebuilding have neglected to account for structural changes to the industry- as characterized by firm consolidation, vertical integration, supply chain management techniques, more responsible capital markets and building code consolidation- which are leading to a period in which there will be two distinct sectors of the industry: the *mega-production builders* and the rest of the industry which will continue to be characterized by smaller local and regional homebuilders.

This thesis argues that the *mega-production builders*, due to many of the trends illustrated in Chapter 3 of this thesis, are entering a period in which they will be ripe for more innovative practices; many of which will serve to lessen the vast environmental impacts which are increasingly evident in the industry. In order to test this hypothesis I have undertaken case studies of two divisions of one of America's largest homebuilders, Pulte Homes. The two divisions which I have chosen to study have both made efforts to incorporate innovative practices and technologies into their operations and in both of the case studies the innovations and technologies used have lessened the environmental impact of the homebuilding process and the homes themselves. That said, the case studies are very different in nature. As previously mentioned, the innovations in the Las Vegas Division, are extremely localized, heavily dependent on the assistance of government programs and strive to improve upon existing building practices without calling into question the fundamental manner in which homes are built. The other, the Washington D.C. Division, is a more centralized effort being propagated by Pulte's national headquarters and has led to systemic changes to traditional homebuilding practices by utilizing more industrialized technologies to build the shell of a home in a factory setting.

The case studies illustrate the feasibility and potential for both the incremental and moderate technologies utilized by the Las Vegas division and the more radical innovations utilized in the Washington D.C. division in addition to gauging the efficacy of government and private sector programs which were largely the impetus for the changes instituted in Las Vegas. Both case studies relied on personal interviews with representatives from Pulte Homes, Pulte subcontractors, regulatory officials and representatives of government programs promoting innovative practices in homebuilding. Additionally, both studies have relied heavily on trade publications and technical studies which have been written on the homes in both divisions. Furthermore, a site visit was made to the Washington D.C. division, though I was unable to travel cross country to view the Las Vegas division's operations. Before looking at the cases, it is important to provide some background on the company itself.

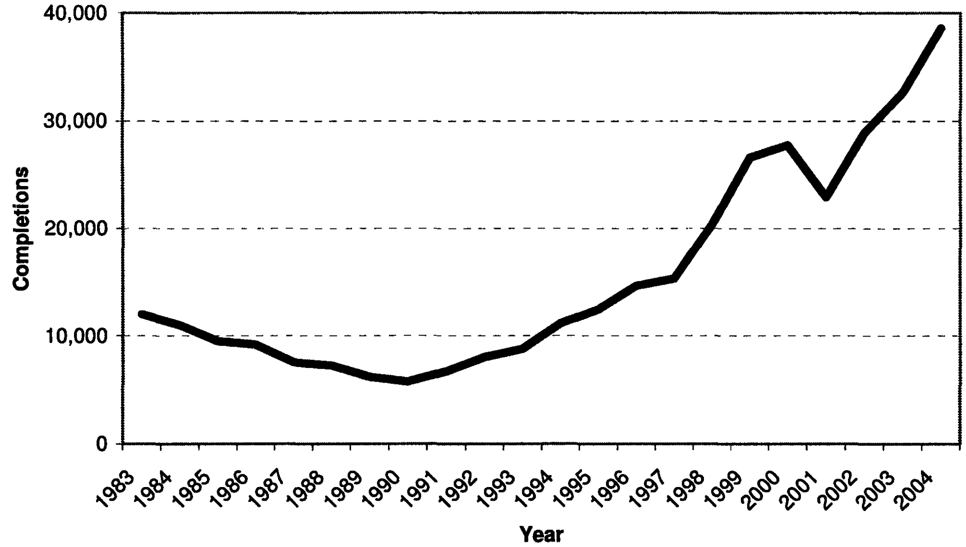
Pulte Homes: Background

William Pulte built his first home in the summer of 1950. The home was a five-room bungalow in Detroit, Michigan and served as the forerunner to Pulte Homes, a corporation that would grow to become one of the largest homebuilders in America. To date, Pulte has built close to 400,000 homes in the 27 states in which the company currently operates.

As with most large homebuilders, Pulte's growth spurt has occurred primarily over the past twenty years. In terms of completions, Pulte has ranked in the top three builders for 16 of the past 20 years. The company's growth in home completions is illustrated in Figure 4.1. Pulte's growth in revenue has also skyrocketed as illustrated in Figure 4.2. Similar to other large builders, Pulte's growth over recent years has stemmed not only from internal expansion, but also from acquisitions.

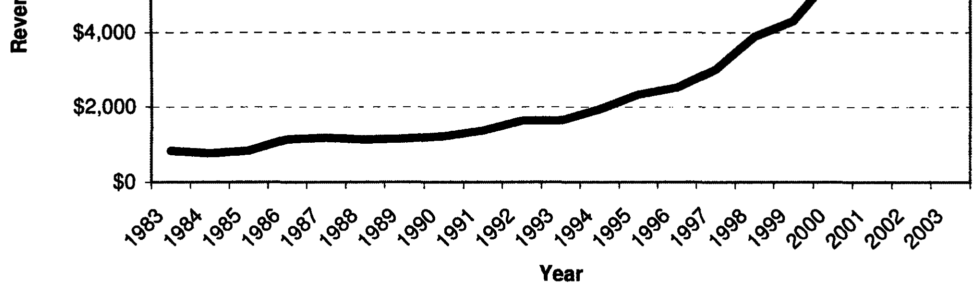
In 1998, Pulte acquired DiVosta homes, a regional builder in Florida. The acquisition stemmed, not from Pulte's desire to enter the Florida market, as Pulte was already operating throughout Florida, but in order to adopt the small builder's savvy methods of construction and vertical integration, as will be discussed below. Another large acquisition occurred in 2001, when Pulte bought Del Webb Homes, a national builder who completed over 8,000 homes in the year prior to their acquisition. The Del Webb merger is interesting in that it, too, was not an effort to enter new markets but rather an attempt to enter into the "active adult" market segment. Pulte and Webb were often competing in the same market, but taking on very different segments and Pulte identified the baby boom generation as being primary homebuyers in the decades ahead and strongly desired Webb's expertise in this particular market.

Figure 4.1: Pulte Home Completions: 1983-2004



Source: Builder Magazine, Builder 100 rankings 1983-2004

Figure 4.2: Pulte Revenue: 1983-2004



Source: Builder Magazine, Builder 100 rankings 1983-2004

At the end of 2003, Pulte posted over $9 billion in revenues and $624 million dollars in income. Additionally, they closed the year with 257,000 lots in their pipeline, 47% of which were owned outright and 53% of which were optioned or pending.[1] These statistics would imply that Pulte has both the land and the money to continue its dominant presence in the U.S. Homebuilding Industry.[2]

Pulte operates largely as a conglomeration of 40 decentralized profit centers, each of which has traditionally functioned with relative autonomy in regards to Pulte's corporate headquarters, still located in Detroit. The individual divisions are largely responsible for land selection, project design and development; while the corporate headquarters serves as a project financing arm either with its own money or through extensive lines of credit established with international banking organizations like Credit Suisse. That said, Pulte's corporate headquarters is playing a more crucial role in product development as the company continues to grow.

As the industry has evolved over the past decade, Pulte, too, is in the early stages of large scale structural changes. Pulte has ambitiously projected that its growth will continue at the rate exhibited over the past ten years by doubling its output by the end of 2006. In order to do so, the company is pursuing a variety of strategic maneuvers in an effort to capitalize on its size, geographic diversity and wealth. One of these changes includes the creation of a centralized supply chain management arm of the company. In order to consolidate their purchasing power, Pulte recently hired the general manager of Wal-Mart's distribution center to streamline the purchasing process across a variety of different markets. Integral to this effort will be the simplification of Pulte's plans and specifications. By the end of 2004, Pulte had trimmed its standardized house plans down to 2000, with an eye to reduce it all the way down to 1,000 by the end of 2005.[3]

To further the effort towards vertical integration, Pulte has developed three distinct models across the country, two of which stem from buyouts of existing homebuilders and subcontractors- the Pratte and DiVosta models; the third of which is an internally driven effort at a factory based approach to homebuilding- the Pulte Home Science Model.

The DiVosta Model

In 1998 Pulte bought DiVosta Homes, a regional homebuilder in Florida. DiVosta was unique primarily for the extent to which the small Florida Builder had vertically integrated its building processes and trimmed extensive time off of its construction cycles through the use of its assembly line approach to on-site construction. DiVosta has their own manufacturing and assembly processes for such things as kitchen cabinets, plumbing, electrical and HVAC systems.[4] Integral to the process is the adoption of a system of re-usable concrete forms which can be rapidly moved from one site to the next. Furthermore, most of the trades working on a DiVosta site are employees of DiVosta Homes, as opposed to subcontractors, which greatly reduces the likelihood of communication breakdowns between horizontally fragmented trades. The DiVosta model trims its construction cycle (the amount of time required to build a single house) to 55 days- twenty days faster than Pulte's own cycle time.[5] Recently, Pulte has attempted to export the DiVosta model to the Southern California market, and it is unclear at this point as to the success of that diffusion. Problems thus far have stemmed from the fact that the DiVosta model is largely dependent on concrete construction as opposed to the Southern California homes which are mostly wood framed; thus the time savings exhibited in Florida have not been realized in the Los Angeles market. Furthermore, the DiVosta model was entirely dependent on the vertical integration of the various trades involved in building a home; in the west, given the size of the trades, this proved much more difficult to do and thus Pulte attempted to operate the system with a fragmented trade base which often switched from job to job.

The Pratte Model

In early 2004, Pulte entered into a joint partnership with the Phoenix-based Pratte Construction Company in order to create Pratte Building Systems. The Pratte model is essentially the buy-out of an extremely large subcontractor in an effort to bring certain construction services into the Pulte suite of activities. The buy-out was initially the idea of Ron Pratte who had a vision of decreasing homebuilder costs by utilizing a single subcontractor to deliver the full shell of the building.[6] The joint venture cost Pulte an estimated $42 million and will provide for framing, plumbing, foundation and trim services in their Arizona and Nevada markets.[7] The markets of the western United States- Arizona, Nevada and California in particular- have posed tremendous problems to large builder's aspirations of vertical integration. This is because these markets are characterized by extremely large trades whose own profitability and purchasing power will often match the homebuilding companies they work for. This has made it difficult for builders to successfully uncouple labor and materials in what is a very hot market- Phoenix and Las Vegas, alone, will account for close to 25% of Pulte's closings in 2004.

In a sense, the Pratte model can be viewed as a regional variation on the DiVosta model, but is, as of yet, not as extensive as the Florida builder's approach. It is, however, expected to reduce the cycle times, lower costs, strengthen manufacturer direct-purchasing and provide for greater regional operating leverage in many of Pulte's key western markets.

Pulte Home Sciences

In the early 90's Pulte began experimenting with manufacturing processes in Detroit, Michigan by constructing a pilot facility to prefabricate foundations in a controlled environment. Other experimentations included floor and wall systems and by 2000, Pulte was ready to export the factory approach into the Washington D.C. market with the construction of a full-fledged manufacturing facility in Manassas, VA. The plant opened up in 2002 and has since produced several hundred homes, expecting to top 400 this year alone. At full capacity, it is expected to produce over 1,000 homes a year. The system entails converting raw materials into foundation, floor and wall assemblies which are trucked to and assembled on site. Eventually, the facility will be handed over to the Washington D.C. operating division and the PHS manufacturing group will focus on building a new plant in a another market.

The PHS system represents a substantial deviation from traditional home construction in that it utilizes SIP wall panels and prefabricated foundations. Furthermore, it has required Pulte to invest heavily in research and development in an industry that has traditionally exhibited an adversity to such large scale investments. The PHS system will be discussed in more detail later in this chapter.

If the homebuilding industry is to be considered as a complex social system, each of the above three models reflect a different approach to the manner in which the participants in that system interact. The extent to which the environmental benefits of a particular innovation can be realized will be largely dependent on the extent to which each of the participants in the system can benefit from that innovation. The following case studies will attempt to dissect two very different approaches to innovation currently being pursued by Pulte Homes in an effort to understand the complexities of such systems.

Earlier in this paper, I introduced the chain-linked model of innovation, and I will include it here again for reference as it is an important process to keep in mind when considering both of these case studies. The components of this model provide us with a framework from which to consider the case studies at hand.

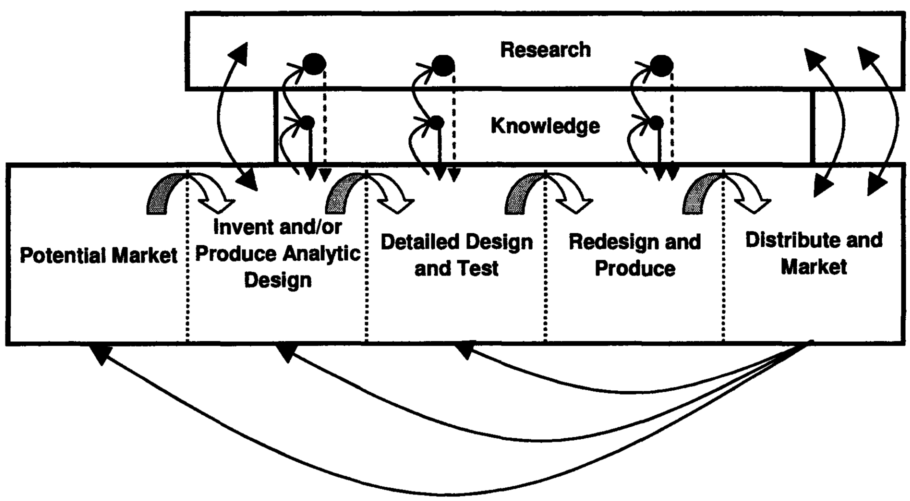


Figure 4.3: The Chain Linked Model of Innovation

Las Vegas: The Building America Partnership

Potential Market

As home prices and property taxes continued to rise in states like California, more affordable markets like Arizona and Nevada became incredibly attractive to homebuyers and homebuilders alike. It is interesting to note that in 1992, none of the nationally ranked builders was operating in Las Vegas, but by the end of 2002 six of them were and they had acquired a 36% share of the market.[8] Pulte entered the Las Vegas market in 1993 and has since become a major market player, holding 8.5% of the entire Las Vegas single family detached market in 2002. This year, Pulte expects to complete approximately 3500 homes in Las Vegas and holds an estimated 8000 lots in their "pipeline" for the next two years.[9]

While Pulte was gaining market share in Las Vegas, the federal government was strategizing on how to improve the energy efficiency of the average American Home. In the early 90's, George James, who at that time was heading up the Industrialized Housing Program at the Department of Energy, met Mike Dickens from G.E. Plastics to discuss problems encountered during a recent G.E. effort to build an all plastic house in Pittsfield, Massachusetts. The two concluded that homebuilding lacked the systems engineering approach which characterized both the aerospace and automotive industries and as a result, the DOE provided a small grant to ABICOS (General Electric's housing products unit) to investigate integrating a systems engineering approach into residential construction.[10] The pilot program proved successful and in 1994 a full RFP was issued and the Building America Program officially came into being with four teams working across the country, one of which was the Building Science Corporation in Westford, Massachusetts.[11]

The Building Science Corporation is a building research consulting firm which specializes in resolving problems related to building design, construction and operation.[12] As experts in building system failures, the firm is often called upon to provide testimony and consultation in cases relating to large scale residential building failures. The past two decades have provided several such instances in which their expertise has been relied upon by large production homebuilding corporations, the most prominent of which were the failures of fire-retardant plywood and Exterior Insulation and Finish Systems (EIFS).[13] Such systems failures, combined with consistent warranty and callback issues resulting from quality control problems, were undoubtedly the genesis of BSC's relationship with Pulte Homes.[14] In recent years, however, the firm has devoted increasingly more of their time to researching energy efficient technologies in residential construction and their expertise in the field is undoubtedly what won them the Building America contract. With contract in hand, it was now up to BSC to find industry partners with whom to test their ideas.

One of the regions in which BSC was anxious to work was the hot and dry climates of the desert southwest. Knowing that Pulte was establishing market share in the area, BSC sought Dave Beck, then the Vice President of Construction for Pulte's Las Vegas Division at the time and asked him to participate in the program. After consulting with management, sales, marketing, land development and the division president, Dave got approval to work with BSC in the partnership.[15]

Pulte's reaction to the BSC offer was neither sudden nor entirely energetic. There are several reasons for why this may be the case. First, Pulte is essentially a large private sector bureaucracy and while the Las Vegas Division had a local "champion" for the project, in the form of Dave Beck, making a contractual obligation with a quasi-governmental third party which essentially ceded design control over certain building systems was not taken lightly. Second, the program did not provide very strong incentives from the builder's point of view. It involved taking large risks, spending a portion of their own money to do so, not necessarily getting all of the credit for their successes and if the systems failed or became problematic the responsibility would largely fall with the builder. The prospects of such a partnership may not have seemed lucrative to a corporation which already devotes a large portion of its time fending off lawsuits from disgruntled costumers.

So why would Pulte pursue such a partnership? One reason may lie in an extensive costumer survey conducted by the company in their Tucson, Arizona Division (a division which can be considered climatically and demographically similar to the Las Vegas Division). The survey illustrated that 55% of those questioned said that energy efficiency ranked as a "very important" factor in deciding to purchase a Pulte Home. The survey also found that approximately 67% of homebuyers were willing to spend $1,200-$1,500 more on a home with added energy efficiency features; albeit with the caveat that those features would provide $300 in yearly savings over the life of the home.[16] Consumer surveys, however, can often yield inconclusive evidence. It has been shown that when homebuyer survey questions are left open-ended and consumers are left to fill in their own responses, rarely do those responses include energy efficiency as a priority. However, when energy efficiency is included as an option for survey respondents to check, it consistently ranks as a top priority implying that when consumers are presented with the option in a survey, they may be "guilted" into the politically correct response.[17]

The answer may also lie in the fact that Pulte, along with most large production builders in the southwest, was experiencing fairly high callback rates. Researches from the University of Central Florida recently conducted one of the first statistically valid studies of new home quality in the U.S. by conducting a random survey of over 400 homes completed in central Florida in 2001. The survey indicated that 95% of the homes had "priority" defects, meaning that the lapses in quality were resulting in potential health, structural, operational and safety risks.[18] Researches summarized that defects were stemming from the rapid cycle times of production homes and the resultant pressure on unskilled, immigrant labor forces that were unable to work at such speeds without sacrificing quality.[19] While the study was conducted in Florida, the research team felt comfortable generalizing the results to the entire production homebuilding industry, and undoubtedly, with the amount of homes being built in Las Vegas, Pulte was feeling the effects of such issues. Serious quality control issues were causing the behemoth builder to reassess its approach to construction, and as previously pointed out, were the catalyst for Pulte's relationship with building science experts to begin with. The affects of these quality control issues were made manifest in several forms.

For one, Pulte had to undertake costly repairs and in some cases buy back homes from disgruntled costumers.[20] Secondly, insurance premiums were exploding and many homebuilding insurers were bailing out of the Las Vegas market altogether. Large national insurers like the Hartford Group and AIG have refused to insure Las Vegas homebuilders as a result of hefty construction defect lawsuits in that particular market.[21] The claims were affecting both the good and the bad subcontractors in the industry. Subs without a defect record were facing premium increases of 30-60% while those with previous claims could expect increases in the 200-300% range, with some subs seeing increases as high as 450%.[22] As these increases would eventually be passed onto the consumer in a fiercely competitive market, Pulte undoubtedly viewed the Building America partnership as a means of not only improving energy efficiency but utilizing the "systems approach" of the program to reign in quality control issues throughout the division. Ed Pollock, of the Building America Program, has acknowledged the fact that energy efficiency isn't a big market driver and that a lot of times, the thing that hooks the builders is the ability to deal with other quality control issues peripheral to energy efficiency, like mold or moisture control.[23]

In essence, we can consider the partnership evolving out of two "potential markets." First, the Building America Program was seeking a market for their research. Building America needed builders, not consumers. While the stated goal of the Building America Program is to work with the production homebuilding industry, it is not clearly stated what size production builder they hoped to work with. Clearly, a builder the size of Pulte and the potential impact of integrating more efficient construction practices into Pulte's operations would be a feather in the cap of any team and BSC was undoubtedly anxious to get them on board. Secondly, there is the consumer market in Las Vegas which is of direct concern to Pulte. While it can not be concluded that the demand for energy efficiency, as exhibited in market research studies conducted by Pulte, was the overwhelming impetus behind the corporation's willingness to participate in the program, the bundle of services which came along with the partnership, including a more careful approach to quality control through partnership field inspections and the ability to reduce call-back and warranty issues were undoubtedly key motivators for Pulte in partnering with BSC.

Inventing and/or Producing an Analytic Design

The nature of the contract between Pulte and BSC was essentially a 50/50 partnership in which BSC would conduct the design, testing and post construction monitoring on the finished projects in addition to providing technical support during construction to trades and code officials while Pulte would cover the bricks and mortar costs of developing the prototype projects along with a commitment to implement feasible changes at the community level (full development) on an ensuing project. Once BSC had a signed contract from Pulte they began the design of the prototype systems for the hot/dry climate zones in which they would be working.

The key concept behind the changes BSC wished to make to the Pulte houses in Las Vegas was the use of an un-vented attic space. BSC believed that the traditional Pulte approach (common with all production homebuilders) of placing the insulation on top of the ceiling rafters and then placing the duct work in the un-conditioned attic space, made the cooling and heating systems in the house work harder than they needed to. In the winter the vented attic would be cool and in the summer the attic would be hot, thus the un-sealed, un-insulated duct work would be absorbing the ambient temperatures of the attic space and working harder to perform heating and cooling functions, in turn using more energy. BSC's idea was to create an un-vented attic space in which the insulation was placed tightly against the sloped portion of the roof, thus making a conditioned space out of the attic.

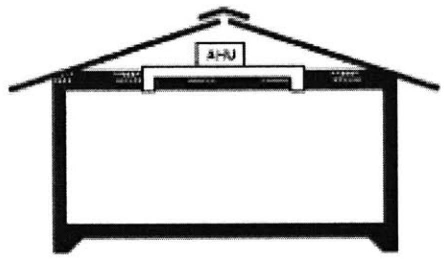


Figure 4.4: Standard House (source: Building Science Corporation)
Fully Ventilated Attic, leaky ductwork, space conditioning in vented attic, barrier at ceiling[24]

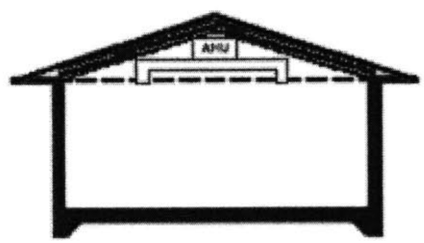


Figure 4.5: Test House (source: Building Science Corporation)
Non-ventilated attic, insulation tight to underside of roof deck, leaky ductwork, space conditioning inside conditioned attic space[25]

Prior to construction of the prototypes, BSC conducted computer simulations of different construction methods to test their theory that un-vented attic spaces would provide for better home energy performance.[26] The analyses were conducted using software packages developed by the Florida Solar Energy Center, a research arm of the University of Central Florida. The software, FSEC 3.0, is a general building simulation program, which provides detailed simulation of a whole building system, including energy, moisture, multi-zone airflows, air distribution systems and cooling and heating equipment simultaneously.[27] The software was far more sophisticated than current energy modeling packages available at the time.

Other proposed design changes included the utilization of advanced framing techniques, downsized HVAC systems (historically HVAC (heating, ventilation air conditioning) systems are over-sized in the production homebuilding industry), Low-E glazing on the windows, integrated hydronic floor and hot water systems and whole house ventilation systems to keep air circulating in what was going to be a very tight building envelope. These systems will be elaborated on throughout the case study.

Detailed Design and Testing

The computer modeling proved out BSC's theory on attic ventilation and it was decided that three houses would be built in Pulte's Angel Park subdivision in Las Vegas, Nevada. Two of the houses would be constructed using BSC's energy efficient measures, while one would be treated as a "control house," built using Pulte's traditional methods of construction.

There were, however, a variety of problems which had to be dealt with prior to construction. First and foremost was that the new roof system ran against the grain of existing building codes. At the time, Las Vegas was working with the 1993 version of the Model Energy Code which mandated the ventilation of attic spaces. The ventilation requirement is based on two commonly held beliefs. First, that attic space will over-heat due to the solar gain on the roof surface and break down roofing materials prematurely, possibly leading to moisture damage in the roof structure; the intent of the ventilation is to lower the surface temperature of the roofing material.[28] Second, the requirement is imposed so that the home's cooling loads, generated by the solar gain on the roof can be lowered.[29]

In order for Pulte to get permission to build the test house, BSC had to convince the building code officials from the City of Las Vegas to allow Pulte to construct the pilot houses. This involved BSC flying to Las Vegas to make presentations to the building department about how their studies were indicating the system would perform and how they planned to achieve the un-vented roofs in the field so that they could get a code variance in order to build the houses. It also involved bringing inspectors out to the field and showing them exactly how the system was being constructed.[30] Once the regulatory hurdle was passed, it was essentially a matter of constructing a "one-off" house prototype and monitoring its performance.

The major obstacle to the construction of the houses was the code variance. There were, however, other minor changes which were required to make the homes more efficient and achieve cost feasibility. The un-vented roof had improved the efficiency of the house to a point where the tonnage of the air conditioning unit could be decreased which resulted in a substantial cost savings. These cost savings, however, were consumed by the framing changes necessitated by the new roof system. Furthermore, the window systems were switched to include low-E glazing, which essentially allows the window to transfer natural light while stopping the transmittance of heat into the structure. The system also involved switching from a forced air to a hydronic heating system, which runs heated water from the domestic hot water heater through fan coils in the ventilation system to heat the home, thereby eliminating the need for a furnace. Finally, the fact that the house was built with a much tighter envelope posed indoor air quality issues and the houses had to be outfitted with controlled fresh air ventilation systems.[31]

All of the technologies being used in the initial prototype house involved what has been defined as *sustaining* technologies. All of the products used already existed in the market place, though they had yet to achieve widespread acceptance. For instance, it was not standard practice for production builders to use the higher end glazing systems on their windows and a shift of this nature disrupted the supply chain relationships between Pulte and their window supplier, Summit Windows.

The trades who were most affected by the changes were the HVAC, framing, and insulation subcontractors, all of whom had to change the way they traditionally worked on a production home. The framers were now being asked to pursue advanced framing methods in addition to accommodating the more sophisticated insulation system in the roof deck which required the placement of draft stops within the framing to prevent air from circulating through what was suppose to be an encapsulated roof plane. Advanced framing methods have been present in the building industry for decades. The system has undergone structural testing and has gained code approval nationwide, though the framing method has failed to gain widespread acceptance until recently, and still commands very little of the stick-built market. The concept behind advanced framing techniques is to increase the stud spacing on a stick built house from 16" to 24" centers, use a single top plate and a variety of other structural details which, when combined, can decrease the amount of wood used to frame a house by approximately 30%. Advanced framing techniques are illustrated in Figure 4.6. The method has the added benefit of increasing the amount of insulation in a wall and decreasing the number of "thermal bridges" between the interior and exterior faces of the wall. The framing, however, must be carefully constructed. Ceiling and roof rafters must align perfectly with wall studs (thus, the system is often referred to as "in-line" framing). Other details require more care- using two studs in each of the corners, as opposed to three or four, requires the use of drywall clips to hold the interior finish systems in place. While the changes aren't rocket science, they require more thoughtful framing, which often puts the technique at odds with the lightening quick schedules of production home framers.

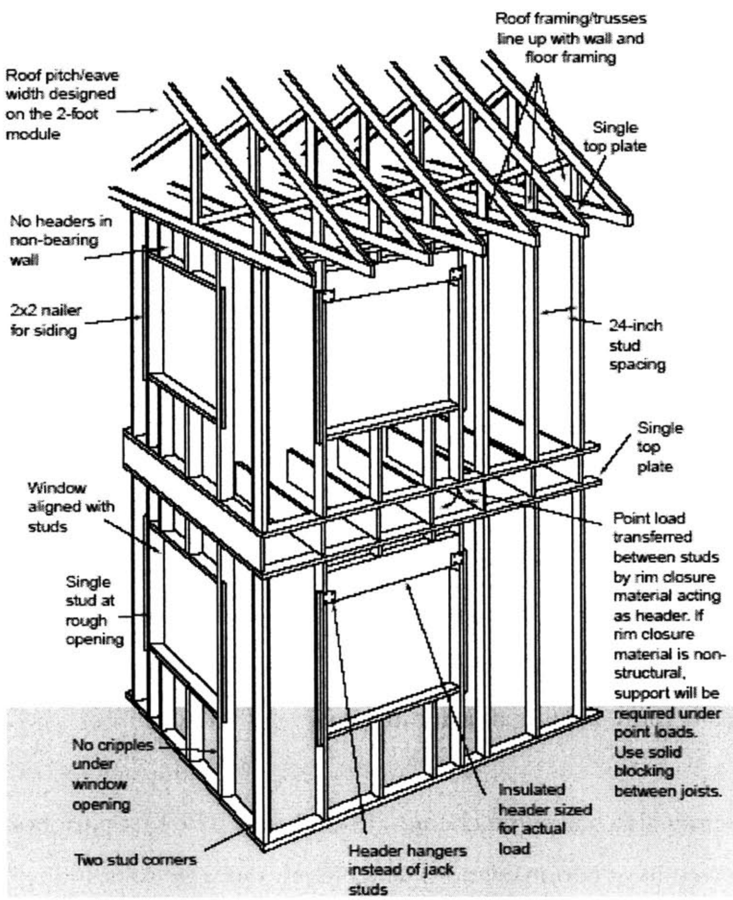


Figure 4.6: Advanced Framing Diagram
(Source: U.S. Department of Energy)

The major change for the HVAC contractors involved the use of whole house ventilation systems. Now that BSC had designed a much tighter building envelope, the amount of fresh air circulating through the structure was greatly decreased and a new mechanical system had to be introduced to increase the air flow. Additionally, the HVAC contractor was now responsible for reducing the "tonnage" of the air conditioning unit. Reducing the size of the ac unit posed market obstacles to Pulte. Sam Rashkin of the Environmental Protection Agency's Energy Star Program has equated the air conditioner to a large eraser used to delete the mistakes of builders. The bigger the eraser, the more mistakes have been made in the house.[32] Large production builders typically oversize air conditioning units in hot climates because they are unsure of the thermal efficiency of their building envelopes, thus consumers have come to expect tremendously over-sized units. Pulte's initial concern was that introducing smaller units into the market would be met with consumer trepidation. To a large extent, the HVAC subcontractor, Sierra Air Conditioning, shared this concern as they would be the party responsible for handling any of the call-back issues.[33] A final important change for the HVAC subcontractor was to properly seal all of the ductwork. BSC identified the joints where two pieces of ductwork come together as extremely leaky in most homes, thus conditioned air was being blown into the space that contained the ducts instead of the home's rooms. It was discovered that by placing mastic on all of the duct joints, air leakage could be reduced by 10%-15% throughout the system, thus saving substantial amounts of energy.

Furthermore, the coordination between the plumbing and HVAC contractors required to integrate the hot water and hydronic heating systems proved very difficult.[34] Traditional system designs allowed subcontractors to behave somewhat autonomously at the site, each performing their desired tasks. A system such as this required careful coordination between two trades who did not traditionally work together, particularly on a large production building job which is more akin to an assembly line.

Insulation contractors also had some changes to deal with. The first pilot houses were built using what is referred to as batt insulation, which comes in large rolls and is manually installed in the cavities between framing members. Moving this insulation into the roof deck meant that the installers had to devise a method of attachment which would hold the insulation in the sloped plane of the roof. The tolerances for the installation had to be zero, as any air space left between the insulation and the roof sheathing could become a condensation point which could spread mold throughout the roof structure. Early experiments involved using metal wire to hold the insulation in the rafter spaces which proved to be incredibly time consuming for insulation installers.[35] A better product was required which could more easily facilitate the installation process, and it came in the form of sprayed cellulose insulation, which though widely used in the building industry had yet to penetrate production builders because of the increased cost of both the raw material and installation process.[36]

Once the houses were built, BSC conducted extensive testing on the pilot and base case homes. Temperature sensors were installed throughout the houses (both interior and exterior), air conditioner energy use was measured and air leakage tests were performed. The initial testing indicated that heating loads were being reduced by 50%, cooling loads were reduced by 25% and gas bills would decrease by 30%.[37] Furthermore, BSC found that by sealing up the attic, they had reduced the duct leakage by 41% which accounted for a 10% reduction in energy used for space conditioning.[38] Finally, the temperature sensors which had been placed in the insulation, roof sheathing and roof tiles indicated that the temperature increases resulting from the un-vented system where minimal.[39] Based on the testing, the decision was made to go ahead with a full scale development.

Redesign and Production

With the success of the Angel Park Homes now firmly established, Pulte decided to carry the partnership forward and implement the changes at the community level on the Cypress Pointe Project, a 116 home subdivision also located in Las Vegas. Given the success of the Angel Park projects, there were very few changes between the two houses built there and the full scale developments at Cypress Pointe. The transition is worth noting, however, because problems which were identified in the Angel Park subdivision became somewhat exacerbated in the Cypress Pointe Project.

Given that the Cypress Pointe houses would be a full-blown production operation as opposed to prototype houses, issues of cost became incredibly important to Pulte. It would appear as if their faith in their own marketing data was less than strong, given that they were reluctant to pass increased costs onto their consumers. Dave Beck estimated that the original houses were costing $1500 more to construct- most likely due to subcontractors getting over the learning curve involved with the new structures.[40] Pulte felt that they couldn't pass these added costs onto consumers, despite the fact that their own consumer survey indicated that they could.

Around this time, Greenstone Industries, a cellulose insulation manufacturer, developed a program in conjunction with BSC called Engineered for Life (EFL- See Appendix #1 for program documentation). Cellulose insulation is a loose filled insulation product, which as previously mentioned, is blown into cavities between studs and provides far superior insulation quality to batt products mainly because of its inherently better installation process which tends to not leave air gaps in the wall system. While cellulose insulation was gaining market share, it had yet to penetrate the production homebuilding industry and Greenstone devised a way to assist production builders in the transition. The concept, developed by Rick Davenport and Brad Townsend at Greenstone (a Louisiana-Pacific Company with whom Pulte would later develop a major supply chain contract for engineered lumber) was to provide a manufacturer guarantee on energy bills. The EFL program essentially stated that if the house was built properly (i.e.- if the house was built to the Building America standards developed by BSC) Greenstone would guarantee the homes energy bills to be below a certain limit. Integral to the guarantee was that the builders use cellulose insulation.

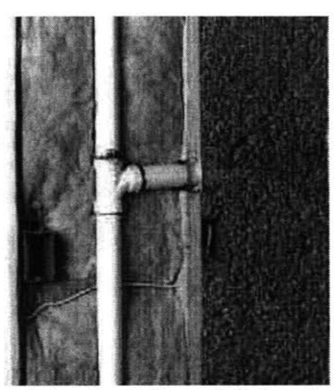


Figure 4.7: Batt Insulation (on left) vs. Cellulose Insulation (on rights)

The EFL program defined three tiers of energy efficiency- silver, gold and platinum.[41] Each level mandates increasingly strict energy efficiency techniques, and if gold or platinum is achieved, Greenstone would make the energy bill guarantee for two years. Some have argued that the notion of having three different rating levels within one program poses the danger of becoming "disinformation" to the consumer- whose attention span for an energy efficiency sales pitch will typically last all of 5 minutes before moving onto countertops and sprinkler systems. The danger lies in a platinum builder implying that anything below that level is inefficient and, conversely, a silver-rated builder implying that there are no added benefits to paying for the higher levels of certification. The average consumer doesn't have the technical savvy to be able to differentiate between the systems, thus the danger of "disinformation."[42] That said, the energy guarantees provided a strong incentive for Pulte Homebuyers. It should also be mentioned that the benchmark for achieving the gold level of certification entails the house meeting Energy Star requirements, which brings us to a third partnership utilized in the Pulte Projects.

Figure 4.8: Pulte Promotional Billboard

Energy Star, an EPA program originally developed to label energy efficient personal computers, evolved to label home appliances like dishwashers, toasters and refrigerators and eventually, in 1995, began labeling whole houses. Unlike the DOE's Building America, which is considered a Research and Development program, Energy Star is a labeling and marketing tool used by third party certifiers to sell a home as "energy efficient." The guidelines for meeting Energy Star typically mean exceeding the Model Energy Code or the International Energy Code by 15%-28% depending on which climate zone you're in. If the state energy code is stricter, the percentage increase will be applied to the state code. The use of the energy star label can often be an important sales attribute for homebuilders attempting to differentiate themselves from the rest of the pack.

The Las Vegas market latched onto Energy Star fairly aggressively through a well organized group of local stakeholders that included builders, raters, local homes guides, publishers, manufacturers and utilities known as the Las Vegas Breakfast Club. The group would meet periodically (presumably over breakfast) to discuss methods for promoting Energy Star ratings in the local market. The Las Vegas Breakfast Club is regarded by the EPA as a model local Energy Star organization who's championing of the program was a key element to the local success. While Pulte was a member of this group, they did not assume a leadership role in the program.[43]

The energy bill guarantee provided a strong incentive for Pulte to shift to cellulose insulation, which in turn made the un-vented attic spaces much easier to construct. It is also an interesting case of multiple parties working together and sharing information to achieve their goals. Greenstone's EFL program depended on Building America's energy modeling and pilot home testing in order to calibrate their financial guarantees. Furthermore, they relied on the Energy Star program in order to set their threshold benchmarks and, finally, they depended on Pulte to purchase and install their product. The program also proved beneficial to Pulte in terms of reigning in their quality control issues, as it required on-site inspection of building systems to ensure each component was properly installed in order to maximize energy efficiency. While the program largely proved a success for everyone involved, other obstacles still remained.

Despite their success in getting the pilot homes approved by code officials, Pulte still encountered regulatory resistance for the un-vented roofs at the Cypress Pointe subdivision. The code approval process required yet another round of seminars and training sessions led by BSC in order to obtain the necessary code variances to install the new system. It is interesting to note that, to this day, the interpretation of the International Energy Code in Las Vegas still requires attic ventilation in spite of the fact that the un-vented system has been widely adopted with proven efficiency results.[44] While the variance procedures have become much easier, a new code has yet to be adopted in spite of eight years of proven success. In 2004, BSC submitted a code change addendum to the International Electricity Conservation Code (IECC, the code now adopted by the City of Las Vegas) and it is expected to take affect in 2006.

Furthermore, the shift to an entire subdivision required more than just one or two subcontracting crews to learn and understand the new building techniques. While framers appear to have been open to the draft stops and un-vented roofs, which they viewed as substantially improving the building envelope, the advanced framing techniques were proving difficult to enforce in the field. This appears to have stemmed from the notion that the framing crews believed that Pulte was just attempting to cut costs by using less wood and that the Pulte supervisors in the field didn't have enough practical experience when it came to building houses. In the words of one framer, "There was no common sense in it, they weren't construction people. Pulte was going to BYU and hiring construction guys fresh out of college, but they didn't have the experience that said 'Sure, you can put one stud on each side of the door, but Ms. Jones isn't going to be happy at the end of the day because the whole front of her house is gonna' shake when she slams her front door.'"[45] The perception appears to have been that the advanced framing techniques needed to be more flexible and less driven by the need to get more wood out of the house.

The framer had a legitimate concern as callback issues related to the framing were entirely his/her responsibility. It is an instance when fear of liability was driving the decision making process in the field for lack of information or structural verification with regards to the plan being built. "We were structured as a cost deal," meaning that Pulte was paying for materials and the framer was providing labor, "it wasn't worth it to me to save them twenty bucks if it was gonna' cost me ten grand down the line."

For years, Building Scientists and engineers have been pointing to the fact that the drawing of a wall framing plan would alleviate much of the bickering about advanced framing techniques. In architectural documents, it is common for a set of plans to include a floor framing plan and a roof framing plan, but hardly ever does a set of drawings include a wall framing plan- a visual representations as to how the studs in a wall are to be placed. The wall framing plan would allow for conflicts between engineering and architectural design to be resolved prior to construction, rather than for people in the field to be arguing about which stud needs to be where. Additionally, the plan would relieve the framers of liability concerns- they would have a plan to point to in case there was ever any problems.

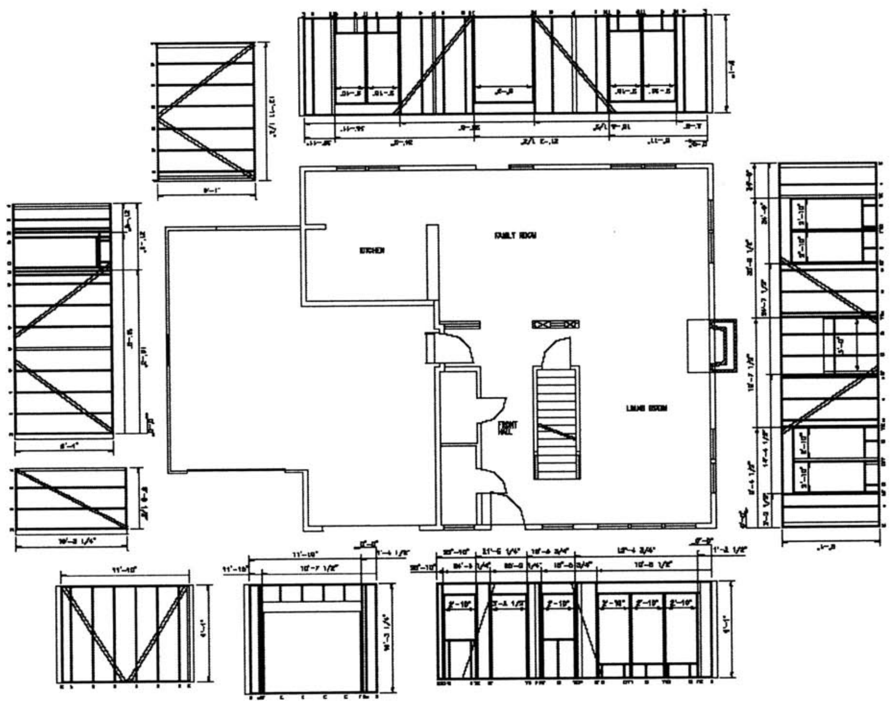


Figure 4.9: Wall Framing Plan (source: Building Science Corporation)

Beyond the framing crews, BSC was encountering difficulty in convincing Pulte's structural engineers to go along with the new framing techniques. Pulte handles engineering on a project by project basis and conducts business with a multitude of different engineering firms.[46] As for the long-term diffusion of the new practices within Pulte, having internal engineers would have helped greatly from project to project, yet when viewed in light of the industry as a whole, it may have helped for BSC to be educating a broader constituency of engineers who could then carry the lessons to other builders. It is, however, unclear whether or not this actually happened.

At the subdivision level, Pulte also had to begin dealing with their material suppliers to bring new and better performing products to the market. In the case of insulation, the change was largely facilitated by the EFL Partnership; however, this wasn't the case for all products. Windows proved to be an incredibly difficult obstacle. The new windows were specified as "spectrally selective," with low-E glazing systems and low solar heat gain coefficients, all of which goes to say that they let in the light and block out the ultra-violet solar rays which generate internal heat gains. These types of windows were a niche product in the mid-nineties and to produce them at the scale required for a builder of Pulte's size entailed substantial costs. It has been estimated that the new vinyl spectrally selective windows, which replaced aluminum windows with clear glazing were commanding a 35% cost premium.[47] Both Pulte and BSC encountered a certain amount of resistance from the window manufacturer and distributor in bringing the product to market. Ironically, once they arrived the windows gained widespread acceptance within a period of a few years, due, not only to their increased efficiency, but the fact that by blocking ultraviolet rays they prevented interior finishes, like wallpaper and carpeting, from fading over time thus tying into what many believe is the key demand driver of the consumer market- aesthetics.[48]

Other product innovations were even more difficult in that they involved collaboration with subcontractors. The house ventilation problem provides a good example of this. As BSC worked on creating tighter, more efficient building envelopes they quickly realized the need for ventilation systems to handle indoor air pollutants and moisture. They also recognized that affordable solutions to this problem did not currently exist on the market.[49] In the Cypress Pointe houses, a costly whole-house ventilation system was installed separate from the HVAC system, yet both Pulte and BSC knew that the cost of this upgrade would make it entirely unfeasible in widespread applications.[50]

An engineer at BSC developed a system that would allow for fresh air to be brought in from the exterior of the house and circulated throughout by means of a centralized fan system connected to the existing duct work. The system, known as the *Fancycler*, also included a damper to prevent excessive outdoor air from being brought into the house during periods of prolonged heating and cooling.[51] After Cypress Pointe, all Pulte homes were outfitted with the *Fancycler* system. The control for the system, however, proved more difficult and became a source of conflict between the HVAC subs and BSC. BSC wanted to use a specially designed controller integrated with the house thermostat which allowed the user to activate and deactivate the system if necessary. For cost and availability reasons, the HVAC sub wanted to use a standard off-the-shelf system from Honeywell which removed control from the thermostat and placed it in a "black box" which the homeowner could not access. The fans were activated for twenty minutes of every hour. It was an eight month battle between BSC and Sierra Air (the HVAC subcontractor on the job), and the Honeywell system eventually won out, but at a cost. The fans were coming on at inopportune times and drawing cold air into the homes during the winter. Eventually methods were devised to alleviate the problem of cold air, but it is held to this day that the thermostat control may have been the better system.

It is an interesting exercise in that, if we return to the model of innovation, it is one of the rare instances in which the existing knowledge base could not be relied upon and new research and development was required. As is predicted from the model (by the dashed lines leading from Research to the given phase of innovation), the new development was extremely problematic to bring to market. Product distributors were non-existent and the HVAC trades were resistant to the innovation as they had not previously worked with it and, for all intents and purposes, did not have access to it. It is also an interesting situation in which to consider the extent to which Pulte could have used their supply chain leverage to convince a manufacturer to market the thermostat control for the Fancycler thus easing the product's entry into the market.

In a sense, the Cypress Pointe project may be considered another form of "prototype" for the innovations at hand. Typically, the Building America Model involved building one or two pilot houses, testing the procedures again on ten houses and then going to a full subdivision. In the case of Pulte, BSC went straight from the pilots to the full subdivision. The projects were widely regarded as successes in that the problems encountered in both the Angel Park and Cypress Pointe subdivisions were not enough to deter Pulte from taking the process developed by BSC and applying it to all of their projects in the Las Vegas Division.

Distribution & Marketing

At this point is was fairly well proven that the integrated approach propagated by BSC and the Building America Program was having a positive affect on the energy efficiency of houses being built by Pulte in the Las Vegas market. The changes were resulting in 35%-40% heating and cooling reductions and whole house electricity use was being reduced substantially.[52] Due to the careful analysis of cost trade-offs which made the added benefits feasible, Pulte made the decision to go ahead and incorporate the changes into all of their new subdivisions in Las Vegas. Pulte also decided to pass the cost increases entailed by the new systems onto their buyers.[53]

Certain technologies, however, proved too difficult. The integrated hydronic heating and hot water system for instance, seems to have dropped from the Pulte projects after the Cypress Pointe subdivision. One reason for the change may have been the fact that the hydronic systems required the coordination of two separate trades- HVAC and Plumbing. Previous studies have pointed out that once these coordination issues arise, the assembly line approach which typifies the production homebuilder's construction practices is disrupted and it is highly improbable that such innovations will be adopted.[54] However, Darren Wilson of Sierra Air Conditioning, the subcontractor who does all of Pulte's HVAC systems in the Las Vegas division has pointed out that it was not the coordination issues which caused the systems to fail, but rather a failed relationship with the product manufacturer (it is also worth mentioning that others have confirmed that the increased amount of coordination between trades in the field was not a problem with the Building America Projects).

During the very hot periods of the summer, when air conditioners were running non-stop, the hot water coils on the hydronic systems were freezing and bursting.[55] An adequate freeze protection mechanism built into the system may have prevented the problem, but the product manufacturer refused to accept any culpability for the failures, meaning that Sierra Air and Pulte had to handle all of the callback issues relating to the systems. According to

Wilson, "Out at Cypress, I've got homeowners that I've had to change two hot water coils this year alone. These homes are 6-7 years old, but I'm not gonna make the customer pay for that, so we change it....I had to eat it and Pulte had to eat it. Manufacturers have got to take care of their customers."[56] It is important to note that after the Cypress Pointe project, Pulte homes reverted to the traditional forced air heating system.

The high efficiency condensation furnace that Pulte switched to came with its own problems, however. Inspectors were uncomfortable with how to deal with the drainage water from the systems and had never before seen the concentric ventilation packages that were being installed with the units (the concentric ventilation package combines the fresh air vent, the combustion vent and the toilet vent and puts them into a single penetration going through the roof- thus cleaning up the roof line and using less venting materials). According to Wilson, "You couldn't get the same inspector on the same job, so it was a constant battle in the field for close to an 18 month period of time as these things progressed." As soon as Pulte began building in the next county or city, the same problems with inspectors would arise all over again.[57] Nat Hodgson, the current Vice President of Construction for the Las Vegas Division has implied that the impending widespread acceptance of the 2003 International Energy Code will solve a lot of the regulatory obstacles that the projects have faced, but in his words, "It's a day late and thousands of dollars short."[58]

One of the problems in Nevada is that when cities reach a particular size (in terms of population) they are authorized by the state to assume their own regulatory framework. Las Vegas reached that size well before Pulte began working there. Thus, Clark County, The City of Las Vegas and the City of Henderson (both within Clark County) were all working with different versions of the Uniform Building Code, and adopted the International Building Code (from the ICC) at different stages and with different amendments.[59] This means that Pulte, who was building within all of these regulatory jurisdictions following the Cypress Pointe subdivision, would encounter the same regulatory barriers with each new development. While all three have now adopted the International Building Code, it is still unclear as to the extent to which each of them has amended it to suit their needs. It is unfortunate that the three different regulatory bodies, all working within the same geographic proximities were, and are, unable to come up with a uniform interpretation of a building code that has been widely accepted in other states.

There were also quality control issues with the furnaces. It was found that the new houses were experiencing high amounts of air leakage through their HVAC systems- a problem that was discovered through quality control checks. To figure out the problem, Sierra Air and BSC tested the ducts two ways: attached to the furnace and disconnected from the furnace. When the ducts were disconnected it was discovered that leakage decreased, thus it wasn't the ductwork that was leaking, but the factory manufactured furnace. During shipping and installation, the furnace was getting banged around and many of its own joints were coming loose. The manufacturer was called out to site with its own engineers and shown the problem. It was found that when the joints of the furnace were sealed with mastic, the leakage was again reduced to minimal amounts. The manufacturer returned to the plant and altered the production process on their furnaces to incorporate the sealing prior to shipping the furnaces. In this case, the leverage of Pulte, combined with the scientific evidence from BSC and Sierra Air, convinced a supplier to provide a better product without adding to that product's costs.

Having gotten several of their trades over the learning curve meant that transferring the new practices to different subdivisions, though not entirely easy, would be less costly. However, Beck found that when the projects were going out to bid Pulte was often stuck using the same subs for lack of competitive bidding on the new techniques. The perception at Pulte was that the only way to get a multitude of trades on board was to start getting other builders to adopt the practices, so Beck decided to chair the new energy committee at the local homebuilders association in order to hold seminars on the practices being adopted.[60] It is unclear as to how many of these seminars were ever actually held and some have implied that the notion of Pulte Homes paying the salary of an employee to educated competing builders is preposterous.

One of the *only* issues with which there was a certain modicum of accordance in everybody whom I spoke with was that getting the sales staff on board was the most important element in the process. Building America, BSC, Energy Star and Pulte all recognized this fact early on and training sessions were held with all sales staff in order to make sure they knew how to "pitch" the new product. In the words of Dave Beck, once the sales team was on board, it was like "chocolate on ice cream." It has also been pointed out that, in other markets, where these innovations have failed, it was largely because the sales staff was un-motivated and uninformed as to what it was they were selling.

The Energy Star Program was an integral part of this sales process. The program views itself entirely as a marketing tool whose job it is to convince consumers that energy efficiency is a wise investment. The energy star program provided two primary tools to builders in order for them to properly market the houses they were building. The first is the *Energy Star Sales Training Curriculum*, where Energy Star reps actually hold seminars on how to sell the product. Sam Rashkin at the Environmental Protection Agency has observed that the sales tactics of most large production builders are horrendous. Most sales staff possess very little knowledge about the product and are very weak on follow through. It has also been my personal experience over the past several months that the few Pulte sales staff I was dealing with in different markets were highly ineffective when it came to truly understanding the energy efficient technologies being used in the homes, despite my having been told that the staff had been extensively trained. The other tool that Energy Star provided was the *Energy Star Sales Toolkit.* The toolkit essentially provides each builder with a set of customized promotional literature explaining "how great they are." The brochures are also riddled with various Energy Star logos throughout in an effort to reinforce to identity of the program. Both of these services were provided to Pulte.

The incredible success of Energy Star's penetration in the Las Vegas Market- it is estimated that 60% of the new homes built in the market are Energy Star labeled- speaks to the willingness and motivation of an extremely active group of local stakeholders. Some, however, have argued that the bar for energy star is set to low. One person I spoke with commented: " Energy star is a great program......but you don't have to do a lot to meet it, and because of the IBC, a code-compliant house practically qualifies anyway. They (builders) are not putting a lot of effort into it and it doesn't cost them a lot of money."

Other sales tools include the use of Energy Efficient Mortgages (EEMs). EEMs are a product of Fannie Mae and were originally designed in the seventies as a means of encouraging energy efficiency in the housing market by making the cost upgrades associated with building more efficient homes easier to finance over the life of the loan. The primary mechanism which EEMs use is to increase the income of the borrower by the amount saved through the efficiency measures incorporated in the house. It is not a strong incentive in that it doesn't provide better rates to borrowers, only allows borrowers on the cusp of affordability to be able to afford a house that may cost a few thousand dollars more because of energy efficiency upgrades.[61] Conceptually, the EEM is a safety net, though builders have long argued that financing tools could be a much stronger argument for increasing energy efficiency and that certain states with strict energy requirements produce EEM qualifying homes simply by virtue of meeting the code.[62] It is unclear at this point how many EEM's have actually been used by Pulte, but management implies that they are minimally utilized.

As previously mentioned, quality control was a major component of Pulte's desire to enter into the Building America Relationship. While the construction systems themselves require more care to be taken, the construction process is still an assembly line prone to all types of failures. BSC certainly didn't have the size or capacity to be inspecting all of the houses that Pulte was building, but as part of the Greenstone EFL program, it was mandated that all homes be inspected by a "Master Certified EFL Tester." These testers are employees of Pulte Homes who are responsible for doing the post construction testing of the homes (ie- duct blasting, blower door testing, etc) in addition to training the various trades on the proper installation of energy efficient products. Although the program has shifted from Greenstone (a product supplier) to MASCO (a service provider), to this day, Pulte has two full time certified testers working in the field on a daily basis.[63] The testing is important, because the energy code is one of the most poorly enforced of all the codes, particularly when compared to structure and life safety issues. Sam Rashkin at the EPA has estimated that as many as 80% of homes are out of compliance with the energy codes under which they were constructed.[64] Pulte subs also seem to appreciate the testing, in the words of Pulte's HVAC subcontractor: "I love testing, it keeps us all honest."[65]

Pulte also utilizes the occasional 3 day seminars provided by MASCO to certify their design staff and construction managers as a means of maintaining the knowledge base with regards to EFL certification.[66] The current VP of Construction in Las Vegas has argued that the EFL inspections have had the single greatest impact on reducing the company's call-backs over the past several years.[67]

Getting a production builder to provide quantitative information on callbacks is somewhat of a battle against windmills, and I was unable to obtain this information. However, reports from BSC have indicated substantial reductions in callbacks for the Phoenix Division which also participated in the program after witnessing Las Vegas' success. Representatives from the Las Vegas division have confirmed that their callbacks were also reduced substantially and were in lines with the Phoenix numbers.[68]

Type	Typical Home	BSC Home
comfort	3%-5%	0
paint and trim	5%	1%
drywall cracking	50%	10%

Table 4.1: Phoenix, Arizona Callback Data

It is unclear as to the extent to which some of the methods used in the system have remained as uniform interventions in all projects. For instance, in Pulte's drive towards standardization, the specification types for new homes built in the Las Vegas Division has been reduced to four (A,B,C and D specifications: depending on the level of finish which the homeowner wants with their product). According to the architectural staff in Las Vegas, only Level D, the highest level of finish, utilizes the 2x6 framing necessitated by the advanced framing techniques, thus the rest of the homes aren't using the process.

It is also unclear the extent to which Pulte's transition to the Pratte Model has affected the Building America systems. Pulte's switch from one framing sub that did all of their work and was familiar with the Building America technologies, to Pratte, who had no experience with the technologies proved to be costly and painful. The transition occurred over a few month period and some subs have argued that it was made more painful solely by the fact that Pratte didn't understand the new system. Time will tell to what degree this large scale vertical integration and Pratte's quasi-religious approach to value engineering will help or hinders the firm's ability to build energy efficient houses.

All in all, Pulte's partnership with the Building America Program would appear to have been a success. The main innovations which were incorporated into the early houses are still incorporated into most Pulte homes being built in the Las Vegas market today. The innovations used, arguably, were fairly painless. Many people I've spoken with have pointed out that, today, getting a home to energy star is considered a "no-brainer," though there are still hold-outs in the Vegas market. The fact that Pulte Homes are able to exceed the Energy Star requirements is largely due to their partnership with BSC and the Building America Program.

However, there were aspects of the program which were not achieved in the Las Vegas market. Recent empirical studies of construction waste have indicated that an average 2000 sq. ft. home built today produces 2.3 tons of waste, 80% of which is recyclable.[69] One of the original goals of the Building America Program was to make substantial reductions in construction job site waste, yet it would appear that Pulte made no effort to pursue some of the construction waste recycling programs which were being experimented with in other markets. The reasoning behind this is unclear. It may stem from the fact that tipping fees in a place like Las Vegas may be minimal when compared to more developed regions like New York or New Jersey. Pulte may also have felt that the added time to separate waste on-site into various recycling containers would have increased their cycle time in an incredibly hot and competitive market. Whatever the reason, it is incredibly unfortunate that an area with such high levels of residential construction has not more aggressively pursued recycling programs.

It should also be noted that other Building America projects throughout the country have utilized a machine known as the "Packer-Grinder," which essentially takes construction waste and grinds it up on-site for use in other applications like erosion control, soil amendments or road base. While the machine requires a substantial up-front investment, it is unclear why a builder the size of Pulte with so many projects in the Las Vegas market would not invest in the equipment.

Figure 4.10: The Packer-Grinder 750

Furthermore, water reduction techniques do not appear to have been utilized, which would seem to be one of the primary concerns in the desert climate of Las Vegas. While structured plumbing systems have been designed that could possibly reduce the water usage in a single family home by 30,000 gallons a year and increase the water efficiency by 15-20%, none of these appear to have been experimented with in Putle's Las Vegas homes. Furthermore, most Pulte projects would appear to have the same front and rear lawns despite extensive knowledge on xeriscaping techniques which use indigenous, drought resistant plantings in outdoor areas to reduce water consumption. It is undoubtedly safe to assume that this is consumer driven and that if water were valued as the finite resource which it actually is, such practices would become common-place.

Washington D.C.: Pulte Home Sciences

Potential Market

The Washington D.C. market, which includes suburbs in Maryland and Virginia, has always been a lucrative market for Pulte Homes. Unlike Las Vegas, the D.C. market has traditionally been dominated by large production builders, with four of the top ten builders competing head to head in the area since the early nineties. The market share of the five largest builders has hovered around 30% since 1992 and these builders have an increasing competitive advantage in a market that is largely defined by a builder's ability to acquire extensive amounts of land and navigate a litany of regulatory obstacles in order to get that land entitled. This year, between the Pulte and Del Web brands, the company plans to close approximately 1300 homes in the Washington D.C. market. This particular market was actually Pulte's first expansion out of the Detroit suburbs in which the company was founded, and it is also one of the testing grounds for Pulte's grandest experiment to date, Pulte Home Sciences.[70]

Critics and supporters alike are fairly consistent in attributing Pulte's motivation for pursuing a more industrialized approach to housing development to William Pulte. Bill Pulte grew his business in an area that was largely defined by the automotive industry and was therefore no stranger to manufacturing techniques. A good portion of his career was devoted to perfecting methods of value-engineering the homebuilding process and he was constantly attuned to more advanced methods of homebuilding in foreign countries.[71] Furthermore, as someone that had witnessed the company's growth from 1 to 40,000 completions a year, he was keenly aware of what he perceived as the erosion of the skill base and the extent to which this erosion was going to present itself as a substantial risks to the industry as a whole.[72]

As a result of these experiences and ideas Pulte decided to begin experimentation with the manufacturing of building components in a factory setting. The idea was to test the concepts in a factory close to the company's corporate headquarters and then export the process as a fully integrated system into a new market. It is unclear whether the Washington D.C. market was always the first choice for the first full scale factory while experimentations were being undertaken in Detroit, though a number of factors made it a likely candidate. For one thing, the Washington market is characterized by an extremely fragmented trade base. Taking more control of a market in which the size of the contractors is much smaller than, say, those in the western U.S., was extremely problematic and a factory based approach would relieve Pulte of constantly writing contracts with undersized trades. Another reason may have been quality control. Reverting to an earlier discussion on callbacks, it is very difficult to get hard data on callbacks for any division of a large production homebuilder. Pulte, with such a high level of activity in the D.C. market coupled with the highly fragmented trade base, was undoubtedly seeking ways to create a higher quality product. Cycle time may have also been a motivator for the factory. With the average Pulte home taking about 75 days to build (the Di Vosta model, as previously mentioned, has this trimmed down to 55 days), Pulte was anxious to make improvements which could build a better house in a shorter amount of time.[73] A final reason may have been the weather. You simply can't build year round in the D.C. climate. Extensive rain and snow can shut a jobsite down for a period of days on end and create extensive problems for material storage and damage to unfinished wood products; figuring out a way to keep the production system rolling along during foul weather in addition to keeping construction materials dry and out of the rain could provide a builder with tremendous competitive advantages.

It should be noted that Pulte was not the first to recognize the qualities in the east coast markets which make it a prime target for factory based approaches. Several large production builders like Toll and Ryan Homes have been pursuing wall panelization techniques in east coast markets for many years. These techniques essentially take the measured dimensions for the walls and build them in off-site location, often in a factory setting. The difference between these walls and the Pulte walls is that other panelized wall systems tend to be built in the traditional way that site built walls are constructed- with individual wood studs. This process, while reaping the benefits of climate controlled production environments, fails to solve many of the problems that more industrialized manufacturing techniques can address. As pointed out in a recent study conducted by HUD, typical wall panelization operations still provide for a wide variety of communication breakdowns between the plant and the field where the rest of the house is built in a rather traditional manner.[74]

All of these factors combined to make Washington D.C. a lucrative market for the PHS system. The problem now, was to develop the concept.

Invent or Produce Analytic Design

Pulte's decision to build their prototype factory in Detroit made logical sense as that was the corporate headquarters of the company. Executives were making a large investment in research and development and the importance of that investment being located in close proximity to the head decision makers at Pulte can not be understated. The decision to move forward was too costly to be left in the hands of a regional division.

The people hired to set up shop were largely industry outsiders and young people fresh out of college.[75] Pulte felt that the key to making the process work was to use people that weren't limited by experience in an industry that needed to change. Many of the characteristics which were perceived as flaws by framers in the Las Vegas division's experience with energy efficiency were considered assets in this new environment. Yet, progress was slow because the inexperience at the plant was creating difficulties with basic processes like job training and material management, so Pulte sought out professionals with more extensive experience in product manufacturing.[76] Chuck Chippero was one of those people, who after 24 years of plant management in the automotive industry realized the potential of applying his skills to homebuilding. In his words, "I was skeptical at first, but took an afternoon and looked at what was going on in the field and what was going on in the factory, and at that point I realized that there really was an opportunity to change the industry." [77]

The Detroit facility was never intended as a full scale production facility for the manufacturing of whole houses; instead it was a means of testing the extent to which the individual components of a home could be fabricated in a controlled environment while still allowing for the design flexibility needed by a company producing 40,000 homes a year. The term flexibility means different things to different people, and Pulte's idea of design flexibility may differ from most peoples.

Each division in Pulte essentially pulls their plans from a pre-determined plan book. Some divisions share a book if they are in similar climatic and demographic areas (the Arizona and

Nevada divisions of Pulte, for instance, share a single plan book). A typical subdivision may consist of anywhere from 4-8 different plans. The plan books are based on a central library of about 2,000 different home designs. Pulte sees the standardization and simplification of plans and specifications as one of the key elements in taking more control over their supply chain and currently has a national team working on just that.[78] According to the lead architect for the Las Vegas division, the number of plans has already been reduced by about 40% to its current number.[79] Short term goals are to rein that number in even further from 2,000 down to 1,500 plans; with a long term goal of working with only 1,000 plans.[80] It's an interesting contrast, in that as the number of homes the company aspires to build goes up to 60,000, the number of plans will drop to 1,000. As previously mentioned, Pulte is also attempting to trim down their specifications extensively to a point where they will essentially have four different offerings segregated based on the level of interior finish.

When Pulte talks about flexibility, they are not referring to the ability to design different houses for each lot, but instead accommodate the plethora of design "options" which a customer can purchase with their home. These options can range from a different style countertop to the addition of a large sun room off of one elevation. While not drastically changing the underlying conceptual design of the house, and while often time's houses in a single subdivision may look very similar, it is rare for two houses in one tract to have exactly the same set of options. Pulte recently ran an analysis of a single plan currently being used in the Washington D.C. division and discovered that when all was said and done, there were 1.2 million different ways in which the final product could turn out.[81] It was clearly important for Pulte to not have PHS homes look any different than those built in the traditional manner, thus they needed to develop design tools that could accommodate these variations.

In order to accommodate this flexibility and still be able to produce components quickly in a factory environment, Pulte needed to invest in new software technologies. Traditionally, most Pulte Homes (and most homes in America) are drawn on some sort of two dimensional computer aided drafting (CAD) system. The programs produce plans that are very similar to traditional hand drafted construction documents, only crisper. The documents are then sent to different trades who use them to estimate construction materials and costs, often re-drawing the plans to better suit their needs in the process.

In order to develop a means for building the shell of a home in a factory, Pulte needed software that could interface with the factory equipment while also producing a set of construction documents that could be used in the field and for permitting. This required what is known as object-oriented-CAD systems. Object oriented CAD systems not only transition the traditional architectural drawing from a two-dimensional into a three-dimensional representation, but imbue each element in the drawing with information- like material properties and structural characteristics, etc.

Pulte partnered with Keymark Systems in order to develop the software for the Detroit Plant. Keymark was started by engineers who had spent several years developing software for Truss-Joist's floor panel manufacturing division and was begun in the early nineties as a whole house engineering software company. The market has yet to embrace the object oriented CAD approach to home design, and according to one Keymark employee, the company has remained on the "bleeding edge," of product development and the Pulte partnership has been integral to keeping them afloat. While Keymark had worked with component manufacturing plants prior to Pulte, they had never had to develop software geared towards a "whole house" approach to manufacturing. Keymark, however, shared the belief with Pulte that the homebuilding industry was ready for serious change. In the words of one Keymark employee, "If Detroit built cars this way, a car would never come off the line."

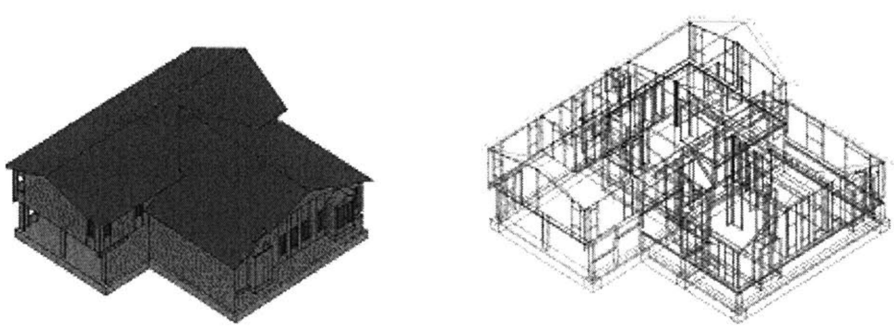


Figure 4.11: Keymark© Models, Exterior Rendering & Structural Model

The first thing to come out of the Detroit facility was foundations, which, due to the controlled environment in which they were being poured came out with a PSI (*pounds per square inch*, a structural moniker of concrete strength) twice that of site-poured concrete. The system is poured in straight walls approximately 8' in height and 4" thick, with thickened vertical reinforcing at 24" centers. Thus the foundations are thinner than, but nearly twice as strong as a typical job-site pour. The system is poured and cured in the factory and then trucked to the site on specially designed trailers where it is craned into the foundation pit. Once in place, the individual pieces of the foundation are bolted together and sealed at all of their joints. The foundation systems, more than any other component were tested extensively in the Detroit market beginning in 2000 and the factory has produced over 3000 of the systems to date.[82]

Figure 4.12: Pulte Foundation System (installed and in transport)

Other experiments at the factory included SIP wall panels, steel interior wall systems and pre-fabricated floor trusses (see Appendix #2 for an explanation of these systems). One of the big shifts in the factory approach was the extent to which it relied on raw materials as opposed to pre-fabricated components. The walls, for instance, were not pieced together with pre-manufactured SIPs supplied by a SIP manufacturer, but were instead assembled out of the three main materials which compose a SIP: foam, oriented strand board and glue. By purchasing these materials direct from manufacturers, Pulte was able to cut at least one step out of the material supply chain. The same is true for all of the systems designed for the factory. The steel interior walls are cold rolled in the factory from large coils of flat 20 gauge steel, as opposed to purchasing the studs direct from a stud manufacturer. The open-web floor trusses are assembled from wood and metal fasteners in the factory, as opposed to purchasing ready-made floor joist from a company like Truss-Joist or Weyerhauser. The foundations are poured from a concrete mixing plant built on site. Careful thought was put into using only "raw" materials in order to capitalize on manufacturing techniques and the material purchasing leverage that a company like Pulte has.

The energy efficiency of the homes was also getting careful treatment at this time. Neither the officials at Pulte, nor the directors of the Building America Program attribute the PHS home in any way to Building America, yet there appears to have been a relationship between Pulte and IBACOS (Integrated Building and Construction Solutions) as they were fine tuning the final specifications for the house.[83] IBACOS is a building science research corporation similar to BSC. Like BSC, they had a longstanding relationship with Pulte and were also one of the five Building America teams at the time. IBACOS was commissioned to make design recommendations for several of the Detroit pilot homes, keeping in mind that the homes were actually being designed for the Washington D.C. market. In a relationship very similar to the Las Vegas division/BSC partnership, IBACOS worked on systems design, field inspection and subcontractor training sessions to test different ideas on the PHS homes. As a result of their tests, several modifications to the standard Pulte specifications were made in an effort to capitalize on the new efficiencies of the SIP walls and open web trusses.

One of the first recommendations was to properly seal the completed building envelope. This included sealing around all installed window and door systems in addition to sealing the joints between SIP panels. In the Detroit region this was done by using a specialized air tightness subcontractor. IBACOS also recommended much better windows, with Low-E glazing similar to those used in the Las Vegas projects. Pulte was extremely hesitant because of the cost issues involved, but was convinced by IBACOS to go with the better windows because they could reduce their comfort related callback issues (which were an apparent problem on the second floor of many Washington D.C. Pulte homes) and the ability to save money by downsizing their cooling systems. IBACOS designed the Detroit houses with two space conditioning systems (down from three on the standard home) and as a result of post construction testing recommended that the Washington D.C. houses be built with one. Pulte agreed to build further test houses with one system, but indicated a need to conduct consumer research to gauge reaction to moving from two systems to only one. IBACOS also recommended a Heat Recovery Ventilator system (HRV's provide a secondary duct system to provide fresh air into the house; the HRV system uses a "heat exchanger" in which the fresh air is passed through the vented air in order to "pre-heat" it) to provide fresh air into what was a very tight building envelope, and while the system worked well, the increased costs for its implementation were higher than Pulte expected and thus they opted for a fan-recycler system similar to that installed on the Las Vegas homes to be used on the D.C. projects. Due to the fact that the D.C. climate would prevent Pulte from using an un-vented roof, it was decided that the efficiency of the air distribution system could be maximized by placing it within the open web floor trusses and Pulte agreed to do this in the D.C. market. Finally, IBACOS recommended that Pulte use high efficiency water heaters and furnaces for all of the homes to improve occupant comfort and energy efficiency, which Pulte agreed to do.[84]

As a result of these measures, IBACOS estimated that the PHS home was achieving 24% reductions based on the standard Building America benchmark home and 27% whole house energy savings over the typical stick-built Pulte home. These numbers would probably be better if Pulte had agreed to go with a more efficient lighting system which they opted out of for cost concerns and fear of consumer perceptions about the quality of the lighting installed. Furthermore, these numbers do not reflect the further downsizing from a double to a single space conditioning system which was recommended for the D.C. homes.

Consumer perceptions about pre-fabricated homes were another concern for Pulte. This was largely the impetus behind the name Pulte Home Science. According to Craig Stempowski, Pulte's Operation's Development Manager, "Calling it prefab drives away customers."[85] Admittedly, the name conveys a certain *gravitas* and level of sophistication which is somewhat atypical of the production homebuilding industry. In addition to good branding, Pulte appears to have polished its sales pitch in the Detroit market also. When the product was moved into a particular subdivision in the Detroit suburbs, Pulte wanted to switch 47% of the scheduled homes to the new foundation, floor and wall systems. Unfortunately, all the homes had been pre-sold as stick-built. Pulte, however, was able to convey the message of what they felt was a superior system and convince 100% of the buyers to accept the PHS home.[86]

By 2002, several of the 800 homes a year being constructed in the Detroit division of Pulte were using one or all of the manufactured components. Despite this fact, the plant is scheduled to be shut down. Some have speculated that the Detroit factory was a failure because of the decision to close it down, but Chippero refutes this point arguing that it wasn't the purpose of the Detroit facility to be a full fledged manufacturing plant. The software and Material Requirements Planning (MRP) systems weren't fully integrated into the process and the plant was designed on a piecemeal basis to test the manufacturing of the individual components. MRP systems release manufacturing and purchase orders to ensure just-in-time manufacturing capabilities which are in line with overall master scheduling.[87] The system coordinates and places orders to balance raw material inventories with work in progress through proper timing of order placement.[88] In its current capacity, the Detroit facility was simply too labor intensive and the engineering of the plant did not allow for some of these more sophisticated processes to occur.[89] The plan was always to export the individual processes into a more integrated system in a new market once they were developed. In the words of Chippero, "To do it right, it would have to be a brand new plant."[90]

Detailed Design & Testing

Having chosen the Washington D.C. market for their first full scale facility, Pulte began to plan for the export of the factory. Given that most D.C. subdivisions are actually constructed in the suburbs of Virginia, the plant was to be located in Manassas, about ten miles south of Dulles International Airport.

The Keymark software that was originally developed had evolved from its initial platform and was now proprietary to the PHS system.[91] One of the key changes to the system was that the architectural and engineering drawings would have to be calibrated with lasers on the factory floor so that components could be properly laid out without factory employees having to constantly consult drawings. Furthermore, due to the fact that the architectural software was now incorporating structural design, Pulte now employed two full time structural engineers in-house so that they could stamp their own drawings. This undoubtedly saves tremendous time during the design process as the traditional approach is for a home to be designed architecturally and then be sent to an engineering consultant who makes the necessary changes before sending it back to the architects for the final set of plans to be drawn. Initially, this savings was undoubtedly offset by the fact that Pulte was having to re-draw whatever existing plan they wanted to use into the Keymark platform (all Pulte plans are drawn on the traditional Auto-desk 2-d CAD software). Interestingly enough, any new plans developed by Pulte will continue to be drawn into Auto-desk software so that they can be more easily proliferated throughout the rest of Pulte's operating division and the PHS plant will continue to convert the drawings. The conversion process takes approximately two weeks.[92]

One of the notoriously problematic aspects of systemic innovations, particularly in the homebuilding industry, is the extent to which they affect the activities of multiple trades related to the manufacturing of the product at hand. The shift to the PHS system firmly placed a large part of the responsibility for the shell of the house in the hands of Pulte, yet Pulte, like most production builders, didn't want to create a system in which they would now be responsible for carrying an excessive amount of employees which would inhibit their ability to weather economic down cycles. Thus, it was decided early on to introduce subcontractors to the new system.

Some may speculate that Pulte's desire to integrate subcontractors into the relationship was in order to relieve them of certain liabilities related to the system, though this appears not to have been the case with the PHS model. Pulte feels that by internalizing many of the processes they are actually lessening the possible quality control issues which may arise from a variety of subs working out the product themselves. Furthermore, the insurance industry reacted positively to the new system. According to Chippero, the houses qualified for a "fortified housing" label from the insurance industry- essentially a label from the Institute for Business & Home Safety provided to home insurers that qualifies a home as being better than average with regards to structural and life-safety characteristics through improved construction techniques. Pulte declined the label, due primarily to the fact that they were still building stick framed houses in the same market that didn't qualify as *fortified* which may have given homebuyers the impression that the structure they purchased was not safe. That said, Pulte has developed several systems relating to the house, including an injection molded gutter and fascia system and a pre-fabricated window sill flashing detail, which could easily be marketed to the outside industry, but for fear of either system being misapplied and Pulte being held liable for the product failure.

Pulte knew that there were certain trades that could take over the installation work once the system was in place, they also knew that there were certain trades that had to be on board from the very beginning- like HVAC and electrical- so they decided to introduce the trades to the system from the very beginning. In 2002, Pulte began bringing trades up to the Detroit facility to introduce them to the system prior to the completion of the Manassas factory. At this point, in terms of the construction, several of the Detroit homes were virtually identical to what was going to be done in Manassas, so it would be easy for subs to familiarize themselves with the product at hand.

Pulte was also concerned about the reaction of code officials to the new system, so around this same time Pulte officials made a presentation to the regional gathering of the *Virginia Building Code Officials Association* at their quarterly meeting.[93] In this meeting, they thoroughly outlined how the factory and construction processes were going to work and extended invitations to code officials to tour the factory once it was up and running. While the full integration of the four different systems (foundations, floors, SIP exterior walls & metal interior walls) had never been done in the region, code officials had had some experience which each of the individual components previously. Pre-cast foundations, for instance, had been manufactured by a local company, Superior Wall, for some time;[94] and while the system had not gained widespread appeal it was certainly familiar to inspectors. SIP walls had also been used throughout the Virginia market, as had open web trusses and steel framing for interior partitions. Thus, by taking the time to orient the code officials to the new processes for assembling familiar products, Pulte made most building officials comfortable with the new approach from the start.

While Pulte was finishing the Manassas factory, they decided to build a local test batch of homes at a subdivision called *Mayfield Terrace* in Prince Williams County, Virginia. Because the Manassas factory was not up and running yet, Pulte shipped the individual components all the way from Detroit. This second round of test homes would allow the subcontractors to familiarize themselves with the new construction techniques and to figure out how they were going to work around the new structural systems. As for the installation of the components, Pulte decided that they, themselves, were going to be placing the foundations, floor decks, SIP walls and interior partitions in the early stages (though this would evolve in later iterations). The crucial subcontractors were the electrical and HVAC crews, because Pulte knew that, as a homebuilder, they did not have the in-house skill base to take over these more complicated processes.

Pulte took special care with the HVAC design, as they knew they were building a more efficient home which could utilize a downsized system. The traditional process for the HVAC design on a production home is to simply allow the HVAC subcontractor to design the loads and the system based on the size and construction of the house- what is known as a *design-build* approach. With the new homes, however, Pulte didn't want to leave that much control in the hands of the subcontractors, so they developed a close working relationship with a mechanical engineering firm who did very specific designs and specifications for the heating, cooling and ventilation systems in the house.[95] In addition to increasing the efficiency of the systems, in the long-term this will allow Pulte to control regional variation in the design of the mechanical systems once the PHS model is exported to other divisions (and throughout the Washington D.C. division). As Chuck Chippero stated during our discussion of the HVAC system design:

> "Autonomy in product design and sourcing drives proliferation to the point where it won't be controllable. How do you leverage your size, if every market uses a different window design and manufacturer, what competitive advantage do you have over the local guy who's using the same supplier, maybe even the same parts? Whereas if you've got a national window program, you have a set of 150 windows that are built to an outstanding quality performance level using new techniques; you've got the leverage, you've got the costs in line and you have a higher performing product. That's what Pulte is aimed to do and the bigger homebuilders are starting to wake up to that but don't have the expertise to really make it go."

Based on the detailed design of the systems, the HVAC subs appear not to have had many problems with the new design, though the possible efficiencies have not been achieved, as will be discussed in the next section. A single system was installed in the test homes as requested by IBACOS, but it was still undecided as to whether or not the final subdivisions would go with one or two. Furthermore, the open web truss designs undoubtedly made the installation of the ductwork much easier for this particular sub.

The electrical subs, however, had a slightly steeper learning curve. Pulte's electrical contractor for the houses has been doing Pulte's D.C. projects for eleven years and has a fairly good working relationship with the builder. While they'd worked with some smaller SIP projects before, they knew that working with a big production builder on the system was going to require much greater efficiencies, so once they were on the test houses, they immediately began experimenting with new systems for fishing the wire through the walls and using different drills/drill bits to get through the SIP panels.[96] Over a three month period, the sub became efficiently comfortable with the product and had enough supervisors trained to maximize the efficiency of the process. Of all the subs, the electrical team has probably experienced the most substantial disruptions.

One of the problems stems from the fact that, while HVAC ductwork is preferably moved about the house through interior walls, the electrical system can't avoid working with the SIP exteriors. The SIP foam which comes into the Pulte plant is like any foam that comes into a SIP plant in that it has electrical channels drilled from top to bottom at two foot centers. However, once this foam is cut and placed in the finished SIP, and the SIP is cut into a finished wall, these channels no longer align with the electrical plan of the house. Rarely do the electrical channels in the foam align with the design or code requirements of the electrical system; i.e. *this is where the toaster is going, the television will be over there* and *the code requires that the electrical socket to be 18" from the face of the abutting wall, etc, etc.* Thus the electricians must cut vertical and horizontal channels into the walls on-site in order to get the wiring where it needs to be. The electricians estimated that the SIP walls were adding 35% increases in electrical costs to the homes and while the open web trusses save about 4 hours of time for the installers (no drilling through floor joists), the savings isn't enough to offset the increased costs of dealing with the SIPs.[97] It will undoubtedly be important for Pulte to work with Keymark in getting the CAD software more carefully integrated with the electrical plans; as it is now dealing mainly with the structural requirements of the house. As the system is now working, the PHS process requires more highly skilled labor from the standpoint of the electrical subs, though it seems as if there is potential in the system for this not to be the case.

Figure 4.13 Open Web Floor Joists (note electrical wiring)

Figure 4.14: SIP Wall Panel (note channels in foam core)

Further complications also occurred in attempting to integrate the IBACOS recommendations into the D.C. houses. While the sealing of the house, a task integral to the ultimate performance of the structure, was being performed by specialized air tightness subcontractors in the Detroit division, no such subs existed in the Washington D.C. area. Thus, Pulte had to hand the task off to other trades which included the framers and the insulation installers.[98] It can be assumed that, given the fact that Pulte did their own framing for the first several houses, they performed the framers air tightening tasks themselves. Post occupancy evaluations have not been performed on the homes to verify if there was any lapse in quality as a result of this task being completed by two separate trades as opposed to the specialist in the Detroit market.

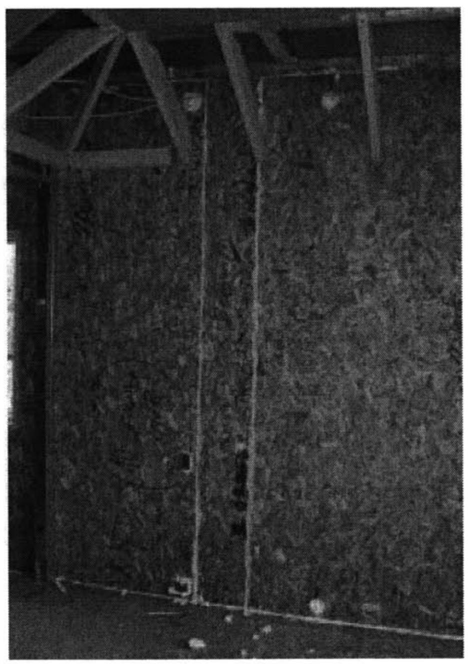


Figure 4.15: SIP Sealing (white caulk on SIP interior)

Having this second round of pilot homes built in the field also allowed Pulte to make a second round of tours with building officials so that they could see the site applications of the factory prior to the full blown subdivision. No problems were noted from either the code officials or Pulte at this point in the process.

Redesign and Production

Shortly after the second round of test homes was built in the Virginia market, Pulte went ahead and began converting entire sections of subdivisions into the PHS model. In the first year the plant was operational, it produced 190 homes. These homes were divided amongst three subdivisions in the D.C. market. The homes were largely being marketed to Pulte's high-end buyers with list prices ranging from $500,000 to over $1,000,000. Consumers seem not to have been put off by the factory approach to homebuilding. Due to the fact that many of the subdivisions into which the PHS system would be moving had already been pre-sold (the D.C. market is *hot*), Pulte was again in the position of having to pitch the new system to those who had already purchased a stick-framed home. Again, according to Chippero, 95% of those offered the PHS home, made the switch. The 5% that refrained expressed concerns of cost over-runs during construction.[99]

Although Keymark continues to work closely with Pulte on the software, very few major changes have been made. One interesting note is that the software currently fails to capitalize on all of the capabilities of an object oriented CAD system in that it is not yet integrated with an MRP system. Such databases are important aspects of most sophisticated manufacturing processes in that they project raw material needs that will match future production outputs to ensure that the plant is provided with adequate materials to follow through on their job orders. Currently, with the fairly low levels of output at the plant, material procurement is handled manually. It is hoped that in the future, a full MRP process can be integrated with the design software to ensure the *just-in-time* delivery of materials to the factory.[100]

Due to the extensive testing of the process, very few changes were made between the new subdivision homes and those that had been tested in Detroit and Prince Williams County. Notable changes between these homes and the second round of pilot homes appear to be the fact that Pulte's marketing division became uncomfortable with installing just a single space conditioning system. It is unclear how thorough the market research was, but by the time the PHS system was moving into full subdivisions, the mechanical system was utilizing two space conditioners- arguably an over-sizing of the systems which would both increase energy bills and result in a less efficient house. No consumer complaints have been documented for the original pilot homes built with a single system. Again, quoting Chippero,

> "We found that we could provide a better performing house using a single system rather than two systems. But in this market, the operating division was concerned that people buying the houses are going to want two systems, they're used to it. So we re-engineered the houses with two smaller units. For marketing reasons, we didn't go all the way to the most cost and energy-efficient system because of consumer perception."

It is also worth noting, that at this stage in the game, Pulte was still doing a majority of the shell labor themselves, installing the foundations, floor systems, exterior and interior walls. However, plans were being made to integrate framing subcontractors to the system so they could eventually take these tasks over. Pulte handled all of the installation labor on the first eighty houses, approximately, before they began experimenting with subcontracting the framing out. The ability for trades to pick up the work was to be an integral element in the process.

Figure 4.16: The New Framing Paradigm (Pulte subs assembling walls)

The three subdivisions into which Pulte was placing the early homes were all in different counties, and therefore different code jurisdictions. Pulte's extensive orientation programs with the staff of all the different building departments undoubtedly reduced the regulatory resistance which they encountered with the new system, though the fact that Virginia utilizes what is called a statewide code, meaning that individual counties are forced to abide by whatever code the state adopts, in this case the new *International Building Code*, was also a tremendous asset to Pulte. According to one local building official, no individual county "can do anything more or less than what is adopted in the statewide code." In a regulatory sense, Virginia is a very standardized state, and code officials pride themselves on this fact occasionally having cross-county meetings in order to discuss a uniform representation of the code.[101] This is clearly the opposite situation to that encountered by the Las Vegas Division as they struggled to proliferate their Building America technologies throughout three cities within a single Las Vegas County- all of which were working with different versions of regulatory documents (refer back to the map in Chapter 3, and it can be seen that Nevada is one of the few states which has not adopted the International Building Code statewide). Pulte, however, chose to play it safe, and whenever the PHS system was introduced into a new county, a new round of tours was held for building officials.

Interestingly, Pulte made no effort to partner with any of the third party certification programs to sell these new homes as energy efficient. The results of the IBACOS study seem to indicate that the homes would pass energy star standards without any problem, and would also undoubtedly qualify for some level of Environments for Living certification, yet none of these avenues were pursued by the builder. Sam Rashkin, the National Director of the EPA's Energy Star program is convinced that these houses exceed state codes by close to 30% (roughly in line with the IBACOS numbers) but due to the strength of the market, labeling is unnecessary. In his words, "They don't need to label them in this market; they sell out before they get the trailer up."[102] Yet the same could be said of the Las Vegas market, particularly in the late nineties when Pulte first began labeling their homes. Chippero has argued that the Pulte Homes are far exceeding Energy Star requirements for the Washington D.C. market, which are requiring 15% whole house energy reductions. In this sense, achieving an energy star rating is, arguably, not a difficult process for most builders. Pulte feels that there needs to be a method by which they can get credit for doubling the performance of the house, which currently isn't possible. Furthermore, it is important to consider that at this stage in the game, PHS homes were being built in the same neighborhoods as traditional stick built houses which were probably struggling to even meet the minimum energy star requirements. In that sense, Pulte would have been in the position of marketing their own product as inferior to the new PHS homes. The dilemma is similar to that posed by labeling the houses as "fortified" for the insurance industry. It is unfortunate in that, by foregoing the partnerships, Pulte has foregone all of the post construction testing of the homes which would verify their efficiencies.

Distribution and Marketing

Pulte is largely still in the process of distribution and marketing the new product. In a sense, this needs to happen on two levels. First, there is the distribution and marketing of the PHS homes within the Washington D.C. division. Then there is the distribution and marketing of the PHS system to other Pulte markets across the country.

Within the Washington D.C. division, Pulte expects to build 450 homes with the PHS system this year. Next year they expect to have made a full transition to the PHS system and will have completely phased out site-built operations.[103] Pulte continues to hand more and more of the work for assembling the structures over to subcontractors. According to Chippero, all of the SIP wall, second floor framing and interior wall framing are now being done by framing subs who were introduced to the system as early as a year ago and Pulte has shifted all of their employees to either working in the plant or installing foundations. While experiments have been conducted with subbing out the foundation installation and first floor deck, it is expected that this task will always be completed by Pulte.[104] This largely stems from the fact that a level and well connected foundation is undoubtedly the linchpin of the entire PHS home. The installation of the foundation system is tricky and can become much more complicated if installed during severe weather conditions which may lead the gravel base, upon which the foundation rests, to come out of level. Pulte continues to have faith in the system, but also continues to monitor it very carefully in the field.[105]

While the regulatory obstacles to the PHS system seem to have been fairly minimal and easily overcome, some code officials are raising eyebrows at perceived quality control issues now that Pulte has shifted the SIP installation process over to subs. One code official I spoke with noted that components were handled much more carefully when Pulte was performing all of their own on-site labor. Since the transition to subcontracted installations has occurred, inspectors are noticing more SIPs being damaged through the installation process in the field. Other problems identified have been the fact that certain field connections are very difficult to verify. One code official I spoke with noted that inspectors are beginning to have confidence issues with the installation process and they are struggling with that aspect of the relationship. I, myself, spent about an hour one day in the field watching the installation process and witnessed at least one SIP have a sizable chunk banged out of it's upper corner during installation. No notice was taken of the damage and construction continued on, though the SIP may have been repaired during a later quality control inspection.

Pulte has also expressed that the PHS product may soon be shipped into Montgomery County in Maryland, well within the 150 mile shipping capability of the plant and still considered part of the Washington D.C. Division. Maryland, unfortunately, is what is known as a "home rule state," in that each jurisdiction has their own authority and can tweak the code to satisfy their regulations.[106] The extent to which this may make the transition process more difficult is unclear at this point, but is undoubtedly on the radar at Pulte.

Pulte's sales staff seems fairly up to speed in terms of pitching the new system. Calls were promptly returned for the subdivision in which I inquired about information. Furthermore, Pulte is banking on their customers embracing the new system and rather than attempt to downplay the "factory" built home stigma which has traditionally been greeted with a certain amount of skepticism in the consumer market, Pulte actively engages consumers in order to make them aware of the systems added benefits. The show houses at the development which I visited had a dedicated space for an explanation of the new approach, a detailed account of how it works and a cut-away architectural model showing the individual structural components (a rarity in most production home sales offices in which construction techniques are considered best hidden). Sales literature is provided to consumers in the form of a well designed informational packet which is evenly divided between an explanation of the development plan (available lots, street design, etc.), Pulte Home Mortgage information (explanation of bonuses given to buyers who finance their homes through Pulte's lending arm) and a detailed presentation of the PHS system and it's added benefits (see Appendix #3).

According to sales staff and Pulte representatives, the homes have been selling extremely well, although it may be interesting to see what happens when the market cools off.

No callback information on the factory approach was provided, which is unfortunate in that Pulte has a unique opportunity to compare the two systems side by side with the division building both stick-framed and PHS homes in the same region. Consumer surveys in the Michigan market have indicated that homebuyers are happier with the PHS system by 7-8% margins in every major category.[107] According to Pulte staff, call-backs in the D.C. division have been reduced, but not eliminated (and probably never will be). Some of the mistakes are stemming from communication breakdowns between the sales staff in the field and the designers in the factory. For instance, sales staff may forget to itemize a masonry fireplace on the job order and the house gets built without it. These are largely communication issues which can be resolved with more sophisticated client-sales-construction interface mechanisms.[108]

In terms of distributing the PHS system to other markets, Pulte expects to pull their PHS engineers out of the Washington D.C. market at the end of next year when the plant will be producing all of the homes in that division. Before that happens, Pulte will verify that the product has been successfully differentiated from the competition, the houses are performing to a high enough level (HVAC, structural, indoor air quality), 20 days have been reduced off the cycle time (right now it's at 10), the service performance is working out and the costs are in line.[109] If everything is where they want it, a new market will be chosen.

At this point, it is undecided as to where the next plant will be located and the decision will be based upon a plethora of different variables. The market will have to be high volume, most likely matching the plants own capacity for producing 1500 to 1800 homes a year. Furthermore, it will have to be a market with long-term projected growth, possibly making those markets which have placed "smart growth" limitations on development less desirable. Additionally, the houses are based on a basement design, which excludes much of the southwest which continues to build most houses with a slab-on-grade system. A fragmented labor pool is also a desirable aspect to new markets, as this is the aspect which truly gives the plant a competitive advantage. Additionally, Pulte executives may weigh the extent to which a given market is unified in a regulatory sense- a criteria which definitely helped with the Virginia market and served as a detriment in the Las Vegas market for certain innovative practices. Finally, the extent to which the labor pool in a given market is unionized may also serve as a detriment to the PHS system, as trade unions, particularly framers and concrete installers, may mount opposition to a construction methodology which they perceive as threatening their livelihoods.

All of these questions will need to be answered as Pulte selects the next location for their new factory, which according to Chippero is a sure bet. While Pulte may have the capital to invest in up to two plants a year, the feasibility of such expansion may tax Pulte's existing knowledge base and their ability to carefully monitor each plant installation and operation in its infant stages. From Pulte's perspective, building two plants a year wouldn't be prudent.[110]

Pulte's factory approach to building home components has several attractive environmental attributes. First, through the systems chosen, it clearly builds a superior home in terms of energy efficiency to that which was previously being constructed by the Washington D.C. Division (notably, however, a division which had not pursued energy efficiency prior to the arrival of the PHS plant). Second, it uses substantially less wood than a traditional stick-framed house. Internal estimates are that the process has reduced the amount of lumber in the house by 35%. Construction waste is substantially minimized through the finely tuned factory processes. Again, internal estimates project that scrap rates on the C & C cutters used to make the floor joists are at about 1%.[111] The fact that steel studs are being manufactured per the wall system means that the only waste being generated through the process is essentially the "punch-outs" for the electrical boxes. Material delivery packaging has been reduced or eliminated through the integration of re-usable packaging which, once unloaded at the factory, is re-delivered to the manufacturer emptied of its contents. Finally, indoor air quality is being carefully managed through processes similar to those used in Las Vegas.

Both the PHS model and the Building America experiments in the Las Vegas Division present us with two very different approaches to innovation in Production homebuilding. As illustrated, the two approaches affect the social systems of the homebuilding industry in very different ways and the feasibility and ease with which both of these systems can be diffused throughout the industry is different in each case. The next and final chapter of this thesis will draw conclusions from both of these case studies in an attempt to detail the successes and failures of each innovation in addition to gauging the extent to which each approach may be spread throughout Pulte's various operating divisions and to the homebuilding industry at large.

[1] Pulte Home Corporation, Annual Report: 2004, (Bloomfield: Pulte Home Corporation, 2003) 2.
[2] It should also be noted that Pulte, along with several large American production builders, is working internationally with operations in Mexico, Puerto Rico and Argentina. It would seem that most American builders are still struggling to find their way in foreign markets. According to its annual report Pulte posted only $7 million dollars in profit for all of its international operations in 2003. While up from previous years, the international numbers are paltry compared to work being done in the United States.
[3] Caulfield, John, *Bold Maneuvers*, Big Builder Magazine, July 1, 2004.
[4] Lurz, Bill. *Trade Partnering*, Giants (available at: www.housingzone.com) February 1, 2004.
[5] Caulfield, John. *Bold Maneuvers*, July 1, 2004.
[6] Chippero, Chuck, General Manager & Plant Designer: Pulte Home Sciences, personal interview, 03.23.05.
[7] Caulfield, John, *Vertical Leap*, Big Builder Magazine, September 1, 2004.
[8] Frey, Elaine F, *Building Industry Consolidation*, Housing Economics, August 2003, 11.
[9] Hodgson, Nat, Vice President of Construction: Pulte Homes Las Vegas, Interview (written reply). March 21, 2005.
[10] James, George, Director, New Construction: Department of Energy's Building America Program, Interview. 3.18.05.
[11] Other Building America Teams included IBACOS, the Center for Advanced Residential Building (CARB) and the Hickory Consortium.
[12] For more detailed information on Building Science Corporation: www.buildingscience.com .
[13] Fire Retardant Plywood is regular plywood treated with chemicals to decrease its flammability. In the mid-80's it was discovered that these chemicals were not only rotting the fasteners used to attach the wood to the frame of the home, but were also rotting the plywood sheets themselves. The National Association of Homebuilders estimated that replacement fees for these systems would cost the U.S. homebuilding industry an estimated $2 billion. EIFS are essentially a multi-layered exterior cladding system with integral insulation and pre-finished stucco. EIFS wrap a house very tightly and when first introduced were thought to be a cost efficient method of providing a stucco exterior along with added insulation to improve the home's performance. Unfortunately, faulty installations were trapping water behind EIFS and rotting structural plywood and framing often causing complete failures in houses that were less than five years old. While exact numbers for the resulting litigation are unavailable, the system failure undoubtedly cost the homebuilding industry hundreds of millions of dollars.
[14] Andrews, Steve. *Pulte Homes and Re-engineering*, on-line posting: Built-Green Colorado www.builtgreen.org. January 14, 2005.
[15] Beck, Dave, National Vice President of Construction, Pulte Homes, personal interview, 3.03.05.
[16] *Consumer Survey Elevates Energy Efficiency*, on-line posting: Green Building News, http://oikos.com/news/1998/9811.html , November, 1998.
[17] Bashford, Howard H. et al, *Drivers for Energy Efficiency Decisions in a Competitive Residential Construction Market*, Cost Engineering, Vol. 44 No. 4, April 2002. 25-26.
[18] Mullens, M. and M. Hastak, *Defining a National Housing Research Agenda: Construction Management and Production,* Proceedings of the NSF Housing Research Agenda Workshop, Feb. 12-14, 2004, Orlando, FL. Eds. Syal, M., Mullens, M. and Hastak, M. Vol 2, p.21-24.
[19] ibid, p.21.
[20] Andrews, Steve, January 14, 2005.
[21] Robison, Jennifer, *Builders' Insurers Leaving Las Vegas*. Las Vegas Sun, April 11, 2002.
[22] Ibid.
[23] Pollack, Ed, Department of Energy: Building America Program, person interview. 3.18.05.
[24] Rudd, Armin, *Performance of Building America Initiative Houses with Unvented Attics and Tile Roofs Constructed by Pulte Homes, Las Vegas Division*, on-line posting: Building Science Corporation Website, http://www.buildingscience.com/resources/roofs/ September, 1999, 1-2. (image & information)
[25] ibid
[26] ibid, 1-2.
[27] Information on the software can be found on the Florida Solar Energy Website: http://www.fsec.ucf.edu/bldg/cap/analytical/
[28] Hedrick, Roger, Residential Duct Placement: Market Barriers (Technical Report, California Energy Commission, October, 2003) 7.

[29] Lstiburek, Joseph W. and Rudd, Armin. *Vented and Sealed Attics in Hot Climates*, Proceedings of the ASHRAE Symposium on Attics and Cathedral Ceilings, Toronto, June 1997.
[30] Beck, Dave, 3.03.05.
[31] Sprenger, Polly, *Five Steps to Tract Home Success*, Home Energy Magazine Online. April, 1998. http://homeenergy.org/archive/hem.dis.anl.gov/eehem/98/980303.html
[32] Rashkin, Sam, Director: National Energy Star Program, Environmental Protection Agency, personal interview, 4.30.05.
[33] Wilson, Darren, President: Sierra Air Conditioning, personal interview, 5.07.05
[34] Building Science Corporation. BSC Final Report: Lessons Learned from Building America Participation, 1995-2003, on-line posting: Building Science Corporation website, February, 2003, p. 11.
[35] Beck, Dave, 3.03.05.
[36] Eventually, Pulte would shift to the new product, but it required building new relationships with both their insulation subcontractors and material providers.
[37] Bodzin, Steven, *Builders Find New Technologies Paying Off*, Home Energy Magazine Online, January/February 1999. http://hem.dis.anl.gov/eehem/99/990110.html
[38] Sprenger, April, 1998.
[39] Rudd, Armin et al. *Measurements of Attic Temperatures and Cooling Energy Use in Vented and Sealed Attics in Las Vegas, Nevada*. The Journal of the Energy Efficient Building Association (Minneapolis, MN: The Energy Efficient Building Association, Spring 1997) p.2.
[40] Beck, Dave, 3.03.05.
[41] The silver, gold and platinum levels should not be confused with the LEED rating systems which also use the same classifications- they are entirely different programs and while the U.S. Green Building Council is currently in the development stages of a residential rating system, at the time none existed.
[42] Rashkin, Sam, 4.30.05.
[43] ibid
[44] Kheir, Odeh, Director of Architecture, Pulte Homes Las Vegas, personal interview, 3.30.05.
[45] Anonymous, personal interview, 4.05.05.
[46] Kheir, Odeh, 3.30.05.
[47] Anonymous, Window Supplier, personal interview, 4.05.05.
[48] Beck, Dave, 3.03.05.
[49] Building Science Corporation. BSC Final Report: Lessons Learned from Building America Participation, 1995-2003. February, 2003, p.10.
[50] Wilson, Darren, 5.07.05.
[51] More information on these two products can be found on the Fancycler website: www.fancycler.com
[52] *State of the Art Building Concepts Lower Energy Bills*, On-line posting: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy02osti/31793.pdf March, 2002.
[53] Beck, Dave, 3.03.05.
[54] Bashford, Howard H., et al, *Drivers for Energy Efficient Decisions in a Competitive Residential Construction Market*, Cost Engineering, April 2002, p.30.
[55] Wilson, Darren, 5.07.05.
[56] ibid
[57] ibid
[58] Hodgson, Nat, 4.20.05.
[59] Anonymous, Building Code Official, City of Las Vegas Building Department, personal interview, 4.01.05.
[60] Bodzin, Steve, *Builders Find New Technologies Paying Off*, Home Energy Magazine Online, Jan/Feb 1999. Further confirmed in an interview with Dave Beck, 3.03.05.
[61] Rashkin, Sam, 4.30.05.
[62] Beck, Dave, 3.03.05. Beck pointed out that California's Title 24 regulations automatically qualify borrowers for the added income in that the EEM is based on the 1993 MEC, which is a much less stringent standard than California's own Title 24 code.
[63] Hodgson, Nat, 4.20.05.
[64] Rashkin, Sam, 4.30.05.

[65] Wilson, Darren, 5.07.05: it should also be noted that the HVAC subs were actually asked to conduct their own testing, in a sense, by integrating a program called "Check-Me" to properly calibrate the systems on newly competed homes. The software required the subs to purchase lap-top computers and run the testing themselves. It lasted about a year, at which point it was found that most every house was in compliance and therefore the program was no longer necessary. Wilson says he learned a tremendous amount, however, from that year of self testing.

[66] Kheir, Odeh, 3.30.05. The shift from Greenstone to MASCO occurred when the two major proponents of the Engineered for Life program became disgruntled with Greenstone and took the program to MASCO, keeping the initials but changing the name to Environments for Living. The shift to MASCO is interesting in that MASCO is not a product manufacturer, but rather an insulation subcontractor. Under the MASCO program, batt insulation may be used, as opposed to cellulose, as long as the installation is performed by MASCO certified installers and is inspected by an EFL certified inspector.

[67] Hodgson, Nat, 4.20.05.

[68] Beck, Dave, 3.03.05.

[69] Mullens, M. and M. Hastak, 2004, p.21.

[70] Guido, Daniel Walker, *Pioneers of Production Homebuilding*, Big Builder Magazine, May 2001, 172.

[71] Chippero, Chuck, General Manager & Plant Designer: Pulte Home Sciences, personal interview, 03.23.05.

[72] ibid

[73] Broad, Robert (Director of Product Engineering: Pulte Home Sciences) & Chippero, Chuck, personal interview, 03.16.05.

[74] Beliveau, Yvan, et al, Industrializing the Residential Construction Site Phase III: Production Systems, (Washington D.C.: U.S. Department of Housing and Urban Development, June, 2002)

[75] Chippero, Chuck, 03.23.05.

[76] ibid

[77] ibid

[78] Beck, Dave, 3.03.05.

[79] Kheir, Odeh, 3.30.05.

[80] Caulfield, John. *Bold Maneuvers*, Big Builder Magazine, 7.01.04.

[81] Broad, Robert and Chippero, Chuck, 3.16.05

[82] Deane, Daniela, *Home from the Factory*, The Washington Post, 12.11.2004.

[83] IBACOS is one of the five Building America teams, but, as with most other teams continues to function as a private company outside of the partnership. It would appear that their involvement with the PHS system fell into the latter category and the PHS homes are not considered Building America projects. Pulte, as with BSC, has a longstanding relationship with IBACOS.

[84] Newhouse, Eric, *Performance Evaluation of Prototype Houses: Minimum 40%-60% Savings* (Pittsburgh, IBACOS, 2004) multiple pages.

[85] Perez, Evan. *Factory-Made Parts Enter More New Homes.* The Wall Street Journal Online, 10.15.02.

[86] Broad, Robert & Chippero, Chuck, 3.16.05.

[87] O'Brien, Michael et al, Industrializing the Residential Construction Site (Washington D.C.: U.S. Department of Housing and Urban Development, 2000) p.33.

[88] ibid

[89] Chippero, Chuck, 3.23.05.

[90] ibid

[91] ibid

[92] ibid

[93] Anonymous, Building Code Official, Virginia, personal interview, 3.18.05.

[94] ibid

[95] Chippero, Chuck, 3.23.05.

[96] Anonymous, Electrical Subcontractor for PHS, personal interview, 4.01.05.

[97] ibid

[98] Newhouse, Eric, 69.

[99] Chippero, Chuck, 3.23.05.

[100] ibid

[101] Anonymous, Building Code Official, Virginia, personal interview, 3.18.05.

[102] Rashkin, Sam, 4.30.05.
[103] Broad, Robert & Chippero, Chuck, 3.16.05.
[104] Chippero, Chuck, 3.23.05.
[105] ibid
[106] Anonymous, Building Code Official, Virginia, personal interview, 3.18.05.
[107] ibid
[108] ibid
[109] Chippero, Chuck, 3.23.05.
[110] ibid
[111] Broad, Robert & Chippero, Chuck, 3.16.05.

Chapter 5: Conclusions and Recommendations

As vast and detailed as this foray into the production homebuilding industry may have seemed, I am confident in stating that it has only skimmed the surface of an incredibly complex sector of an industry which has historically eluded academic research. What follows is a list of conclusions and recommendations based on the past several months of my interacting with and researching two divisions of one very large corporation operating in an enormous industry. The extent to which these conclusions are upheld will be largely dependent on subsequent research into the topic.

Conclusions

1. *Innovations which are systemic in nature are largely dependent upon more centralized models of diffusion.*

Comparing the two different innovative processes presented in the case studies, the Building America projects and the PHS homes, it becomes clear that one is more clearly linked to the corporate vision of Pulte Homes. The decision to pursue the PHS model largely rested in the hands of Pulte's corporate headquarters and its success to date has been dependent upon their willingness to commit human and financial capital to the project. It is highly unlikely that a local division head would have the ability over-ride the decision to go with the PHS model, and once the model was in place the ability to tweak its functions would be very difficult.

That said, Pulte spun off a separate arm of the company to pursue the manufacturing processes. While it is questionable whether or not the PHS experiment can be considered "disruptive" in nature, it possesses many of the characteristics which Christensen uses to define such technologies. One important step for a company to take, argues Christensen, in its drive towards disruption is to spin off a smaller more flexible arm of the parent company within which the technologies can be pursued. This essentially frees the "innovators" from the constraints of the pre-existing methodologies of the corporate structure within which they are working. This was very important in the case of PHS. Many of the people I interacted with believed that they were pushing Pulte to the forefront of the industry in addition to revolutionizing homebuilding itself. With few exceptions, that type of enthusiasm was not found in the Las Vegas division's efforts with the Building America program.

The extent to which more industrialized processes are diffused throughout the industry at large will be largely dependent on competitor's perceptions of Pulte's success with the current model. It has already been rumored that other large national builders are planning similar facilities in the Washington D.C. market, possibly a testament to the keenness of the competitive forces working within the production homebuilding industry.[1] It should also be acknowledged that issues of the costs of this plant have been conspicuously absent from this thesis, furthermore so have issues of the profitability of the Washington D.C. division both before and after the plant. For competitive reasons, Pulte has refrained from releasing these numbers and they can not be gleaned from Annual Reports.

It is interesting to consider the evolving nature of the role played by the corporate entities of the *mega-production builders*. One person I spoke with implied that in the past, corporate was nothing more than a "banker" financing projects once the feasibility studies had been completed by the local operating divisions.[2] This is clearly no longer the case, as evidenced by several of Pulte's national initiatives like the Pratte, DiVosta and PHS models, not to mention the current national efforts towards plan simplification and standardization coupled with tighter supply chain management processes. While such trends may have detrimental impacts on the extent to which local forces can interact with the built environment around them, large scale changes geared at creating more efficient building practices and better homes could be greatly facilitated by the trend.

It is also worth noting that the systemic innovations typified by the PHS projects would doubtfully have been possible without some of the aforementioned trends in the homebuilding industry which have given companies like Pulte a distinct competitive advantage in the marketplace. The consolidated codes of Virginia, Pulte's size, profitability and market share in the region and their supply chain leverage were all crucial elements towards them being able to pursue more industrialized housing practices. I believe that the extent to which these trends continue to shape the strategic actions of large production builders will be largely responsible for the diffusion of such processes throughout the *mega-production* homebuilding sector.

The innovations typified by the Building America projects were not, and it is doubtful that they ever will be, diffused throughout Pulte nationally. Their implementation was placed entirely in the hands of local "champions," and while the importance of these local players can not be understated, their failure to influence the corporate agenda of Pulte should be noted.

2. *Incremental/sustaining innovations will diffuse more rapidly to small and large firms alike because, in general, they are easier, less costly and their results can be readily proven.*

It was noted in several instances that technologies adopted in the Las Vegas division of Pulte were rapidly adopted by competing builders in the market. This stemmed from two primary factors. First, Pulte was working with very large subcontractors who worked for other builders in the area. Once the subs realized the added benefits, in terms of efficiency and call-backs, they readily convinced competing builders to utilize them. This was clearly the case with the duct sealing which instantly reduced air leakage in the HVAC systems by upwards of 15%, while only increasing construction costs by less than $100.[3]

Second, the added benefits of some products, like the Low-E glazing on the window systems, were readily apparent to competitors and as the windows were more widely used, the price differential between these and the previously used glazing systems began to decrease, making them much more attractive to large and small builders alike.

More moderate and radical innovations, like the advanced framing techniques and cellulose insulation packages in un-vented roofs would appear to have diffused much more slowly, if at all, which may stem less from issues of cost than from trade resistance. Other builders may also have perceived the regulatory barriers which Pulte encountered with the system as too time consuming and costly to be implemented.

3. *Government partnerships are not the only catalysts for achieving successful innovations geared towards energy efficiency and sustainability.*

There is the widespread perception in the industry that building codes are to be treated as the baseline for the worst possible structure and as long as this belief persists the use of building codes to adequately push the envelope in terms of energy efficiency and sustainability will never be accomplished. It is important to return to the example of California and its Title-24 regulations for energy use. The codes are the strictest in the country and have required builders to make changes to their thermal envelopes which they may not have otherwise made.

There have also been instances in which federal and state governments have superceded codes in an effort to remediate the environmental impact of certain building technologies. The 1992 Energy Policy Act stipulated stringent low-flow toilet requirements in order to decrease water consumption in residential structures.[4] Furthermore local governments have also taken measures to increase the efficiency of homebuilding, like the City of Frisco Texas which mandates that all new homes must meet the EPA's Energy Star requirements.[5] Some have argued that the social dilemma implicit in using the code to make homes more efficient is that such innovations would greatly reduce the home's affordability, yet this is where the use of an energy efficient mortgage as a "safety net" could be incredibly beneficial.

The mortgages have not been widely used because, to date, they have not been needed. The affordability of homes has not been affected by most up-grades. The ability of regulatory bodies to revolutionize an industry can not be understated, recall for instance the affect on automotive technologies that California's increased emissions standards had in the eighties. Codes also have the ability to look beyond energy efficiency at other environmental impacts created by the homebuilding industry. Construction and Demolition waste is rampant and easily controllable. With an estimated 75% of construction waste being recyclable/reusable, technologies, like those illustrated at the end of the Las Vegas case study (the Packer-Grinder), can easily turn construction waste into usable construction materials. If such technologies were more regularly required on job sites across America, land fills would be making much less money on an incredibly wasteful construction industry. Neither of the case studies used in this thesis were driven to succeed through regulatory measures (they were, arguably, held back by them), but both proved that achieving fairly substantial levels of efficiency is not beyond even the largest and most profit-driven production home developers.

Furthermore, energy codes need to be enforced to the same level that structural and life-safety codes currently are. With so many homes in America not even meeting the minimum requirement for energy efficiency, it seems futile to push the 20% that actually are to even higher levels. The Las Vegas projects, in particular, have proven the importance of post-construction inspections and certified testing. While there is always the danger of such measures adding to an already clogged regulatory environment, requiring them of all builders would undoubtedly provide for more efficient residential construction practices.

Beyond building codes, it is important to note that the innovations adopted in the Las Vegas Division of Pulte are being wholly sustained by Pulte's partnership with the Environments For Living Program through MASCO. This private sector endeavor has proved incredibly beneficial to energy efficiency throughout many regions in the country and while it will always be important to consider the extent to which the government can assist in the development and deployment of new technologies and innovations, the ability of the private sector to add value to those innovations is of tremendous importance. Returning to the example of construction waste, it would seem entirely feasibly for the private sector to find a way of adding value to the waste generated by construction processes, particularly if that waste can be used to meet other construction material needs.

4. *The inflexibility of architectural design is a barrier towards more sustainable practices for large production builders.*

As production homebuilders reign in the number of plans and specifications which they work with in their drive to increase profitability, they place strict limitations on the ability of those homes to achieve maximum efficiencies through adapting to the constraints of the site. Previous studies have illustrated that by utilizing passive solar techniques in the design of a home (i.e. not placing large expanses of glass on south facing walls, designing louvers, sun shades and sun shelves, etc.) heating and cooling load reductions could be achieved much more easily. Yet when plans are being pulled from a book and consumers are purchasing based on nothing more than the aesthetic image of the rendering in the catalog, these types of efficiencies become impossible to achieve. The consolidation of building plans will eventually become a straight jacket for builders, entirely limiting their ability to expand on the efficiencies of the homes they're building.

One Pulte architect made an interesting statement when he said, "The Building America program does not affect the way we design a home, only the way that home is built."[6] Another Pulte sub explained to me that in a particular Pulte subdivision, ¼ of the homes built are experiencing higher cooling loads because they were designed with south facing sun rooms in a desert climate.[7] Such design inefficiencies must be overcome.

Furthermore, the model homes that I have looked at are incredibly inefficiently designed (spatially). I'm confident that close to 1,000 square feet of space could be trimmed off of the houses without sacrificing any programmatic requirements. The plans today are being marketed as bigger and bigger with much less attention paid to how a house is used and what is actually required for living. Reigning in some of these design issues could greatly benefit homebuilders, homebuyers and the environment in general. It should also be noted that these types of design inefficiencies clearly open the door for more *disruptive* design innovations which may capitalize on some of Pulte's manufacturing techniques and target a less demanding consumer who will be happy to do away with the extravagances of the contemporary Pulte Plan.

5. *That said, buildings are only part of the problem.*

Issues of site planning and urban design have not been dealt with extensively in this thesis, partly because they are not entirely relevant to the topic, partly because I have not perceived any innovative practices being pursued in this regard with either of my case studies. The site design issue is an important one, and it does not appear to be addressed in any of the programs that I've come across. Notions of permeable and drought resistant landscapes and higher density housing typologies are not currently in the vocabulary of production homebuilders. I did find, however, that the leverage for such issues is typically addressed when Pulte buys into a master planned development project and is forced to abide by the goals of the project therein, thereby implying that this may be a good direction for concerned communities to take.

In Chapter 2 of this thesis I briefly reviewed methods currently being used to attach high performance building programs to progressive planning agendas- typically through market or regulatory drivers. To my knowledge, neither of the divisions which I studied was involved with any developments of this nature. However, Pulte Homes has purchased the right to develop the second and third phases of the Civano Project in Tucson, Arizona, and there would already appear to be problems with their meeting many of the requirements. For instance, Pulte immediately declined to incorporate many of the mixed-use amenities which were part of the original design and has strayed from the original intentions of the community to place garages in the rear of the homes, thereby improving the streetscapes. Pulte has, furthermore, voiced its intentions to include certain gated areas within the development which is in direct violation of the original developer's guidelines. Finally, there appears to be a disagreement on the amount of open space being provided by Pulte. The original plan for the community stipulated a 30% minimum requirement, and current residents are arguing that Pulte is failing to meet this by including things like power line easements in their calculations of open space.[8]

In the second chapter of this thesis I outlined the difference between *sustaining* and *disruptive* technologies and their affect on existing industry leaders. The extent to which these labels can be applied to the innovations studied here will be discussed later in this chapter. It is important, however, to point out that the potential for truly disruptive technologies lies not in changing only the process by which a home is built, but also by considering the types of homes a firm is building. I believe that the truly *disruptive* technologies in housing will stem from homebuilders that recognize the extent to which consumers are being entirely "over-served" by existing practices in that they are being sold inefficient, over-sized houses built at low densities. Disruptive housing technologies will likely adapt many of the PHS innovations and find a way to apply them to smaller, higher density forms of housing to meet the needs of the ever-burgeoning group of consumers that don't need what companies like Pulte are selling them.

6. *The production homebuilding industry is characterized by embedded networks, as opposed to "arms-length relationships," and this is beneficial to the process of innovation.*

When beginning this study, I fully expected to discover an industry characterized by competitive bidding and adversarial relationships, yet this was not the case. Many of the subcontractors in both the Washington D.C. and Las Vegas Divisions have longstanding relationships with Pulte Homes, often in excess of ten years. The subcontractors in the PHS homes, while at first hesitant and critical of the new process, were anxious to continue working with Pulte and have adapted to the new system. Building code officials have commented on the fact that they often draw on Pulte's knowledge with the system, and are not afraid to call Pulte executives or project managers with questions that they may have regarding other projects. Product suppliers dealing with the PHS factory have ambitions of growing along with the system and in most cases, Pulte intends to allow them to do so. It has previously been mentioned the extent to which software developers have depended on Pulte to grow their own businesses.

Similar traits have been exhibited in the Las Vegas market. However, it should be noted that some of these loyalties have been disrupted by the new Pratte model which has displaced a longstanding framing relationship and caused both Pulte and Pratte severe growing pains during the transitional phase, often to the detriment of the efficiency measures at hand. It is interesting to note, in this instance, the extent to which a corporate decision to integrate Pratte into the Pulte fold disrupted existing networks in the Las Vegas market. In order to complete the work before them, Pratte had to beef up their labor forces extensively, thereby "stealing" employees from framing operations which had previously completed a majority of Pulte's work in the market.[9] None-the-less, other subcontractors I spoke with held the company in high regard, and viewed themselves as members of the Pulte team, rather than mere subcontracted laborers. Some even implied that they were looking down the line at the possibility of entering into a relationship similar to the Pratte deal, in addition to having used the Pulte relationship to enter into new markets where they had not previously worked. Product suppliers also leverage their relationship with Pulte to enter new markets, a window manufacturer, whose partnership with Pulte began in the Las Vegas Division is in negotiations with Pulte National to enter into a nation-wide purchasing contract which would help bring their product into markets where they do not currently operate.[10]

Furthermore, the EFL and Energy Star Programs have spawned a cottage industry of professionals whose sole purpose is to test and inspect homes for energy efficiency so that they may achieve either rating. As their livelihoods are largely dependent on builders pursuing these practices, they have become some the most aggressive salespeople for the pursuit of more efficient building practices. Pulte staff also appears to make efforts to be involved with local trade organizations; for instance, Nat Hodgson, the current VP of Construction for the Las Vegas Division is the chairman of the Southern Nevada Homebuilders Association Energy Code Committee and is actively involved in working with the state on the adoption of the new 2003 International Energy Conservation Code (IECC).

I believe that the existence of such embedded networks has facilitated Pulte's ability to adopt innovative practices in both Divisions, and that these types of networks should continue to be built upon.

7. *The possibilities of the incremental innovations in the Building America Program to be expanded upon are extremely limited, while the PHS model poses greater opportunities for growth.*

As previously mentioned, the Building America Program has been designed in stages. The fist stage was to reduce heating and cooling loads by 30% and the next stage was to get to 30% whole house energy reductions. These first two steps, while not necessarily easy, were entirely within the capabilities of most production builders today. This is because the changes did not entail substantial costs and could be accomplished, for the most part, using existing technologies built into products that were already in the market place. The next step is to go to 50% energy reductions in homes, and it would appear that the relationship between Pulte and BSC has largely broken off at this point. Early experiments with higher levels of efficiency in the Phoenix market indicated cost premiums of $7,600 in order to achieve 44% reductions in energy use, which undoubtedly scared most other Pulte Divisions away from the process.[11] Nobody I spoke with at Pulte implied that the program was moving forward or that there were any plans to pursue increased efficiencies in the Las Vegas Division. Most people I spoke with outside of Pulte felt that it was going to be difficult, or impossible, to get the large production builders beyond where they are today. Furthermore, some subs implied that the entire program may be dropped and Pulte may simply revert to their old way of building. It is entirely dependent upon the leadership in the division at any given time. Dave Beck, former V.P. of Construction for the Las Vegas Division, told me himself, "If management changes at Pulte and the next guy says 'I don't want to do it,' it'll go by the wayside."

The Building America interventions can be considered as a "cluster" of sustaining incremental and moderate technologies. Each intervention required the attention of different product manufacturers, subcontractors and code officials. To a certain degree, each of these parties will again be affected if Pulte decides to pursue the partnership to the next level. It is extremely laborious, and without the centralized authority like that exhibited in the PHS model, where it was recognized that the entire system was dependent on the changes at hand, each party is left with a certain degree of flexibility in resisting what will happen next.

The PHS model, on the other hand, appears to possess tremendous potential for growth. Individuals involved with the system are clearly excited and energetic about the possibilities of achieving higher efficiencies and are currently working on systems to do so. Experiments with a manufactured roof system, which will finally put the entire shell of the home in the factory's hands, are underway and there would appear to be constant tinkering with architectural and structural details being pursued in an effort to improve on the homes performance.

However, it is important to note that, based on Christensen's definitions, the PHS model should not be considered a *disruptive* technology, as defined in Chapter 1. While the technologies used are systemic in nature and radical in their impact and could, furthermore, be considered to affect the entirety of the social system surrounding homebuilding, they were essentially designed to provide an identical house in price and appearance to the system it replaced. While Pulte exhibited many of the traits which would imply a disruptive technology (i.e. spinning off a separate, quasi-independent branch of the company, hiring people from other industries, etc.), they never targeted consumers who were being over-served by the current housing market by providing a lower priced, under-performing product. Instead they simply added value to their existing product line.[12] Pulte went to great lengths to insure that the average consumer would not be able to visually discern a PHS home from the traditional site-built structures they were used to seeing at a production homebuilding site. It is almost ironic when one considers the pains Pulte went through to construct houses with no perceptible differences to the ones they were already building.

8. *Well trained sales and marketing staffs are an integral component in overcoming consumer misperceptions of innovative practices and new technologies.*

Both of the divisions I looked at commented on the importance of training their sales staff to pitch the new products they were offering. It is important to note that consumer perceptions of factory-built housing have long been held up as one of the primary obstacles to the adoption of more industrialized homebuilding processes. Yet Pulte undertook an extremely aggressive marketing campaign in order to sell the PHS home (see Appendix #3). With a thoughtful and well organized sales pitch, the organization has easily overcome this barrier and convinced costumers of the inherent qualities of the PHS system which make it superior to traditional building practices. The sales staff was well-informed, presented the system clearly and had lots of supporting documentation readily available in a clear concise language that the average consumer could easily understand. It is interesting to note that this very same division and sales staff considered themselves incapable of marketing a downsized HVAC unit to cool the home in a much more efficient manner.

The extent to which *mega-production homebuilders* are vertically integrated and utilize their own in-house sales staff bodes well for their ability to market technological innovations. Just like employees, consumers need to be trained to look at homes differently and to develop a deeper understanding of the systems which make a home work (or *not* work). The ability to train their own staff and have them integrally involved with the deployment of new technologies gives *mega-production builders* a distinct advantage in this regard. With the exception of the PHS system, they do not appear to be capitalizing on it.

Recommendations

1. *Government Programs prioritizing incremental innovations should focus on small to medium sized builders in the future.*

The Building America Program has been incredibly successful given its fairly minimal budget of approximately $16 million. Much of this can be attributed to the structure of the program in which the DOE has assumed a managerial role of a series of private sector organizations which were charged with the day to day operations of the research. Previous studies have downplayed the role played by DOE in this regard and it is questionable whether this was a fair criticism given that the vision and goals for the project rested entirely in their hands.[13]

That said, there were some outcomes of the program which were unforeseen by the planners at DOE. For one, it was expected that large builders would pursue the program and small builders would implement their best practices, in essence, the "bell-cow" approach.[14] It would appear that this has not been the case, and in many instances the most aggressive partners have been those small operations which were attempting to differentiate themselves from the *mega-production builders*. Small builders tend to be characterized by local leaders, often times they are family owned businesses which are distinguished by a strong internal vision for building a quality product. Infiltrating these organizations can be much less tedious than trying to work with a large production builder and growing the innovations and technologies within them tends to be less riddled with issues of cost and liability. With smaller builders, decisions are made more promptly and implementation tends to occur more rapidly. Thus as the Building America Program ascends to higher levels of energy efficiency, focusing on these smaller homebuilders could provide tremendous results.

2. *Should government programs continue to work with mega-production homebuilders, they should attempt to infiltrate those organizations at the corporate level and not the division level.*

It has been stated at several points in this paper that large production builders are becoming increasingly centralized in their drive to boost market share and increase profits. For government programs to continue working with *mega-production homebuilders* at the local or division level will continually put them at odds with corporate mandates. The Energy Star Program has made efforts in the past to work directly with the corporate organizations of large production builders in order to make energy efficiency part of those company's larger vision for how to build homes, and while the program failed with most builders, it succeeded with Pardee Homes who will now rate all of their projects as Energy Star.[15] That said, Energy Star is setting the bar lower than many of the Building America Projects, yet if a more collaborative dialogue with corporate entities could be established, the effects of such programs could be much more far-reaching.

3. *Innovations and new technologies will need to address the lack of skilled labor in the trades, while also making such innovations beneficial to the trades who adapt to the changes.*

The PHS model grew largely out of a concern that there was a shrinkage of skilled labor in the construction trades. The process was designed to address this issue by "dumbing" down the systems where possible and by taking more control over the product design to give the trades a clearer road map where particular innovations involved more complicated processes. Arguably, Pulte did a poor job of passing the benefits of this more economical and less skill-driven process onto their subs, who were not allowed to increase their profitability under the scheme (with the exception of the electrical sub who's fees for the PHS homes have increased by approximately 35%). Fewer laborers are now required to build a PHS home and the home can be constructed in a shorter period of time, yet Pulte appears to have wholly internalized the increased profitability once it was passed over to the subs, and this may explain the increasing quality control issues currently coming to light on some of the projects. This internalization of the process benefits may ultimately degrade the "embeddedness" of the networks in the Washington D.C. Division in a manner similar to the way the Pratte model has disrupted many of the Las Vegas networks.

In the less systemic innovations typified by the Building America projects, extensive work went into ensuring that trades were able to complete the tasks at hand, yet alterations to the design process (with the exception of the initial technical support provided by BSC) were never made. Once BSC strayed from the partnership, the ongoing implementation of the technologies at hand was largely left in the hands of the remaining trades, which is problematic in a field with such high turnovers. In essence, it placed the onus of retraining new workers to complete more complicated tasks, entirely on the shoulder of the trades themselves. This is why subcontractors, like Sierra Air Conditioning, must have bi-weekly "tool box talks" in two different languages in order to ensure that their workers are kept up to date on the latest technologies.[16] It is also why moving to higher levels of efficiency may be difficult.

4. *Partnering with product developers and building material suppliers will be a key component of integrating technological innovations into the homebuilding industry.*

While the PHS model took more control of product development in the systems they were working with (making their own SIP panels and floor trusses, etc.), the Las Vegas Division was dependent on what many of their product developers could provide them with (recall the problems with the ventilation control devices and windows). Arguably, this process of working with product developers and suppliers was easier for Pulte due to the purchasing leverage it had, both locally, and nationally. Yet for smaller builders, the added costs and liabilities associated with new products can often serve as a detriment to those products being adopted for use. Future government programs should pay very careful attention to the materials and products being placed in homes and work on improving the efficiency and affordability of better products. Well designed product development programs will not only focus on creating better products, but making a more cost feasible transition to market by building bridges between the homebuilding industry and those manufacturers and suppliers to insure widespread acceptance of new products which could thereby reduce the initial cost of such innovations to homebuilders. Given their size, purchasing power and geographic scope, the bridges should clearly be built between product developers and *mega-production builders*. It is clearly one of those instances in which government programs designed to foster innovative practices would benefit from working directly with corporate entities as opposed to individual divisions, as this is where the real purchasing power lies.

The impact of working directly with material providers and product developers has been illustrated in the Weyerhaeuser example of transitioning all of their forest land to FSC and CSA sustainable forestry practices. The importance of working with product suppliers was also seen in the Las Vegas Division's experience with getting York to seal their furnaces in order to decrease leakage in the HVAC systems. Currently, such partnerships are anomalies in the industry, yet with the increasing supply chain leverage of *mega-production builders* and the incredible research capacity of government programs like Building America they could become the norm.

5. *Large production homebuilders need to develop more carefully integrated design and engineering systems.*

I believe the key to the success of both the PHS and Building America innovations was the extent to which they integrated design and engineering services. In the PHS model, it is widely acknowledged that the factory was only a small part of the problem, and that changing the engineering process to accommodate the new system was the major obstacle. This required Pulte to internalize the structural engineering services and to develop stronger relationships with mechanical engineers and software designers rather than simply allow the trades to handle such processes.

In the Building America projects, engineering approaches were arguably the genesis of the program itself. Early proponents of the program made strong arguments for taking a "systems engineering" approach to homebuilding which created stronger links between structural, mechanical and architectural design. One of BSC's roles in the partnership was to actually design and engineer the mechanical systems which would be used in the houses (the willingness of trades to cooperate with BSC largely stemmed from BSC's technical and practical knowledge of home mechanics), early obstacles entailed convincing structural engineers to sign off on the changes. The only engineering that's being internally driven today in the Las Vegas division is the value engineering typified by the Pratte partnership. One can't help but think that if more effort were put into integrating engineering processes into the original designs, things like value engineering, which tend to occur at the very final stages before construction, might not be necessary in the end.

6. *A cross-industry dialogue needs to be established so that homebuilding can learn lessons from more sophisticated manufacturing and development industries.*

One interesting conclusion in studying both of these cases is the extent to which the theoretical underpinnings for both projects were essentially derived from other industries. The PHS model required the manufacturing know-how of several individuals who were recruited from the automotive industry. Without their knowledge of more sophisticated manufacturing processes, the efficiencies achieved in the PHS system would doubtfully have been accomplished.

Similarly, the Building America program, while implemented by building science experts, was largely designed by industry outsiders- people who had experience in other scientific fields and manufacturing processes. Their ability to step back from the homebuilding industry's current practices and evaluate where the flaws existed led them to designing a program that was less based on the product, but more focused on the means by which that product was brought into existence and the many relationships which were involved in the process. Currently, much of the effort in the homebuilding industry is being placed on improving communication channels *within* the industry- a noble effort indeed, given their somewhat lacking state. Yet, very little effort is focused on cross industry dialogues to see what can be garnered from the expertise of other manufacturing and development processes. It is my belief that such a dialogue would greatly improve the efficacy of the homebuilding industry's effort to build a better product.

Research Limitations

There were several difficulties in the research and writing of this thesis, and I feel it is important to make mention of them here. The major difficulty was in obtaining first hand accounts of both processes. The production homebuilding industry tends to operate at lightening quick speeds and getting people involved with, or related to, the industry to stop and give their time to research endeavors was an incredibly difficult task. Emergency situations arise on the radars of production homebuilders on a nearly daily basis, and graduate student researchers do not merit high on the list of phone calls to be returned. When I went to visit the PHS factory in Manassas, one of the financial officers had had a heart attack while visiting the plant the day before and much of the local staff was embroiled in dealing with the problem. Chuck Chippero, despite this crisis and an incredibly busy work schedule, still managed to give me an incredible amount of his time, for which I am extremely grateful. The Las Vegas division is still in the midst of transitioning to the Pratte System and the transition is anything but smooth- wreaking havoc on construction schedules and project deadlines. The turbulent nature of that division and the extent to which Pulte's profitability is tied to its prosperity were definite barriers towards obtaining the time of Pulte staff in Las Vegas.

Furthermore, several of the people I spoke with expressed concern as to their views being misinterpreted by Pulte and were extremely uncomfortable with the notion that their thoughts and ideas were going to be incorporated into a research project dealing directly with Pulte Homes. Some refused to speak with me.

It is also important to note that in many instances there was an extreme information disconnect between data provided by trade journals, Pulte employees, government agencies and Pulte subcontractors. In most instances, I have attempted to double and triple check statistics provided in this paper, but I must say it is with some trepidation that I write this conclusion, knowing full well that I, myself, may be providing misinformation to future researchers. In every instance, I have tried to account for this and where I felt that information was entirely unreliable, it has not been included.

Finally, I would like to address the fact that I used two case studies within a single corporate entity. I did this because I felt it was interesting to see a single company pursuing such different avenues and also because working within a single organization greatly eased my ability to conduct research. However, the method that I have used makes it difficult to extract conclusions which can be applied to the industry as a whole; as different builders will often exhibit different propensities to pursue innovative practices. Pulte Homes, based on conversations I've had with many people in the industry, is more progressive than many other ***mega-production builders***, thus to draw inferences from its activities may provide somewhat of a slanted viewpoint.

Conclusion

I do not necessarily feel that the contemporary production homebuilding industry, Pulte included, is sustainable by any measure. The ability of large builders to adopt innovative practices which can help to remediate the environmental impacts of their homes is feasible; however, the production homebuilding industry will never be "sustainable" in its current form. The degree to which the industry consumes land and builds single-use, auto-dependent communities of over-sized homes at extremely low densities will never allow it to be qualified as such. The extent to which innovative practices can address such issues is well beyond the scope of building scientists and will largely depend on the ability of planning agencies to define a better agenda for how we are to inhabit the landscapes in which we build.

This thesis finds that what has traditionally been recognized as a single industry characterized by a number of structural traits which have made it "resistant to change" is rapidly evolving into a bifurcated industry of *mega-production homebuilders* and smaller regional entities. At the outset of this thesis I asked whether some of the current trends in production homebuilding (increased builder size, more stable capital, code consolidation, vertical integration and supply chain management techniques) were creating an environment in which large production builders would be "ripe" for more innovative practices, and what the remaining obstacles to the adoption of such innovations might be. This thesis concludes that, based on two case studies of a single *mega-production builder*, the hypothesis is supported. The Pulte Home Science projects, in particular, clearly exhibits how a large production builder can capitalize on these current trends in the industry to pursue more systemic innovations. It also finds that consumer perceptions and demand-side resistance, in addition to the lack of more carefully integrated design and engineering processes are still substantial obstacles for *mega-production builders.*

I also asked whether contemporary government programs, designed to foster innovation in homebuilding, were going to be successful in dealing with the evolving structural characteristics of *mega-production builders.* While the thesis supports the fact that the Building America Program has been largely successful in dealing with large production builders to date, it acknowledges that it will be difficult to expand on those successes without tying into the larger corporate agenda of the parent company and developing stronger relationships with product manufacturers. I have also concluded that such programs may better serve the industry by focusing on the smaller regional and local builders who will increasingly need to differentiate their products in the face of severe competition from the *mega-production builders.* Future research, while continuing to understand the traits of the smaller, regional homebuilding industries around the country, will need to pay careful attention to the special traits inherent in *mega-production homebuilders* because it is a sector of the industry whose impact will increasingly be felt in the decades to come.

[1] Anonymous, Electrical Subcontractor for PHS, personal interview, 4.01.05.
[2] Beck, Dave, Area Vice President, Pulte Homes, personal interview, 3.03.05.
[3] Wilson, Darren, President: Sierra Air Conditioning, personal interview, 5.07.05.
[4] Eisenberg, David and Yost, Peter, Sustainability and Building Codes, Environmental Building News, September 2001, p.3.
[5] ibid, p.3
[6] Kheir, Odeh, Director of Architecture: Pulte Homes, Las Vegas, personal interview, 3.30.05.
[7] Anonymous, personal interview, 5.10.05.
[8] Civano Neighbors, Civano Neighbors Neighborhood Association Position Statement on Civano Master PAD Formal Submittal, Civano Neighbors website: www.civanoneighbors.com , Feb. 11, 2005.
[9] Anonymous, personal interview, 5.10.05.
[10] Anonymous, Window Supplier, personal interview, 4.05.05.
[11] Building Science Corporation. BSC Final Report: Lessons Learned from Building America Participation, 1995-2003. (Building Science Corporation Website: www.buildingscience.com , February, 2003.
[12] Some researches that I have spoken with have implied that Christensen's definition of disruption is too narrow in its dependence on shifting consumer preferences. The extent to which the PHS model affects the labor relationships in the homebuilding industry and the extent to which it could potentially affect the profit margins of the homebuilder may lead some to forgo Christensen's definition and allow PHS to be deemed "disruptive."
[13] Norberg-Bohm, Vicki et al, Building America Program Evaluation: Volume 1, Main Report, (Cambridge: Kennedy School of Government, September 2004).
[14] James, George & Pollock, Ed. Department of Energy: Building America Program, personal interview, 3.18.05.
[15] Rashkin, Sam, Director: Energy Star Homes, personal interview, 4.30.05.
note: Pardee Homes of California and Nevada has been very aggressive for a production builder in terms of environmental practices. They have experimented with photovoltaic panels, pursued the use of sustainably harvested wood products and paid careful attention to issues of indoor air quality. It should, however, be mentioned that they are a much smaller builder than most national companies and only operate in the California and Nevada markets and completed approximately 2,600 homes in 2004.
[16] Wilson, Daren, 5.07.05.

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Energy Star Program, U.S. Environmental Protection Agency:
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Environmental Building News (EBN, subscription required):
http://www.buildinggreen.com/

Environments for Living (MASCO contractor services):
www.eflhome.com

Home Energy Magazine Online:
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Housing Zone, directory of information and services for the homebuilding industry (contains links to both *Professional Builder* and *Giants Magazine*)
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Integrated Building and Construction Solutions (IBACOS):
www.ibacos.com

International Code Council (ICC):
www.iccsafe.org

National Association of Homebuilders (NAHB):
http://www.nahb.org/

National Association of Homebuilders Research Center (NAHBRC):
http://www.nahbrc.org/

National Renewable Energy Laboratory (NREL):
www.nrel.gov

OIKOS, green building source:
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Partnership for Advanced Technology in Housing (PATH):
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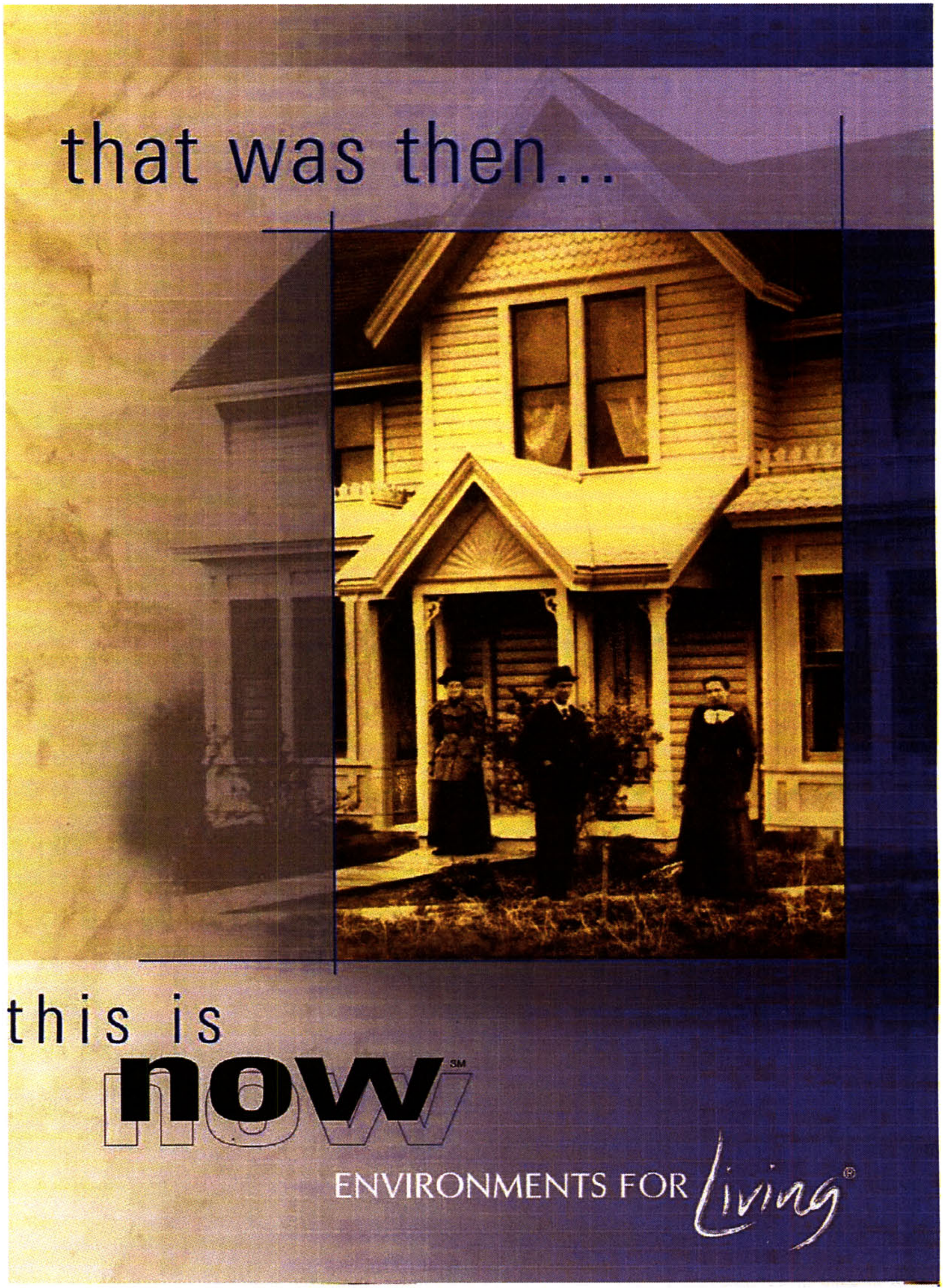
Appendix #1
Environments For Living® Guarantee


that was then...
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now℠
ENVIRONMENTS FOR Living®

ENVIRONMENTS FOR Living

Dear Builder,

Thank you for your interest in Masco Contractor Services' *Environments For Living*® Program. Working closely with selected builders, we at Masco Contractor Services believe that the *Environments For Living*® Program has great potential to promote the principles of Building Science. The Program's **energy usage and comfort guarantees** have the capability to generate **builder marketing and sales benefits** that we believe will help you deliver **increased value and satisfaction** to your customers.

The enclosed materials explain the basic *Environments For Living*® Program and how it operates. These enclosures, together with this cover letter, constitute the **Program Documents.** Your Master Certified Contractor (MCC) can answer any questions you might have and help you complete all documents.

Although more fully explained in the Program Documents, here is **a brief overview** of what you can expect from the *Environments For Living*® Program:

First, you will send your building plans and specifications to our Plan Review Center for comparison with the Program Requirements. The results of the comparison will be communicated to you. You should carefully evaluate the Plan Review, since your participation may require you to incur additional costs.

You will then receive a Project Agreement for each subdivision and each custom home that you wish to be included in the Program. You will be responsible for designing and constructing each home to include the Program Requirements and to satisfy the Performance Criteria. This means that you will need to understand and clearly communicate the enclosed Program Requirements and Performance Criteria to your subcontractors.

During the construction phase, you will be provided with consulting services and performance testing. The amount, type and timing of the testing may vary, depending upon your level of participation *(Silver, Silver Plus, Gold, Gold Plus, Platinum or Platinum Plus)*. Once we receive your weekly job schedule, we will arrange for the required testing.

In order to receive the *Environments For Living*® Program's Limited Guarantee, all Program fees must be paid, and the homes must have passed the required testing. If any tested home fails to successfully pass the required tests, you may be charged additional fees for follow-up testing.

Please note that the liability of Masco Contractor Services, Inc. is expressly limited to the Energy Usage and Comfort Guarantee provisions as described in the *Environments For Living*® Program Limited Guarantee. Since the liability of Masco Contractor Services is limited, it is extremely important that you review the Program Requirements and Performance Criteria and validate them based upon your own best practices and expertise in the building industry.

As a participant in the Program, **you will receive promotional support**, including point-of-purchase signs and consumer brochures. The Program Documents describe, in detail, how you can use the ***Environments For Living*® Program mark** in your own promotional materials.

For a complete description of other provisions of the Program, please review all of the enclosed Program Documents carefully. The Program Documents include a Project Agreement that is required for each subdivision and custom home that you wish to enroll in the Program. **The Program Documents supersede any agreement to which the Program Agreement is attached.** As this program grows and expands, it may be necessary for Masco Contractor Services to modify the Program Documents. Notice of any changes will be sent to you.

If, at any time, you decide to end your participation in the Program, simply send me written notice by certified mail 60 days prior. Masco Contractor Services will notify you in the same manner if, at any time, you are no longer eligible to participate.

I look forward to welcoming you to the *Environments For Living*® Program!

Sincerely,

Masco Contractor Services, Inc.

Rick Davenport
Director of Building Science

Enclosures:

Frequently Asked Questions
Fee Structure
Program Requirements and Performance Criteria
Level Comparison
Sample Limited Guarantee
Homeowner's Brochure
EFL Project Agreement
Use of *Environments for Living*® Mark

ENVIRONMENTS FOR Living®

LIMITED GUARANTEE

LENGTH AND LEVEL OF GUARANTEE

THE ENERGY USED FOR HEATING AND COOLING YOUR HOME LOCATED AT:

IS GUARANTEED NOT TO EXCEED AN ANNUAL USAGE OF:

WE ESTIMATE THAT YOUR HEATING AND COOLING COST WILL NOT EXCEED AN AVERAGE OF $________ /MONTH BASED UPON ENERGY RATES OBTAINED FROM:

THIS COST IS STRICTLY AN ESTIMATE AND WILL VARY WITH YOUR ACTUAL COST OF ENERGY. THIS HEATING AND COOLING COST IS BASED ONLY ON THE UTILITY RATE AND DOES NOT INCLUDE TAXES, SURCHARGES, OR OTHER FEES CHARGED BY YOUR UTILITY PROVIDER. SEE REVERSE SIDE HEREOF FOR FURTHER DETAILS.

www.eflhome.com

ENVIRONMENTS FOR *Living*®

LIMITED GUARANTEE

Comfort Guarantee (Limited) : If the front of this guarantee indicates that it is "Silver Level," then this paragraph does not apply to you. Otherwise, the *Environments For Living*® Program guarantees to you, the original homeowner, that the temperature at the location of the thermostat in your home will not vary more than 3 degrees from the temperature at the center of any conditioned room within that thermostat zone. If your home has a room that does not meet this comfort guarantee, the *Environments For Living*® Program will identify the reason(s) for the temperature variance and coordinate with your builder to have the necessary repairs performed. In some cases, this may involve the addition of screens or protective window coatings to decrease the radiant effect of sunlight on the temperature in your home.

Heating & Cooling Guarantee (Limited): The *Environments For Living*® Program guarantees that the energy you use to heat and cool your home (as calculated in the Account Analysis below) will not exceed the Guaranteed Usage listed on the front of this guarantee subject to the terms of this guarantee. Since this is a guarantee of energy use and not cost, any cost will vary with your cost of energy. The Guaranteed Usage is calculated using a computer model to simulate gas (therms) and electricity (kilowatt hours) energy required to heat and cool your home in a typical weather year. If the energy used to heat and cool your home (as calculated in the Account Analysis below) exceeds the Guaranteed Usage, the *Environments For Living*® Program will reimburse you 100% of the cost of the difference between the Guaranteed Usage and the Heating/Cooling Energy (defined below) subject to the limitations listed in this guarantee. The reimbursement will be based on an average of your monthly utility rates during those 12 months. At its discretion, the *Environments For Living*® Program may (but is not required to) inspect, meter or make repairs as necessary to lower the energy requirements for heating and cooling your home in the future.

Guarantee Duration: To activate this guarantee, you must send in your reply card within 30 days of the date you purchase your home. Once you activate the guarantee, it will begin on the first day of the second month after your closing date (the Start Date) and continue for the duratior listed on the front of this guarantee. This guarantee is not transferable.

Your Responsibilities: Since your actions can greatly affect energy use, this guarantee does not apply and is void unless you exercise prudent energy management of your home. In order to maintain this guarantee, you agree to:

1. Use windows and doors prudently when operating your heating, ventilating, and cooling (HVAC system.
2. Follow manufacturer's instructions regarding operation and service of the HVAC system, including annual inspections and filter replacement.
3. Set your thermostat at no higher than 72 degrees F during the heating season and no lower tha 75 degrees F during the cooling season.
4. Notify the *Environments For Living*® Program of any change to your home that may increase th energy use, its equipment or occupancy after the date of this guarantee so that appropriate adjustments can be made to the Guaranteed Usage. You will be charged a fee for the re-evaluation and adjustments to the Guaranteed Usage.
5. Submit any claims and notices in writing to:

   The *Environments For Living*® Program
   2339 Beville Road
   Daytona Beach, FL 32119

   Submit claims relating to the first year of the guarantee within 30 days after the first anniversa of the Start Date. Submit any remaining claims within 30 days after the second anniversary of the Start Date. Include copies of your monthly energy statements and proof of the HVAC syster maintenance and service work.

Annual Account Analysis: Your utility bills include all the energy you use for your home, including activities other than heating and cooling (such as lighting, appliances, pools, and spas). To determine whether you may have a claim under this guarantee, you will need to complete and submit the enclosed Energy Use Worksheet. For each 12-month period during this guarantee, the worksheet uses a formula to estimate the part of your total energy use that applies to heating and cooling and then compares it to this guarantee. Sample worksheets are provided for your reference. The following is a description of the formula. First, we calculate the average of your three lowest full months of energy use when your home is occupied. We assume that this average estimates the energy you used for activities other than heating and cooling. That average is then multiplied by 12 and subtracted from your total energy use during that 12-month perioc The remaining number estimates the portion of energy that was used to heat and cool your home (the Heating/Cooling Energy). If needed, we also may adjust the Heating/Cooling Energy to exclude other unusual energy use not related to heating and cooling, such as seasonal use of pools and spas.

Limitations: This guarantee does not cover claims due to the malfunction or improper installation or maintenance of the HVAC system. This guarantee does not cover claims due to abuse, neglect, accident, flood, fire, or other natural disasters.

Disclaimers: Except as listed above, The *Environments For Living*® Program makes no other express warranties. Where permitted by law, The *Environments For Living*® Program disclaims all implied warranties including warranties of merchantability or fitness for a particular purpose. If the law does not permit such a disclaimer, then any such implied warranties shall be limited to the duration of this express warranty. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. The *Environments For Living*® Program is not liable for any incidental or consequential damages. Some states do not allow the exclusion of incidental or consequential damages, so the above exclusion and limitation may nc apply to you. Without limiting the general disclaimers above, the *Environments For Living*® Program makes no representations or warranties of any kind, express or implied, to anyone with respect to mold, Radon, or any other environmental contaminants or pollutants, whether biological or chemical in source or characteristics. This guarantee gives you specific legal rights, and you also may have other rights which vary from state to state.

For more information, call toll-free 1-866-912-7233

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ENVIRONMENTS FOR *Living*

Fee Structure

1. The Plan Review

All guarantees require a plan review.
$250 per production plan level plus $.05 for each additional sq. ft. over 2,500
$450 per custom plan plus $.05 for each additional sq. ft. over 2,500

- Pricing is based on the selection of a single level (Silver, Gold or Platinum) per plan, per climate.
- Additional review levels or climates for a plan are $50 each.
- More than one option will require additional fees.
- Re-analysis of a plan is $50. Re-analysis includes, but is not limited to, the addition of sq. ft. to an original plan, change of utilities (i.e. all electric to electric and gas) or change of equipment (i.e. electric furnace to gas furnace).
- Additional fees are required for *Energy Star®* certification.
- Submit all plans, original input sheet and your payment of the appropriate fees to:
  The *Environments for Living®* Program
  1496 Airway Circle
  New Smyrna Beach, FL 32168

If you have any questions concerning appropriate fee amount, please call the ***Environments For Living®*** Program Sales Office at **1-866-912-7233**.

FEE STRUCTURE

2. The Guarantee Package

Pricing varies by sponsorship status, type and the number of homes dedicated to the Program. Contact the *Environments For Living®* Program's Customer Service department at **1-866-912-7233** or visit **EnvironmentsForLiving@masco-csc.com** for a list of approved Program sponsors.

	Sponsored Fee	Non-Sponsored Fee	Guarantee Length
500+ Production Homes*	$145	$185	2 Years
Less than 500 Production Homes*	$170	$210	2 Years
"Plus" Production Homes**	$430	$480	3 Years
Custom Homes**	$525	$575	3 Years

*Subdivisions must contain a minimum of 75 houses to qualify for the production price.

**Requires a full series of tests on each home.

You will receive an invoice for each guarantee. Make all payments payable to the *Environments For Living®* Program.

Each guarantee package includes the following:

- **Silver Level: Heating & Cooling Energy Use Guarantee**
  The limited energy use guarantee refers to the estimated amount of energy needed to heat and cool the home. See guarantee for further details and limitations.

  OR

Fee Structure (continued)

- **Gold and Platinum Levels: Heating & Cooling Energy & Comfort Guarantee**
  The limited energy use guarantee is combined with a Comfort Guarantee. "Comfort" means that the temperature at the location of the thermostat will not vary more than 3 degrees from the center of any conditioned room within the zone. See guarantee for further details and limitations.

  NOTE: Gold and Platinum levels also include an *Energy Star®* designation. Additional fees will be charged for the *Energy Star®* certification.

  OR

- **Custom and "Plus" Level Homes: Three Year Guarantee**
  By requiring that each home is tested, Custom Homes qualify for a three-year guarantee, at the designated level of participation. **Silver, Gold and Platinum level production homes** may also qualify for a three-year guarantee, if each home is tested.

- **Performance Testing**
  Testing is included with each package:

  - **Silver, Gold and Platinum Level Production Homes**
    Testing for air tightness, duct tightness and pressure balancing. The first two production homes of each model will be tested to assure the standards are met. After compliance has been confirmed, 15% of all homes will be tested.

  - **Custom and "Plus" Level Homes**
    Testing for air tightness, duct tightness and pressure balancing. All homes will be tested.

- **Quality Control**
  Random quality control testing is included with each package.
  All test results are monitored, and a random sample of all tested houses are re-tested to ensure that results and testing procedures are in compliance with the Program Standards and the Plan Review.

- **Marketing**
  - Standard model home package - no charge (one package per subdivision of 75 or more homes).
  - Includes up to 5 corplast signs with stakes, 100 consumer brochures, Program video, subdivision opening flyers, and point-of-purchase display.
  - Customized signs and additional collateral materials may be purchased through the *Environments For Living®* Program.

3. Incremental Construction Cost

As bid. See Program Requirements and Performance Criteria, and Plan Review.

The *Environments For Living*® Program
Level Comparison with *Energy Star*®

Silver	Gold	Platinum	*Energy Star*®
• **Plan Review**	• **Plan Review**	• **Plan Review**	• **Plan Review**
• **Tight Construction** - .50 cfm or less per square foot of envelope area at 50 pascals.	• **Tight Construction** - .35 cfm or less per square foot of envelope area at 50 pascals.	• **Tight Construction** - .25 cfm or less per square foot of envelope are at 50 pascals.	• **Tight Construction** - .35 cfm or less per square foot of envelope area at 50 pascals.
• **Sealed Ducts** - 5% of conditioned floor space are in cubic feet per minute at 25 pascals or 7% of the high speed fan flow. R-6 Insulated Ducts.	• **Sealed Ducts** - 3% of conditioned floor space area in cubic feet per minute at 25 pascals or 5% of the high speed fan flow. R-6 Insulated Ducts.	• **Sealed Ducts** - 3% of conditioned floor space area in cubic feet per minute at 25 pascals or 5% of the high speed fan flow, R-6 Insulated Ducts. If ducts are in conditioned space, 7% of conditioned floor space area in cubic feet per minute at 25 pascals; or 10% of high speed fan flow.	• **Sealed Ducts** - 10% of conditioned floor space area in cubic feet per minute at 25 pascals.
• **Fresh air ventilation** - Fresh air provided at a minimum rate of 7.5 cfm per person plus .01 cfm per square foot of conditioned area.	• **Fresh air ventilation** - Fresh air provided at a minimum rate of 7.5 cfm per person plus .01 cfm per square foot of conditioned area.	• **Fresh air ventilation** - Fresh air provided at a minimum rate of 7.5 cfm per person plus .01 cfm per square foot of conditioned area.	• **Fresh air ventilation** - No requirement.
• **Improved Thermal Systems** - Insulation installed to code and manufacturer's specifications with special attention paid to gaps, voids, compression and wind intrusion. Insulation and the air barrier shall be installed in physical contact with each other.	• **Improved Thermal Systems** - Insulation installed to code and manufacturer's specifications with special attention paid to gaps, voids, compression and wind intrusion. Insulation and the air barrier shall be installed in physical contact with each other. Efficient Windows required (see Program Requirements and Performance Criteria).	• **Improved Thermal Systems** - Insulation installed to code and manufacturer's specifications with special attention paid to gaps, voids, compression and wind intrusion. Insulation and the air barrier shall be installed in physical contact with each other. Efficient Windows required (see Program Requirements and Performance Criteria).	• **Improved Thermal Systems** - Insulation must meet code. Efficient windows may be required to meet HERS rating.
• **HVAC sized and installed correctly**	• **HVAC sized and installed correctly**	• **HVAC sized and installed correctly**	• **HVAC sized and installed correctly** - Not part of program.
• **Internal Moisture Managed**	• **Internal Moisture Managed**	• **Internal Moisture Managed**	• **Internal Moisture Managed** - Not part of program.
• **Combustion Safety Standards** - No Vent Free Fireplaces. Combustion Appliances must be sealed or vented. CO Detectors.	• **Combustion Safety Standards** - No Vent Free Fireplaces. Combustion Appliances must be sealed or vented. CO Detectors.	• **Combustion Safety Standards** - No Vent Free Fireplaces. Combustion Appliances must be sealed or vented. CO Detectors.	• **Combustion Safety Standards** - Not part of program.
• **Pressure Balanced** - Not part of program.	• **Pressure Balanced** - All rooms within 3 pascals pressure difference.	• **Pressure Balanced** - All rooms within 3 pascals pressure difference.	• **Pressure Balanced** - Not part of program.
• **Testing Protocol** - Testing for air tightness, and duct tightness, and pressure balancing. The first two production homes of each model will be tested to assure the standards are met. After compliance has been confirmed, 15% of all homes will be tested. 100% of all Custom and Plus series tested.	• **Testing Protocol** - Testing for air tightness, duct tightness, and pressure balancing. The first two production homes of each model will be tested to assure the standards are met. After compliance has been confirmed, 15% of all homes will be tested. 100% of all Custom and Plus series tested.	• **Testing Protocol** - Testing for air tightness, duct tightness, and pressure balancing. The first two production homes of each model will be tested to assure the standards are met. After compliance has been confirmed, 15% of all homes will be tested. 100% of all Custom and Plus series tested.	• **Testing Protocol** - Blower Door and Duct Blaster test required in 15% of participating homes.
• **Energy Star** - May qualify.	• **Energy Star** - Qualifies. At least 30% more energy efficient than homes built to the 1993 Model Energy Code (MEC).	• **Energy Star** - Qualifies. Up to 50% more energy efficient than homes built to the 1995 Model Energy Code (MEC).	• **Energy Star** - Qualifies. At least 30% more energy efficient than homes built to the 1993 Model Energy Code (MEC).
• **Guaranteed* Heating and Cooling Energy Use (2 years)**	• **Guaranteed* Heating and Cooling Energy Use (2 years)**	• **Guaranteed* Heating and Cooling Energy Use (2 years)**	• **Guaranteed* Heating and Cooling Energy Use** - Not part of program.
	• **Guaranteed* Comfort (2 years)** - Consistent Temperatures within 3 degrees of Thermostat setting.	• **Guaranteed* Comfort (2 years)** - Consistent Temperatures within 3 degrees of Thermostat setting.	• **Guaranteed* Comfort** - Not part of program.
• **Plus Series (3 year guarantee)** - Available with complete series of tests.	• **Plus Series (3 year guarantee)** - Available with complete series of tests.	• **Plus Series (3 year guarantee)** - Available with complete series of tests.	• **Plus Series (3 year guarantee)** - Not part of program.

*See program description and guarantee for details and limitations.

Appendix #2
Pulte Home Science Factory Processes

Pulte Home Sciences VIRGINIA

Panelized Foundation Wall System

PHS System Benefits over Standard Construction

Wall system utilizes high-strength steel reinforced concrete rated at a minimum of 5,000 PSI.

Walls are available in 8' and 9' heights and accommodate walkouts and welled exits.

Walls are level and square within ¼" and a complete home foundation can be set in the field in less than one day.

Walls have a smooth, clean appearance that is easier to finish.

SETUP ⇒ REBAR ⇒ POURING ⇒ CURING ⇒ STRIPPING ⇒ LOADING

Process and Material Overview

Setup

40' X 12' moving form tables start in the SETUP area where the PANS and BULKHEADS are placed assisted by a laser outline projection system to layout the foundation walls. Multiple walls are setup on one form table.

Rebar

The moving form table travels to the reinforcing bar (REBAR) station where precut assemblies are added and the initial wall quality check is completed.

Pouring

At the POURING station a moving concrete spreader is filled from the "flying bucket" which transports concrete from the batch mixer to the spreader. The concrete spreader then travels the length of the form table filling all wall cavities.

Brick Ledge

After the walls are poured, brick ledge is added and the form table travels to the CURING chamber until the concrete walls have achieved sufficient strength to be removed from the form table.

Final QC
At the stripping station the walls receive a final quality check and are lifted by a specialized crane rig from the form table. All components including pallets, bulkheads and pans are automatically cleaned and staged for reuse.

Loading
The finished walls are loaded onto custom designed trailer carriers for delivery to the field installation crews.

Truss Assembly

PHS System Benefits over Standard Construction

Trusses are lightweight and allow for a rigid deck design.

Trusses span very long distances, which allow for large deck panel assembly.

Open metal web trusses allow for timesaving during plumbing and HVAC installation inside the truss and maximize basement ceiling height clearance.

Pulte Home Sciences
VIRGINIA

SAW SHOP ⇒ TRUSS FABRICATION ⇒ CNC CUTTING ⇒ PANEL ASSEMBLY ⇒ LOADING

Process and Material Overview

Precut Dimensional Lumber

All dimensional lumber required for the deck panel trusses are pre-cut, labeled and staged on specialized carts in front of the truss machine.

Component Assembly

Operator loads machine rated 2X4 premium lumber into the first stage of the truss machine for the assembly of the top and bottom truss chord lengths as well as insertion of the vertical 2X4 truss supports. Trusses are manufactured in a sequence to match deck panel assembly.

Web Insertion

At the second stage of the truss machine the metal "V Webs" and "I Webs" are hydraulically pressed to complete the truss fabrication. Trusses can be up to 44 feet in length.

Final Assembly/Inspection

In some cases special features are added such as OSB sheathing. The trusses are then inspected for quality and staged for transfer to the deck panel assembly table.

Deck Panel Assembly

PHS Floor System Benefits over Standard Construction

High-resin premium 7/8" thick OSB floor decking contribute to a very rigid floor system design (L/720 max deflection)

Jumbo 8' X 24' OSB sheathing allows for fewer floor seams compared to 4' X 8' sheets.

Open metal web trusses allow for timesaving during plumbing and HVAC installation and maximize basement ceiling height clearance.

PHS floor systems can be installed in the field in less than one day.

Pulte Home Sciences
VIRGINIA

SAW SHOP ⇒ TRUSS FABRICATION ⇒ CNC CUTTING ⇒ PANEL ASSEMBLY ⇒ LOADING

Process and Material Overview

CNC Multifunction Bridge
Automated CNC Multifunction Bridge cuts 7/8" Jumbo 8X24 Oriented Strand Board (OSB) sheathing to custom fit each deck panel for a complete first or second floor deck system.

Component Assembly
Team members assemble deck panel components (sill plate, rim board, open web trusses, blocking and braces) assisted by a laser outline projection system. Components fit together within +/- 1/16".

Automation
Automated CNC Multifunction Bridge drives in mechanical "scrail" fasteners, cuts HVAC and plumbing openings in the sheathing and draws outline for field installed interior steel walls.

Loading
Panels are loaded on a flatbed trailer for delivery to field installation crews. A typical house plan requires 15-20 deck panels.

Structural Insulated Panel (SIP) Wall Assembly

PHS System Benefits over Standard Construction

Pulte Home Sciences VIRGINIA

Overall quality is improved by delivering walls that are built under controlled conditions resulting in straighter walls inside and out.

The SIP wall system is stronger than conventional 2X6 framed walls in every category (axial, bending, racking and shear tests).

SIP walls provide better energy efficiency by delivering a whole wall R-14 rating and allow for a tighter envelope with less air filtration.

Building wall panels up to 36 feet in length reduces field construction time.

LAMINATION ⇒ CNC CUTTING ⇒ SUB-COMPONENTS ⇒ FRAMING ⇒ WINDOW INSTALLATION ⇒ LOADING

Process and Material Overview

SIP Lamination

SIP Blank panels are fabricated by laminating an EPS foam core between two sheets of 7/16" thick Oriented Strand Board (OSB) 24 feet in length. The SIP composite is then placed under pressure while the adhesive cures. After lamination, the SIP blank is staged for cutting using specialized material handling equipment.

CNC Machine

The cutting operation is performed by a state-of-the-art CNC machine, precisely cutting and routing each section of SIP wall via a cut routine derived directly from the engineering drawings. This provides a high quality wall component built to tighter tolerances than can be economically achieved utilizing conventional "stick" framing techniques.

Sub-Component Assembly

A computer controlled framing table is utilized to frame window and door assemblies. Pneumatically powered brackets clamp the dimensional lumber in the correct position for assembly while SIP sections are attached to complete the component. The entire assembly is then flipped by the machine allowing the opposite side to be nailed together.

Framing

Sub-components and larger wall sections are mated together on the framing tables. Mechanical clamps aid in the assembly ensuring a tight fit of all wall components. Lifting straps are installed, house wrap is applied and the wall section is now framed.

Window Installation

A precise and repeatable window installation procedure in a controlled environment provides a high level of quality control. Plant installed windows also reduce assembly time in the field.

Steel Wall Assembly

PHS System Benefits over Standard Construction

Interior steel walls will not rot, warp, split, crack, or creep and will remain straight and true reducing dry-wall "nail pops"

20 Gauge Material is used to support Load Bearing Walls

Interior steel walls are Non-Combustible and will not contribute Fuel to Fire

Steel roll-form process is lean with very little waste and steel is 100% recyclable

Pre-Assembled Panels speed up Field Erection

Pulte Home Sciences
VIRGINIA

Coil Loading ⇒ Frame Master Process ⇒ Wall Assembly ⇒ Loading and Shipping

Process and Material Overview

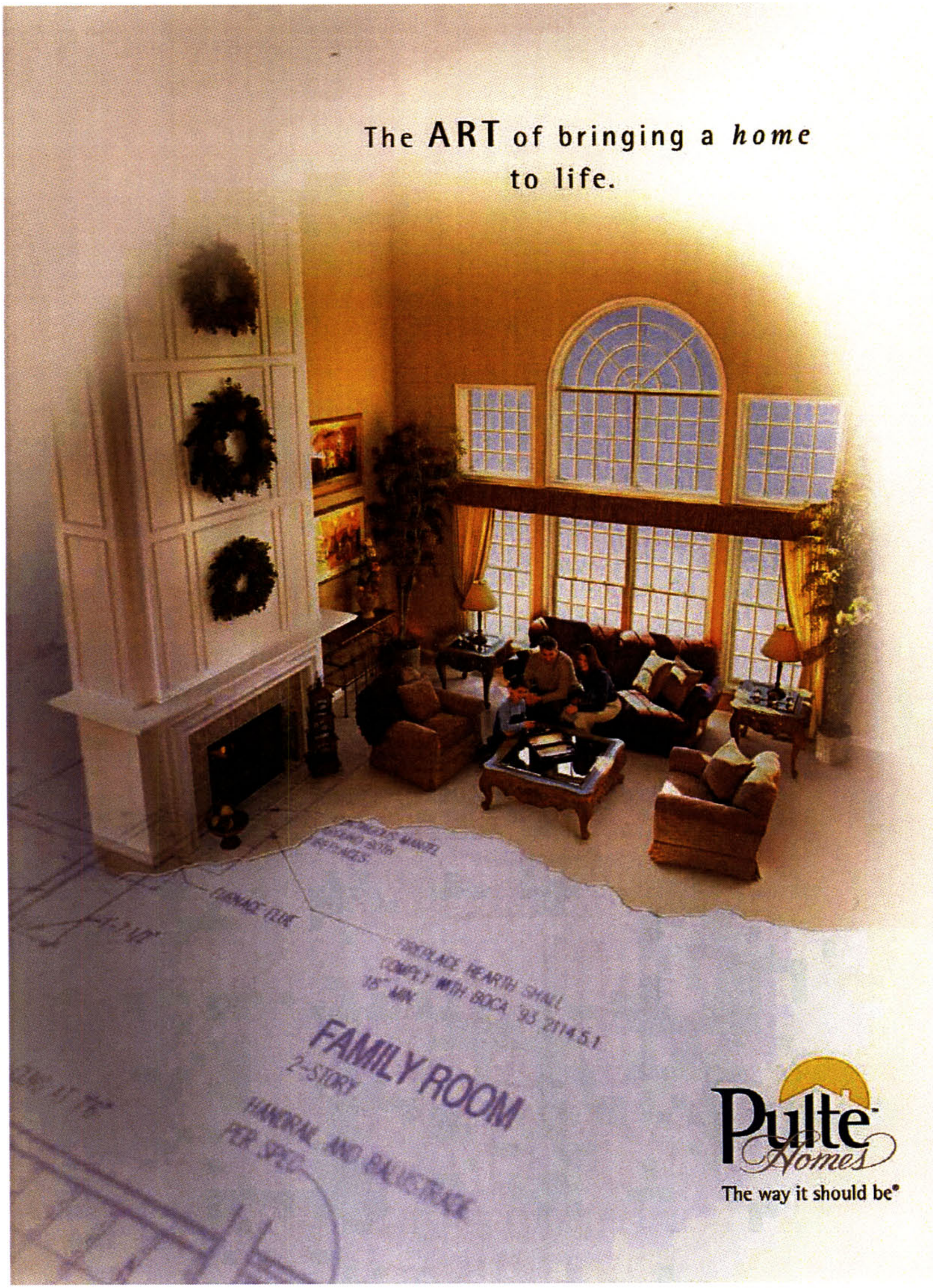
Coil Loading
3000 lb steel coils are inspected for quality compliance and loaded on the decoiler. The flat steel is then threaded through the automated FRAME MASTER forming machine.

Frame Master Process
The automated "roll forming" machine fabricates all steel studs, top plates and bottom plates. All required holes and indentation details are automatically stamped and each steel piece is labeled to ease wall panel assembly. The overall process is lean with very little waste.

Wall Assembly
Aided by a computer "CAD" display, operators assemble each interior steel wall panel by connecting the steel studs to the appropriate top and bottom plates. High speed collated screw guns are used to attach all wall components together with specially designed screws.

Loading and Shipping
After the interior steel wall panels are assembled, the completed wall is pushed forward and inspected for quality compliance. Completed walls are stacked to form a pallet and the pallets are labeled for delivery to the job site for field installation.

Appendix #3
Pulte Home Science Sales Literature


The ART of bringing a *home* to life.
FIREPLACE HEARTH SHALL
COMPLY WITH BOCA '93 2114.5.1
18" MIN.
FAMILY ROOM
2-STORY
HANDRAIL AND BALUSTRADE
Pulte Homes
The way it should be®

Pulte Homes
The way it should be
pulte.com

Our floors are quality underfoot

At Pulte Homes, we are dedicated to finding a better, more efficient way to build our homes. And in this community, the difference it makes is noticeable as soon as you take your first steps inside. Utilizing precise factory manufacturing techniques, we build technologically advanced floors that offer homeowners many advantages.

The strong, quiet type

Pulte Homes engineered flooring systems use steel webs that make them stronger. And factory manufacturing also enables them to accommodate larger sheets of subflooring. Larger sheets mean fewer seams, so there's less chance of squeaks, cupping or warping.

Multi-functional design

The other benefit to this approach is under the floor. The floor joist design permits ductwork and plumbing to be run through the trusses, out of view. And it saves space, so you get more headroom and a cleaner look in the room below.

Environmental improvements

At Pulte Homes, we are always looking for ways to be more environmentally efficient in the homes we build. For example, we use metal webs in our engineered flooring system instead of wood. And using less wood helps save more trees.

At Pulte Homes, when you stand on our floors, you'll know we stand for quality.

Pulte Homes is devoted to identifying better materials and methods that lead the industry. We develop environmentally friendly applications and constantly search for innovative, next-generation ideas that contribute greatly to the high quality found in every home we build. It's part of an ongoing effort to make owning and living in our homes more comfortable, enjoyable and efficient.
The way it should be.

These engineered flooring systems are not available in all communities. To learn where else you can find this product, ask your Pulte Homes representative.

Pulte Homes

The way it should be

pulte.com

A foundation
you can build dreams on

Doing things the same old way is not the Pulte Homes way. We construct ideal basement foundations in this community by combining the advantages of controlled factory manufacturing with on-site building. As a result, we are able to realize a number of benefits for homeowners like you.

Weather ready

Imagine building a home without delays caused by weather or temperature changes. With our pre-cast concrete foundations, Pulte Homes offers exactly that. Because they're made to exacting standards in a constant and controlled environment, our foundations can be installed rain or shine.

Formed to function

Our pre-cast foundations are pressure rated for the same tolerances as heavy-use airport runways – 5000 psi. They provide greater strength, resist leaks and make for a warmer, drier basement area. In other words, they offer a basement ideally suited for living.

Advantages you can see

Along with a smoother, cleaner finish than conventional-poured foundations, Pulte Homes pre-cast walls readily accommodate additional insulation or drywall, quickly and easily. And depending on the area, our basements may offer up to eight inches more headroom than the industry standard, so they don't "feel" like basements.

At Pulte Homes, we build on innovation. And that's important because quality construction starts with a solid foundation.

Pulte Homes is devoted to identifying better materials an methods that lead the industr We develop environmentally friendly applications and constantly search for innovati next-generation ideas that contribute greatly to the high quality found in every home w build. It's part of an ongoing effort to make owning and livi in our homes more comfortabl enjoyable and efficient. The way it should be.

Pre-cast foundations are not available in all communities. To learn where else you can fin product, ask your Pulte Homes representative.

Pulte Homes
The way it should be®
pulte.com

Exterior Walls:

Innovative technology creating superior structure

Finding a better way to improve an old idea sets Pulte Homes apart. Applying innovative technologies to basic structural components, such as walls, makes our homes stronger, safer and more energy efficient.

A scientifically advanced exterior wall

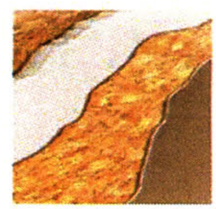
The exterior walls of Pulte Homes in this community are Structural Insulated Panels (SIPs), which consist of exterior sheathing, a foam core and interior sheathing, bonded with advanced adhesives. Similar technology is employed to keep aircraft light enough to fly, yet strong enough to withstand incredible levels of force.

With structural attributes similar to an I-beam, SIPs have demonstrated their superior stiffness and strength by withstanding the trauma of earthquakes, tornadoes and hurricanes better than homes with conventional exterior walls. And they're more fire resistant – there is no hollow cavity in the SIP solid insulation core, so there is no internal "air" space in which fire can quickly spread.

Improved efficiency and comfort

Built in an off-site, factory-controlled environment, our SIP design puts insulation in the ideal space. Small holes are built into the foam core that serve as conduits for electrical wiring, so insulation is not damaged during on-site wiring. This contributes to constant interior temperatures with fewer hot or cold spots. In fact, a new study by the Oak Ridge National Laboratories (ORNL) proves that a 4-inch SIP wall outperforms conventional 2"x 4" framing with batt insulation. This same energy efficiency is good for the outside environment, too, resulting in a reduction of carbon emissions.

Strong. Reliable. Efficient. These innovative exterior walls take the most fundamental building task – creating the outside structure of your home – to a higher level of dependability and performance.



Pulte Homes is devoted to identifying better materials ar methods that lead the industr We develop environmentally friendly applications and constantly search for innovati next generation ideas that contribute greatly to the high quality found in every home v build. It's part of an ongoing effort to make owning and liv in our homes more comfortab enjoyable and efficient.
The way it should be.

Structural Insulated Panels are not available all communities. To learn where else you can this product, ask your Pulte Homes represent

Pulte Homes
The way it should be
pulte.com

Interior Walls:
Building a better home,
from the inside out

At Pulte Homes, the same old wall just won't do. Our relentless pursuit of quality improvement results in the kinds of innovations that make for stronger, safer and longer-lasting construction. Pulte Homes interior walls are a perfect example.

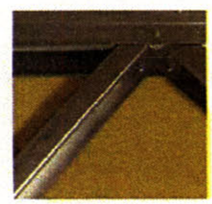
Steel-framed strength and longevity

Our interior walls in this community are framed with steel. The structural benefits of steel construction are numerous. Steel-framed walls are straighter, with less twisting and bowing, resulting in fewer unsightly nail pops. And since steel is non-combustible, our interior walls are safer in the event of a fire.

Forest-friendly engineering

The absence of wood studs in our interior walls yields benefits for the environment, as well. Simply put, using less wood saves more forests.

Walls are the most fundamental component of any home, creating structure, defining living space and providing comfort. The interior walls of Pulte Homes are engineered to exceed your expectations in all of these areas.



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Interior walls like this are not available in all communities. To learn where else you can fin them, ask your Pulte Homes representative.

Pulte Homes
The way it should be®
pulte.com

Introducing
Pultrim™

You may not think too much about exterior trim and gutters, but fortunately, at Pulte Homes, we do. With a restless curiosity to improve the looks of your home, keep maintenance requirements low and provide maximum strength and durability, our engineers have developed a better gutter and exterior trim material. It's called Pultrim – and it's available in this community.

Exterior gutters and trim that look and perform better

This innovative idea at Pulte Homes is born with a difference in materials. Like boat hulls and auto body parts, Pultrim is mostly fiberglass. Fiberglass strands are saturated with resins, heat activated and precision formed. The benefit is a precise shape on gutters and trim that holds crisp edges year after year. Pultrim highlights the accents on our homes, but it has functional benefits as well. It's resistant to all kinds of weather extremes, which minimizes warping and shrinkage. Gutters are structurally stronger to stand up to heavy snow and ice without sagging. Pultrim is coated with a high performance paint, so, unlike wood trim, it doesn't require painting. And it's resistant to fading and discoloration, so your home looks good as long as you own it.

Protection is another finishing touch

In the production process, Pultrim exterior trim and gutters form an interlocking barrier that also protects your new home from weather, wind, and warping. This patent-pending process is perfect for Pulte Homes because of the way our homes are precision framed. And because we're always looking for a better way.

Pulte Homes is devoted to identifying better materials and methods that lead the industry. We develop environmentally friendly applications and constantly search for innovative, next-generation ideas that contribute greatly to the high quality found in every home we build. It's part of an ongoing effort to make owning and living in our homes more comfortable, enjoyable and efficient.
The way it should be.

Pultrim is not available in all communities.
To learn where else you can find this product, ask your Pulte Homes representative.