

Bridging the Diffusion of Innovation Chasm for Green Housing

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ABSTRACT

Limited transaction and unit attribute information curtail the diffusion potential of green homes and create significant valuation and underwriting problems for the housing debt capital markets—more specifically mortgage originators (lenders) and appraisers. Put into the context of the technology adoption life cycle this missing information prevents green homes from crossing the chasm into the mainstream market. As lenders and appraisers are the gatekeepers of the mainstream mortgage markets, they will be key stakeholders in any strategy for green homes to cross this chasm. The missing transaction and attribute data creates two opportunities for scholarship. The first opportunity is to create and provide preliminary evidence of the chasm in the green housing market place. The second opportunity is to analyze, in the context of this chasm, what information and tools appraisers are using, at present, to estimate the value of high performance homes.

Acknowledgements

In, *A Confederacy of Dunces*, author J. K. Toole describes a young man by saying, “You could tell by the way he talked, though, that he had gone to school a long time. That was probably what was wrong with him.” First and foremost, I offer my sincere thanks to the constellation of individuals who, in the last three years, worked to keep me from drifting too far towards becoming this character. To each of you, I will remain forever grateful.

With respect to this dissertation, I would like to express deep and abiding gratitude to Prof. Ted Koebel for his patience as well as his valuable and constructive guidance throughout the project. Your willingness to share your expertise and criticism was greatly appreciated and was instrumental to its success.

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Preface & Attributions

Though the lion’s share of the work in this research project was the principal responsibility of the author, the work as a whole would not have been possible without the efforts and support of the co-authors involved. Each provided intellectual, methodological, and organizational guidance. Much of what is presented here was built from the foundation of their ideas from which the author was able to explore in new

directions. The author is beyond grateful for their guidance and contributions; the work would not have been possible without them. Below is a summary of each co-author's contributions by chapter.

Chapter 3: Establishing the Framework for the Green Housing Information Chasm

All work for this chapter was performed by the author and through guidance by faculty members from Virginia Tech and the University of Virginia. Their contributions are listed below:

- Professor Ted Koebel, PhD (Department of Urban Affairs and Planning): Concept development and refinement, literature review, methodology development
- Professor Andrew McCoy, PhD (Department of Building Construction): Concept development and literature review
- Professor George Overstreet, PhD (Department of Commerce, University of Virginia): Concept refinement and financial concept oversight

Chapter 4: Towards a Temporary Solution for Estimating the Contributory Value of High Performance Housing Technologies

All work for this chapter was performed by the author and through guidance by faculty members from Virginia Tech. Their contributions are listed below:

- Professor Ted Koebel, PhD (Department of Urban Affairs and Planning): Concept development and refinement, methodology development

Chapter 5: Appraisal of High Performance Single Family Homes

All work for this chapter was performed by the author and through guidance by faculty members from Virginia Tech. Their contributions are listed below:

- Professor Annie Pearce (Department of Building Construction): Methodological development and conceptual criticism

Chapter 1: Point of Departure

Research Problem Background

According to the US Census Bureau and the Energy Information Agency, from 1980 to 2009, the number of housing units in the US grew from 81.6 to 113.6 million. During the same period, the consumption of energy per housing unit dropped from an average of approximately 114 million to 89.6 million BTUs (Energy-Information-Administration, 2010). The US Green Building Council (USGBC) reports that 384 cities or towns across 45 states have adopted public policies creating incentives or requiring use of green building rating systems (Kontokosta, 2011; USGBC, 2012a). Additionally, the USGBC, the Department of Energy (DOE), and the Environmental Protection Agency report that, since the late 1990's, over 1.5 million homes have been certified under either the voluntary Energy Star or Leadership in Energy and Environmental Design programs (EPA-DOE, 2012; USGBC, 2012b). Taken en masse, it appears that energy efficiency and green building, specifically green housing, is a growing phenomenon.

In 2011, the Virginia Center for Housing Research embarked upon a HUD sponsored analysis of the diffusion of innovative green and energy efficient products into the US homebuilding industry (McCoy, Koebel, Rahmandad, & Frank, 2010). Initial literature review and anecdotal evidence suggested home valuation as a substantial obstacle to the diffusion of green homes into the mainstream housing market (Adomatis, 2010). Deeper analysis indicated that appraisers might not be able to accurately estimate the value of green homes due to missing data describing their value proposition (or the compelling set of reasons that a consumer would purchase a product).

Green homes are often described as having a two-part value proposition. They create both increased environmental performance and increased financial performance for home occupants (Yudelson, 2008). In the context of the efficient markets hypothesis applied to property markets, one would expect that current prices for a green home should reflect all available information about it. However, the market failure of missing or limited availability or accessibility of comparable attribute and home sales data for comparable analysis (Adomatis, 2010; Fuerst, McAllister, van de Wetering, & Wyatt,

2011) creates significant difficulty in price discovery leaving scholars to propose new methods of valuing the contribution of increased environmental performance of homes and commercial buildings (Popescu, Mladin, Boazu, & Bienert, 2009). This missing information will be referred to as the missing information problem or the information gap throughout the dissertation.

Where data exist, residential real estate scholars have been analyzing green housing prices using multiple regression techniques to describe the relationship between greenness and price (Bloom, Nobe, & Nobe, 2011; Nevin, Bender, & Gazan, 1999; Nevin & Watson, 1998). So, too, have commercial real estate scholars (Dermisi, 2012; Eichholtz, Kok, & Quigley, 2011; Fuerst & McAllister, 2008; Harrison & Seiler, 2011; Wiley, Benefield, & Johnson, 2010). Most have assumed that the green certification carried by a home (or building) describes the value proposition fully enough for research purposes. Similarly, appraisers of green homes have attacked the valuation of green homes in the same way, using comparable sales analysis and hedonic regression with green certification as a key binary (or at least ordered classification) variable (Popescu, et al., 2009). However, searches to identify homes with green certifications are difficult to conduct in many multiple listing services (MLS) because the certification is not a searchable field or because one cannot yet compare between rating systems (Price-Robinson, 2013; Stuart, 2012). Additionally, the literature and practitioners note that when data describing any high performance technologies in homes are available, it is often unsearchable or buried in a 'comments' field for many of the same reasons (Fuerst, et al., 2011); so, creating large data sets is a challenge.

Given the missing information problem, it is unlikely that valuation problems for high performance homes are related to the mechanics or mathematics of the comparable sales method or the science of performance measurement (though some problems limit their effectiveness). In fact, the tools from building science are growing more accurate and, where sufficient data exist, the comparable sales and hedonic valuation methods are capable of ferreting out the value contribution of the most complex building and site attributes (AI, 2008; Babcock, 1932; Donnelly, 1989; Pagourtzi, Assimakopoulos, Hatzichristos, & French, 2003). Where this information gap exists, it is very likely to limit the diffusion of green homes into the market place and reinforce the problem of

limited information flows blunting the precision of green home valuations. This lack of precision in valuation creates a negative feedback loop or vicious cycle that distorts market signals and reduces the number of comparable units built in the future, which further suppresses the amount of information about attributes and sales available for valuation purposes. Without sufficient information to make judgments about the value of a high performance home, which, all other things being equal, should be worth more than an identical comparable without the high performance attributes, a potential adopter is placed in a position similar to that described by a used car buyer (see (Akerlof, 1970) for his discussion of used car pricing in the context of asymmetric information). They do not have the data to substantiate the choice between two products—one could be a lemon and the other a cherry or some combination thereof (to borrow from Akerlof).

Research Opportunity

Missing or inaccessible information about green building attributes makes it difficult to describe the value contribution of those attributes. Where one can't estimate the value of the home including these attributes, it is difficult to explain to a buyer or lender why they should choose to adopt them in the first place—the value proposition of increased environmental and financial performance cannot be fully substantiated. High-technology entrepreneurs also face a similar problem when bringing innovative products to market. They often have little trouble convincing technophiles to adopt their product, but face headwinds when describing the product's value proposition to more pragmatic buyers (Moore, 1991, 2002). Where the entrepreneur cannot convince the more pragmatic buyers to adopt their product, the product tends to fail.

Moore describes this process as crossing the chasm or crossing the gap between groups of buyers who want the newness of the innovation and buyers who want the pragmatic benefits of an innovation (e.g., increased productivity). Moore's theory of the chasm specifically posits that the diffusion of innovations is not as continuous as the normal distribution of potential adopters (also known as the technology adoption life cycle) would seem to indicate (Moore, 1991). The technology adoption life cycle is segmented into five groups: innovators, early adopters, early majority, late majority and laggards, where innovators are the earliest adopters and laggards are the last (Beal &

Bohlen, 1957). Moore condenses these five market segments into two. Innovators and early adopters form the early market while the early majority, late majority, and laggards form the mainstream market. Between these two market segments, Moore contends, are gaps representing the information need differences of the two different markets. To cross the gap between the early market and the mainstream, the product developer must craft a message citing the innovativeness of the product and also its pragmatic benefits (e.g., efficiency or lower costs) (Moore, 2002). In other words, they must define the product's value proposition with appeal for both markets.

Here, this work aims to analyze green housing valuation problems related to the information gap. The first paper seeks to establish that the information gap exists by adapting the theory of the chasm to the valuation of green homes—hypothesizing that the chasm in the housing market is the missing information about green certifications, attributes, and other related information. Further, it responds to and helps answer the question ‘what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?’ Further, it identifies the problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations. Its contribution to the literature will be the suggestion of a method that should help temporarily close this data gap until greater diffusion can occur and valuations can be conducted using comparable or like-type homes.

The second paper offers a temporary valuation solution for appraisers working on the high performance housing assignments. The temporary solution articulates a method for estimating a discount rate and period for the discounting of energy savings based cash flows. It uses those and other inputs to drive a present value calculation that can be used to make a ‘high performance’ adjustment. This solution is designed recognizing that once sufficient numbers of comparable high performance homes are built and catalogued across markets, it should become a method of reconciliation amongst other valuation tools—not a primary valuation tool. The third paper analyzes how appraisers with green valuation training make decisions using limited information about green homes; investigating the types of data required, empirical decision-making rules, and adaptive strategies for low-data markets.

Description of Intellectual Frameworks

Efficient Capital Markets and Housing

The standard model for financial decision making assumes that managers and other decision-making actors have very similar, if not the same, information about a firm, its current cash flows, future risks, and existing liabilities (Brunnermeier, 2001; Fama & Miller, 1972; Miller & Modigliani, 1961). When all parties have the same information (symmetrical information), each party's estimate of a firm's price should be similar (Akerlof, 1970; Brealey, Myers, Allen, & Ross, 2006). It follows then that where various actors do not have the same information, there are asymmetrical perspectives of a firm or opportunity that can create different estimates of the firm or opportunity's current market value (Miller & Modigliani, 1961). This standard model can be observed in real time via the public equity and credit markets as news, earnings reports, and speculation about the future events push and pull the prices paid or prices offered for various securities.

Market efficiency is often described as a continuum where the lower transaction cost, including the cost of and availability of information, the higher the efficiency of the market (e.g., publicly traded securities). Similarly, where the cost of information is greater and availability of it is lower, the market would be less efficient (e.g. shares of private partnerships) (Fama & MacBeth, 1973; LeRoy, 1989; Malkiel & Fama, 2012). Regardless of where an investment opportunity falls on this continuum, investors tend to consider the price of a security a reflection of all relevant publicly available information about the asset (Fama, 1998, 2012). Much of the information upon which these prices are based comes from millions of previous transactions, required disclosures from the firms issuing the securities ("Securities act of 1933," 1989), and from news or third party analysis of individual firms, products, and people. However, not all markets are as informationally robust as the US public capital markets.

The market for housing units is primarily one of complex local variation (DiPasquale & Wheaton, 1996). Buyers and sellers, through various agents, work to transact housing units in unique geographic areas based on a range of building, location, and other intangible attributes (Hays, 2012). While there are only a few types of products that these market participants can trade, the market is typically defined as a fully product

differentiated market on account of the fixed geographic location of each asset (DiPasquale & Wheaton, 1996; Geltner, Miller, Clayton, & Eichholtz, 2007). However, housing is a heterogeneous product only to some extent; there is a great deal of homogeneity (also known as substitutability) that allows appraisers to use the comparable sales model of price estimation to work. This stands in contrast to the market for commodities such as corn or natural gas where products are, irrespective of supplier and location, identical (Mankiw, 2011).

The process of establishing the market price for a housing unit is equally as complex as its market place. Most market participants rely upon a trained and licensed real estate appraiser to generate a professional estimate of the value of a housing unit (AI, 2008). To generate this estimate, appraisers draw data upon information about previous transactions, data about property currently for sale as advertised in multiple listing services (MLS), and also from county tax assessors' property tax rolls describing physical attributes of the housing unit and any real property being sold with it (Pagourtzi, et al., 2003). Just as with the public capital markets, information symmetry is critical for accurate pricing of assets for all parties.

Innovative products, processes, and services create valuation and capital allocation uncertainties for markets and investors (Baumol, 2010; Greenhalgh & Rogers, 2009; Harhoff, Henkel, & Von Hippel, 2003; Moore, 2002). Innovative products and processes tend to cause valuation and capitalization obstacles related to intellectual property right protected information or asymmetrical information about the value proposition of the product (Harhoff, et al., 2003; Moore, 1991). Problems of valuation and capital allocation related to missing and asymmetrical information limit both investors' and adopters' understanding of the value proposition of the product and may lead to slow diffusion for a product or worse (Sahlman, 1990). For this dissertation, green homes will be considered innovations, and the manuscripts will analyze the role of the missing information problem on their diffusion into the housing market.

Technology Adoption Life Cycle

Diffusion trajectories, the cumulative percentage of adopters, for innovations are expected to approximate a normal distribution (typically represented as an S-shaped

curve) when the factors influencing adoption are normally distributed. This expectation for a normal distribution of innovation adoption behavior is based on the cumulative impact of the adopters' social networks (E. Rogers, 1995) [Also see (Beal & Rogers, 1957; Beal, Rogers, & Bohlen, 1957; Bose, 1964; E. M. Rogers & Beal, 1957, 1958; Ryan, 1948).]

While this distribution of individuals initially appears continuous, scholars of high-technology products and businesses point out that there are gaps between many of the major adopter groups (Moore, 2002). These gaps represent the differences in attitudes about and needs for new products and services. Entrepreneurs must craft strategies that clearly communicate the value proposition of their innovations to each of the first three adopter groups (innovators, early adopters, and the early majority), as they are the most disparate types of consumers.

Innovators tend to be venturesome (E. Rogers, 1995). They also tend to be technology enthusiasts (Moore, 2002). Readers probably recognize innovators as their nerdy uncle who bought an HD television long before there was a cable package capable of providing it with enough programs in high definition. Innovators seek out the leading edge of technology hoping to peer over the leading edge of change into R&D labs and garages of inventors to find their next purchase. Early adopters are often considered to be visionaries (Moore, 2002) as they work to match emerging or breakthrough technologies with strategic opportunities. Other consumers see early adopters as thought leaders, because they help to reduce adoption uncertainty about products through their early adoption and communication of their subjective evaluations (E. Rogers, 1995). Together with innovators, the early adopters form the early market for any new product or service (Moore, 1991, 2002).

Early majority adopters represent the leading edge of the mainstream market (Moore, 2002; E. Rogers, 1995). This group is composed of pragmatists who care about product quality, support, reliability and productivity gains from product use. Early majority adopters are deliberate and are keen to find products and services with strong economic value propositions—a distinguishing factor from the early market segments. This distinction also will be very important in the context of green housing, where early market adopters appear to have purchased for a number of non-economic reasons (though

not exclusively).

Given that the early and mainstream markets have very different attributes and needs, Moore writes that the “greatest peril in the development of a high tech market lies in making the transition from an early market dominated by a few visionary customers to a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation” (Moore, 2002). This gulf between markets is so wide that it is known as the chasm (Moore, 1991). Crafting a strategy to cross the chasm is the key for any entrepreneur with something to sell. Crossing the chasm signifies market acceptance of a product or process and connotes a high degree of business success, as it met the needs of the early market and can meet the needs of the pragmatic mainstream market.

Point of Departure

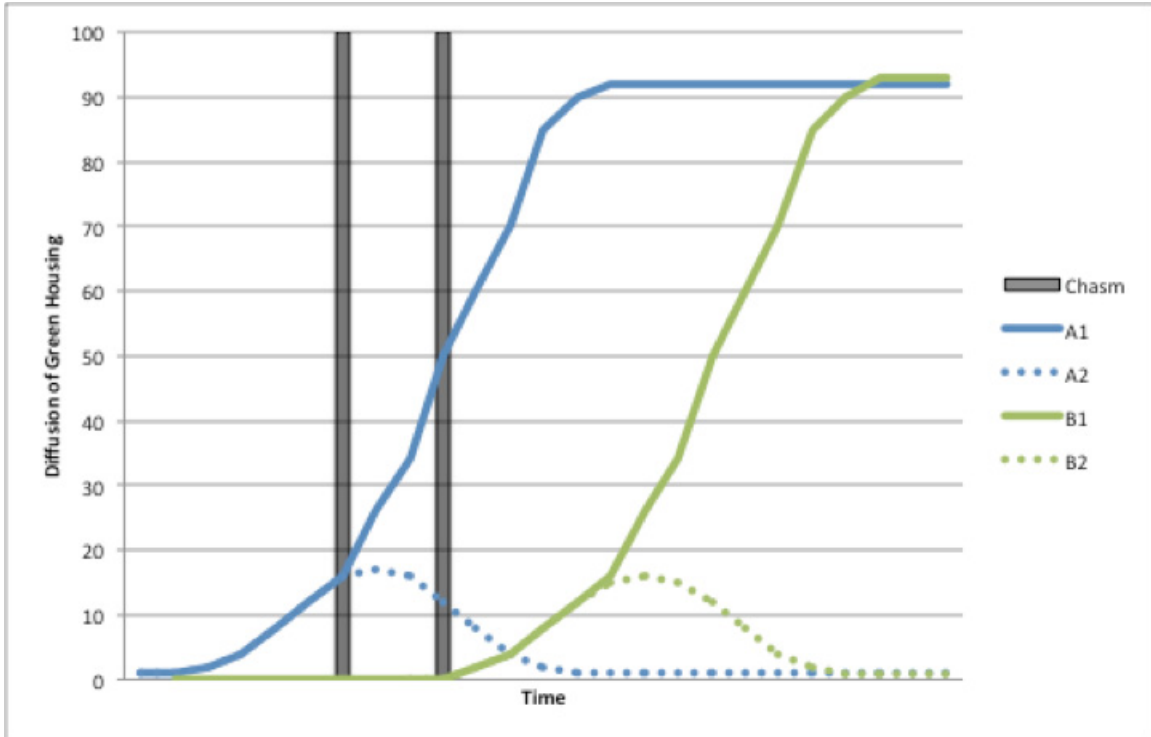
The point of departure for this work is the confluence of the technology adoption lifecycle and the efficient market hypothesis applied to the study of green home valuations. Blending these two intellectual frameworks creates the opportunity to adapt Moore’s theory of the chasm to the valuation challenge faced by green homes and to establish that this chasm exists in the housing market. The point of departure for the dissertation can be described by a set of five linked statements:

1. Innovative products, processes, and services create valuation and capital allocation uncertainties for capital markets and investors. Where typically markets are thought to be efficient and capitalize all available information about the future revenues of a product into an asset’s current price, innovative products/processes tend to cause valuation and capitalization obstacles related to asymmetrical or missing information about the value proposition of the product. Problems of valuation and capital allocation related to missing information may lead to slow diffusion for a product or worse.
2. The diffusion of products, especially innovative products, into markets is a discontinuous process. Punctuating the normal distribution curve describing the technology adoption life cycle are gaps between each of the adopter groups (innovators to laggards). The most significant of these gaps exists between the early adopter and the early majority adopter groups. This gap is known as the chasm, as it represents the gulf between the most disparate of the adopter groups. On one side of the chasm are early market buyers who purchased with an awareness of their homes’ innovativeness or increased environmental performance, but they are unclear on the increased financial performance. On the

other side of the chasm are the pragmatic homebuyers who will wait until the increased environmental performance is capitalized into increased financial performance before purchasing.

3. High-technology firms tend to rely upon informed intuition to develop strategies to cross the chasm rather than on heavy quantitative analysis. Housing markets work quite differently. Lenders and appraisers tend to require significant amounts of data to mitigate risks. In areas such as energy policy diffusion, there are key stakeholder that act as gatekeepers and are pivotal to information flow. In housing markets, lenders and appraisers are the gatekeepers and are, by extension, the gatekeepers of the green housing information chasm.
4. Green homes are considered innovations, and the ratio of green certified homes to non-green certified homes is quite small. Given the small number of green certified homes, the amount of sales data (including unit green attributes) is limited in most markets. Where the housing debt capital markets are the gatekeepers of the industry (Haney Jr, Crask, & Isakson, 1978) and the housing market chasm, they will require high levels of data to analyze potential capital allocations to green housing as an innovation.
5. Insufficient transaction and housing unit attribute data related to green homes limits the appraiser's ability to optimally use the comparable sales method to estimate the market value of green homes. Where estimates of market value are potentially inaccurate because of limited availability of or access to data, lenders will not be able to accurately analyze the home as collateral for a mortgage. However, to produce accurate appraisals and loans, the market needs an increased number of transactions—a catch 22. A stop-gap analytical method is needed to help provide appraisers with the ability to estimate the value contribution of high-performance green building technologies until such a time as sufficient comparables can be catalogued and/or constructed.

Please see C1_Figure 1 for conceptual representation of these statements.



C-1_Figure 1

The curves are plotted with time on the x-axis and the level of diffusion on the y-axis. The scale is arbitrary. Curve A1 represents the diffusion curve of green homes with full information and understanding of their value proposition to all parties. A2 represents the diffusion curve of the same housing units in the absence of this information. A1 crosses the chasm and diffuses over time where A2 reaches maximum diffusion with the innovators and early adopters, failing to capture market share beyond these groups. B1 describes the number of re-sales for green homes that can be used to establish the market value for green features including certifications. This curve is dependent on which of the two green home diffusion trajectories occur. If the information gap for valuation results in the lower trajectory for green homes, the comp-sale line will also be suppressed.

To date, early market adopters have been willing to pay production cost plus some margin without knowing greater detail of the value contribution of green building components to those homes. Information inadequacy has limited the ability of these homes to diffuse more broadly into the markets. However, where more information can be made available and communicated credibly to the appraisers and mortgage originators, valuations can be relied upon and loans can be made using traditional tools and

mechanisms. The long-term benefits of understanding and filling this information gap relate to the standardization of green home valuation information, higher market diffusion of green housing, and the potential for these units to be included as part of securitization pools.

Research Methodology

This dissertation will be structured as a group of several articles, also known as the manuscript method described in Virginia Tech Graduate Catalogue Appendix 1, Section: Preparation of Dissertation or Thesis. Chapter 2 is a literature review focusing on the over-arching and guiding topics of innovation and the diffusion of innovation. It helps to place the second and the third articles into the broader context of the innovation literature. Chapter 2 also defines innovation relative to green housing and describes the various innovation typologies identified by the literature to date.

The first substantive article, Chapter 3, applies the theory of the chasm to green housing and establishes how the chasm plays a role in blocking the diffusion of green homes into the mainstream housing market. Chapter 3 provides additional recommendations on correcting the information flow problems related to green home valuation. To do so, Chapter 3 relies on a multi-stage review of the literatures of corporate finance, innovation and entrepreneurship, building construction, and real estate appraisal—drawing it together under a new investigative framework. The authors hope to distinguish the unique aspects of the chasm as it relates to the housing market and establish where the information gap limits conversation about green homes' value propositions. Additionally, this chapter responds to and helps answer the question '*what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?*' Further, it identifies the problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations.

Chapter 4 extends the logic and problem identified in Chapter 3 and offers a temporary valuation strategy that appraisers can use until such time that sufficient numbers of green homes can be built or catalogued, allowing them to become traditional comparables for comparable analysis. While there could be other solutions such as value insurance or subsidies for the targeted consumers, the proposed valuation approach is

superior because it is practical, relatively inexpensive to implement, captures the most recent advances in building science, and allows most stakeholders to remain path-dependent. Further, it relies upon the best practices developed through consistent application in corporate finance, securities valuation, firm valuation, and commercial real estate underwriting.

The third article, Chapter 5, builds upon the theoretical work of Chapter 3 and analyzes the research question ‘*in the context of the chasm, what information and tools do/could appraisers use to make more accurate single-family attached and detached unit valuations?*’ Here, Annie Pearce and I discuss green home valuations with real estate appraisers using semi-structured interviews to generate pair-wise descriptions of how they would appraise three hypothetical variations of a single home (ranging from code built to fully green). We then analyze these interviews to discover themes related to methods of analysis, other frictions in the process, and observations about the state of the appraisal business.

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Chapter 2: Literature Review & Description of Intellectual Frameworks

Andrew R. Sanderford

Introduction

While green building principles tackle national and global problems related to climate change, understanding how these principles are converted into financial value in the housing stock will shed significant light on green home diffusion patterns into the housing market. Substantial effort has focused on regulations, certifications, and consumer awareness as means to accelerate green home diffusion. However, an obstacle to greater diffusion of green homes is the flow of information about the environmental benefits and energy performance to real estate appraisers, underwriters, and the broader real estate market. Where building science has developed various rating systems, certifications, and tools for measuring the increased environmental performance of housing, these tools have yet to be converted regularly into defensible value contributions by appraisers or accepted by underwriters.

The problem is not principally with the appraisal methods or the science of performance measurement (though some problems within these fields limit their effectiveness). In fact, the tools from building science are growing more accurate and, where sufficient data exist, the comparable sales and hedonic valuation methods are capable of ferreting out the value contribution of the most complex building and site attributes. The problem is that either too few green homes exist, or insufficient information is catalogued or accessible about those homes that exist in most markets to use these valuation methods successfully. This limited information is one cause of the break down in the price discovery cycle for these homes, as limited comparables lead to incomplete home prices that then suppress the diffusion of green homes into the market place.

Researchers and policymakers have struggled with this valuation problem for quite some time. As housing researchers have successfully used diffusion of innovation frameworks to successfully study market behaviors and patterns of both green builders and green building technologies, using it to analyze the valuation-information -

suppression of the green home creation problem seems quite appropriate. Chapter 2 reviews the literature of innovation and the diffusion of innovation, as they are the intellectual foundations of the dissertation. It begins by distinguishing green homes as innovations, then moves on to review the literature beginning at its broadest point in high-technology innovation. Chapter 2 concludes by reviewing the literature focusing on innovation in building construction and housing. It contains the following sections:

1. Definitions of Innovation and Green Housing;
2. Innovation Typologies;
3. The Technology Adoption Life-Cycle;
4. Diffusion of Innovation Literature;
5. Innovation in Building Construction;
6. Innovation in Housing and Homebuilding; and
7. Green Homes, the Efficient Markets Hypothesis & Crossing the Chasm

Definitions of Innovation & Green Housing

Scholars of innovation trace its formal study back to the period of time starting just after World War I (P. Hall, 1998; Weber & Friedrich, 1962). Weber's "location theory" catalyzed the work to explore innovation with its discussion of optimal industrial factory locations for material and labor supply, consumer access, and sharing the potential of resources with other factories (P. Hall, 1998). Today, we know this term as *agglomeration* (Hall, 1998). Schumpeter argued that innovation was the process that stirred new firms led by new men to develop products and processes to replace those that could no longer produce revenue in excess of costs (J. Schumpeter, 1911,1982). He distinguished between invention and innovation, noting that innovations were commercial applications that required a working partnership between the capitalist and the entrepreneur (Hall, 1998). Von Mises extended this argument, highlighting the centrality of the consumer in driving markets to produce innovation (Baumol, 2010; Von Mises & Greaves, 1998). Through innovation, Schumpeter and others believed capitalism could creatively destroy the old to generate new centers of profit and growth (P. Hall, 1998).

Traditionally, green housing is a term used to describe any home carrying a certification from a green building rating system (e.g., Energy Star or LEED). According to Ng et al. 2010, green building means improving the way that homes and homebuilding

sites use the site and materials to reduce impacts on human health and the environment (Ng, 2010). Several green building rating systems were created to help describe the environmental and locational aspects of design and construction to potential buyers, designers, regulators, and financiers (Ellison & Brown, 2011; Stuart, 2012). Each of the green building rating systems emphasizes different aspects of environmentally conscious location, building construction techniques, materials, and design (see VCHR working paper *Defining High Performance in Housing*). Further, each of these rating systems helps to frame the two-fold value proposition of a green home to the consumer. Green homes are distinct in that they are built to deliver both increased environmental and financial performance for the occupant. For the remainder of the dissertation, I will consider a green home to be a high performance home or any home that contains the building technologies or design features that can deliver on this value proposition—whether or not it carries an official certification. In this context, a green home should qualify as an innovative product. However, more precision is required to ensure this is the case.

A meta-analysis of innovation related papers discovered that there were more than 60 definitions of innovation spread across the fields of marketing, management, entrepreneurship, and technology/science/engineering as of 2009 (Baregheh, Rowley, & Sambrook, 2009). Given the recent focus on innovation through the Federal Jumpstart Our Business Start-Ups Act (JOBS Act) and the venture capital industry's growth in total dollars invested and number of deals since 2009 (Pricewaterhouse-Coopers, 2012), innovation has likely been further defined by even more industry groups and firms.

The most widely used definition of innovation comes from Evert Rogers' seminal book *Diffusion of Innovations* where he argues that innovations are “practices or objects that are perceived as new by an individual or other unit of adoption” (E. Rogers, 1995). This definition is also used in the building construction literature (Freeman, 1990; Slaughter, 1998). *Prima facie*, Rogers' and Slaughter's definitions provide readers with simple and ample tools with which to identify innovations in the field. Both focus on novelty and the perception of newness to the adopter. However, before one needs to stretch these definitions *reductio ad absurdum* to find an error, they should recognize that simply acknowledging something as new to the adopter is logically flawed, as neither the

electric typewriter nor the safety razor could be classified as innovations today no matter how novel they are perceived by an adopter to be—hipsters notwithstanding.

To address the logical short circuit included in older definitions of innovation focusing exclusively on perceived novelty, others have argued that innovation (in the context of housing) can be “the application of technology that is new to an organization and that significantly improves the design and construction of a living space by decreasing installed cost, increasing installed performance, and/or improving the business process” (Toole, 1998). While still not fully able to shed some elements of the same logical fallacy of previous definitions, Toole introduces an important thread—that of creating a benefit for the adopter. This benefit would most likely be an economic benefit, but could be construed widely enough to include non-economic benefits. The distinction between an innovation’s creation of economic and non-economic benefits for adopters will be quite important in the next section describing the needs of two major types of adopters separating markets. Extending Toole’s emphasis on benefit creation to include competitive advantage, Baregheh et al. suggest that “innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace” (Baregheh, et al., 2009).

For this dissertation, I will build upon Greenhalgh and Rogers’ definition of innovation found in *Innovation, Intellectual Property, and Economic Growth*—a definition that culls the best of previous innovation scholarship. Greenhalgh and Rogers contend that an innovation has three elements. First, innovative products and processes must be both new to the firm and new to the relevant market (Greenhalgh & Rogers, 2009). Second, they must be introduced into the market place so that ‘consumers or other firms can benefit’ (Greenhalgh & Rogers, 2009). I will assume that in order for consumers and firms to benefit, each is capable of implementing or capitalizing on new information about the new product. Third, Greenhalgh and Rogers’ definition brings together the threads of extant scholarship about the nature of innovation by adding their first and second components to a third vital component—dynamism. Where innovation is a series of processes leveraging constant change, the new replaces the old in both incremental and giant disruptive steps (H. W. Chesbrough, Vanhaverbeke, & West, 2006;

Christensen, Anthony, & Roth, 2004; J. A. Schumpeter, 1939) as innovators continuously examine the leading edge of technology, business, and consumer needs and work to meet and lead them in new directions. Any definition of innovation must acknowledge the ever-shifting nature of the needs of a variety of stakeholders (Von Hippel, 1998).

Greenhalgh's definition of innovation is both broad enough to encompass homes certified under a rating system such as the US Green Building Council's Leadership in Energy and Environmental Design (LEED) or a regional rating system such as Earthcraft. LEED debuted as a pilot program in 1998 and officially as a full system in 2000. It can still qualify as an innovation under this definition, as there are only several thousand homes that are certified out of the entire US housing and mortgage market (USGBC, 2012a). The same logic applies to Earthcraft or other regional certification systems.

This definition of innovation can also accept homes without a green certification system but that would include varying clusters of green, energy efficient, or high performance building technologies or design features such as high R-value insulation, high SEER heating and cooling systems, energy management systems, high efficiency windows, or water efficient technologies. Many of the products in these clusters could be considered both new to the market and new to their relevant markets, as most do not have high degrees of market penetration. In most cases, these types of certifications and building products are designed to create an economic benefit for the home occupant. Further, where the individual products in the clusters defining high performance change over time, they would meet the dynamic aspect of the definition. Given the discussion above, it seems logical to describe green homes with performance enhancing technologies as innovative.

Innovation Typologies

Just as scholars have articulated a multitude of definitions of innovation, they have also identified a number of dyadic types of innovation that are useful in describing the development and diffusion of new products, processes, and services (Li & Sui, 2011). Four types of innovation typologies stand out in the technology literature: 1) Incremental vs. Radical innovations, 2) Sustaining vs. Disruptive innovations, and 3) Continuous vs.

Discontinuous innovations and 4) Open vs. Closed Innovation (H. W. Chesbrough, et al., 2006; Christensen, et al., 2004).

Incremental innovations are improvements to products, processes, and services that iterate the existing functional capability of that product, process, or service forward by improving it modestly for performance, safety, quality, and lower costs (Christensen, et al., 2004). *Radical innovations* cause significant changes in an industry. They create a new to market functional competency that did not exist prior to the launch of the innovation and which creates a gap in present capabilities (Fagerberg, Mowery, & Nelson, 2006). An example of an incremental innovation might be the addition of one new function to a blender model, while a radical innovation might be development of Uber, the car-service hailing mobile phone application that has turned the taxi industry on its head. Uber allows users to request a car to their current location via a GPS feature in the user's phone and pay for the ride using a credit card stored on file with the company.

Sustaining innovations are innovations that advance a product, process, or service along a reasonably predictable trajectory (Christensen, et al., 2004). Many sustaining innovations are driven by a firm's desire to improve a technology in ways that create marginal value gains and retain existing customers while attracting those interested in the new marginal improvements in functionality. Sustaining innovations can be both *continuous* or *discontinuous* (Christensen, et al., 2004). Continuous innovations do not require any behavioral changes on the part of the adopter while discontinuous innovations demand some behavioral change (Christensen, et al., 2004). *Disruptive innovations* shock existing products, processes, and services by creating new markets that eventually disrupt existing markets so much that they supplant previous products, processes and services against which they initially compete (Christensen, et al., 2004; Greenhalgh & Rogers, 2009; Manseau & Shields, 2005). Disruptive innovations are always discontinuous innovations (Christensen, et al., 2004). An example of a sustaining innovation might be the trajectory of improvements by Google to Gmail while an example of disruptive innovation might be the introduction of Wikipedia and other free, crowd-sourced, dynamic online databases that have supplanted printed encyclopedia sets.

Open and closed innovation describe two management and intellectual property right protection strategies used by entrepreneurs and firms to facilitate all types of

innovation (H. W. Chesbrough, et al., 2006). The open/closed innovation typology does not distinguish between incremental vs. radical or sustaining vs. disruptive innovation. Instead, it is more of a framework in which those two typologies can be pursued and executed (H. Chesbrough, 2004; Dahlander & Gann, 2010). *Open innovation* describes a management style and IPR framework in which a firm blends ideas generated externally from the firm with those ideas generated within the firm to advance an innovative product, service, or process (H. Chesbrough, Vanhaverbeke, & West, 2008). Ostensibly, supporters of open innovation believe that no firm (no matter how brilliant the staff) can rely solely on endogenous action to generate innovation. Instead, they must leverage the broader marketplace for ideas and then protect innovations generated there using IPRs such as licenses and risk shedding corporate forms (e.g., Limited Partner Limited Liability Companies-LPLLCs) (H. Chesbrough, et al., 2008; Greenhalgh & Rogers, 2009). *Closed innovation* is distinguished from open innovation in that it follows a more traditional pattern of hiring staff, investing in research and development, commercializing the most promising products, processes, or services from R&D, and then fiercely protecting these commercialized technologies with patents and other restrictive IPRs and law suits (H. Chesbrough, 2004).

Within the discussion of the best management style and intellectual property rights framework to facilitate innovation, Von Hippel identified user driven innovations as a critical component of success across several industries (Von Hippel, 2005). Termed *democratized innovation*, this process suggests that users of products and services are increasingly able to innovate for themselves (Von Hippel, 2005). Examples include the development of big wave riding surfboards, mountain bikes, and computer software. A particularly notable version of an increasingly open and democratizing innovation is Google's open source Android mobile phone software and application development space. Android developers are able to write and post applications to a central repository freely for users to test, use, and judge for quality. Conversely, Apple fiercely guards its iOS operating system, and developers must participate through rigidly defined parameters. Both achieve similar results—the ability to customize a smart phone. However, proponents of each argue that their method is superior.

In many ways, the distinction between open and closed innovation systems could be described similarly to the internal debate in Joseph Schumpeter's work on the size of a firm and its role creating innovation (Fagerberg, et al., 2006). In both, scholars debated the merits of the multiple contexts of best suited to facilitating the development of innovation. Early in his career, Schumpeter suggested that innovation was best driven by 'new men' who could come into business from the outside and invigorate it both with new ideas and debt capital from outside investors (Fagerberg, et al., 2006; J. Schumpeter, 1911,1982). These 'new men' would create small to medium sized enterprises (SMEs) that could leverage their comparative advantages in size, short chains of command, and reaction time to innovate more quickly than their larger competitors (P. G. Hall, 1998).

However, during Schumpeter's career, Terman built Stanford's business park and early tenant start-ups such as Intel and Hewlett-Packard grew and flourished (E. Glaeser, 2011; E. L. Glaeser & Gottlieb, 2009). Similarly, Boston's American Research and Development Company grew firms like the Digital Equipment Company (DEC) from dreams into public companies (Ante, 2008). The success of these and many other large corporations provided Schumpeter with evidence that perhaps his earlier belief in small firms as the engines of innovations was fragile. By the time he published *Business Cycles*, Schumpeter argued that larger firms with greater access to capital and the ability to self fund the processes from research and development to product commercialization perhaps had the innovation advantage (J. Schumpeter, 1989). Though Schumpeter did not comment on the open vs. closed innovation typology, his thoughts on the ingredients of innovation provided a probable scholastic underpinning from which Chesbrough and others moved forward.

Each of the major dyadic innovation typologies provide a way for researchers and entrepreneurs to explain the success and failure of certain firms, products, processes, and services, especially when combined with a broader analysis of history (P. G. Hall, 1998; Schunn, Paulus, Cagan, & Wood, 2006). Reflecting on the ingredients of the primordial soup of innovation—the innovative milieu—studied across six key global cities, urbanist Peter Hall noted, “building innovative milieu is not something that can be done to either easily or to order” (P. Hall, 1998). Though slightly befuddling to urban planners and economic development agents, Hall argued that despite the immense quality of

innovation research and the intense debate, often *ad nauseum* by scholars, entrepreneurs, investors, regulators, and consumers, there is not much predictive capability in the field. Frank Bass, the renowned professor of marketing, has cornered the market on the predictive power in his diffusion model using parametric estimation of inflection points in a product's adoption cycle (Bass, 1969).

Technology Adoption Life Cycle & The Chasm

Where many human and firm traits are normally distributed, the degree of innovativeness or willingness to adopt innovations also appears to be normally distributed. Researchers expect a normal distribution for adoption of an innovation because of the cumulative impact of adopters' social networks (E. Rogers, 1995) [Also see (Beal & Rogers, 1957; Beal, Rogers, & Bohlen, 1957; Bose, 1964; E. M. Rogers & Beal, 1957, 1958; Ryan, 1948).]

While the distribution of individuals appears continuous, scholars of high-technology products and businesses point out that there are gaps between many of the major adopter groups (Moore, 2002). These gaps represent the differences in attitudes about and needs for new products and services. Therefore, entrepreneurs must craft strategies that clearly communicate the value proposition of their innovations to each adopter group (innovators, early adopters, and the early majority) to achieve full product diffusion (Egmond, Jonkers, & Kok, 2006c). Moore's work helped entrepreneurs and researchers by condensing the TALC into two primary groups: 1) the early market composed of innovators and early adopters and 2) the mainstream market made up of the early majority, later majority, and laggards (Egmond, Jonkers, & Kok, 2006b). Moore described the gap between these two markets as a chasm across which products must cross in order to become successful (Moore, 2002). This follows Rogers' logic that a product is considered safely diffused into the market once it achieves market penetration of at least 13-16%.

The early market combines innovators and early adopters as they share similar characteristics and information needs relative to the value proposition of an innovation (Egmond, Jonkers, & Kok, 2006a). Innovators tend to be venturesome (E. Rogers, 1995). They also tend to be technology enthusiasts (Moore, 2002). Innovators seek out the

leading edge of technology, hoping to peer over the leading edge of change into R&D labs and garages of inventors to find their next purchase. Early adopters are often considered to be visionaries (Moore, 2002) as they work to match emerging or breakthrough technologies with strategic opportunities. Other consumers see early adopters as thought leaders because they help to reduce adoption uncertainty about products through their early adoption and communication of their subjective evaluations (E. Rogers, 1995). Together with innovators, the early adopters form the early market for any new product or service (Moore, 1991, 2002).

On the other side of the chasm, the groups that make up the mainstream market also share similar characteristics and information needs about the value proposition of an innovation. Early majority adopters represent the leading edge of the mainstream market (Moore, 2002; E. Rogers, 1995). They are pragmatists who care about product quality, support, reliability and productivity gains from product use. Early majority adopters are deliberate and are keen to find products and services with strong economic value propositions—a distinguishing factor from the early market segments. This distinction also will be very important in the context of green housing, where early market adopters appear to have purchased for a number of non-economic reasons (though not exclusively). The late majority and laggards share these characteristics but also prioritize product testing and more full product offerings in their decision to adopt.

Given that the early and mainstream markets have very different attributes and needs, Moore writes that the “greatest peril in the development of a high tech market lies in making the transition from an early market dominated by a few visionary customers to a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation” (Moore, 2002). This gulf between markets is so wide that it is known as the chasm (Moore, 1991). Crafting a strategy to cross the chasm is the key for any entrepreneur, as it indicates that a product can meet the needs of those valuing innovation and those valuing more pragmatic aspects including performance benefits.

Moore portrays the process of crafting a chasm crossing strategy as one that is built upon the informed intuition of veteran entrepreneurs. Research about effectuation, or the entrepreneurial method, has indicated that entrepreneurs see problems in unique ways (Read, Song, & Smit, 2009; Sarasvathy, 2008). For example, many take risks

guided by the affordable loss principle, or the maximum amount of money they are willing to lose on a venture. They balance the outcomes of affordable loss analysis with their estimated return on investment to determine the viability of their ideas (Sarasvathy, 2004). Effectuation and crossing the chasm is likely a low-data environment where micro-numeracy could cause as many problems as it is likely to solve (Moore, 2002). It is easy to imagine a situation where estimates of market size and demand could contain flawed assumptions or, at the least, assumptions where the variance is quite wide. Acting based on these numbers could cause catastrophe; it could lead to success. Given this uncertainty, Moore contends that a low-data informed-intuition approach could be equally as valuable a strategy development tool (Moore, 2002).

However, similarly to the construction industry where clients drive innovation (Blayse & Manley, 2004), the valuation of green homes is a data heavy process, and the pragmatic buyer is interested in an accurate estimate of the value contribution of their home's performance enhancing attributes. For green homes to cross the chasm into the mainstream market, their crossing strategy will rely on increasing information flows. Green homes will also need to identify and direct analysis towards a concept developed in the diffusion of innovation literature—the innovation gatekeeper (E. Rogers, 1995; Slaughter, 1998) [related but not precisely an innovation champion (C. Koebel & McCoy, 2006; Mitropoulos & Tatum, 2000)]. Gatekeepers are those who are aware of solutions to problems and champions are those who absorb risks of innovation and drive change within their firm or industry. Without identifying a gatekeeper, generating an appropriate chasm crossing strategy is likely untenable.

Diffusion of Innovation

The diffusion of innovation is the 'process by which an innovation is communicated through certain channels over time among the members of a social system' (E. Rogers, 1995). Diffusion describes a special type of communication focusing on the nature of an innovation all the while in the context of uncertainty (Manseau & Shields, 2005; E. Rogers, 1995). There are four primary elements in the diffusion of an innovation: 1) the innovation, 2) communication channels, 3) social systems, and 4) time (Meade & Islam, 2006; E. Rogers, 1995). Specific to the innovation, there are five

characteristics that determine its rate of adoption or relative speed with which an innovation is adopted by members of a social system or market: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability, and 5) observability.

1. Relative advantage is perception that the innovation is better than the idea, product, or process that already is in use by the potential adopter. If a potential adopter can readily see the benefits of using an innovation there is greater likelihood for adoption. The greater degree the adopter perceives the advantage, the more likely they are to adopt.
2. Compatibility is the degree to which an innovation is perceived as being consistent with needs and systems of existing adopters. Adopters are looking for products they can incorporate into their systems without much effort and without having to change values.
3. Complexity is the degree to which the potential adopter views the innovation as difficult to use or understand as part of their system of practice.
4. Trialability of an innovation is an adopter's ability to use an innovation on a trial basis before committing to adoption.
5. Observability is innovation in practice. If observers can readily see the results of an innovation, the likelihood of adoption increases (E. Rogers, 1995; Weidman, 2012).

Communication describes the process by which members of a social system share information with one another so as to create mutual understanding (E. Rogers, 1995).

Diffusion is a special type of communication where an individual or group with knowledge of an innovation connects and communicates with an individual or group who does not possess the same information. This communication can take place via broad channels such as mass media or through small channels such as interpersonal interactions (E. Rogers, 1995). Where advertisers are becoming increasingly sophisticated at targeting individuals based on the trail of electronic information they leave behind them, the types of communication channels used to communicate about various innovations can become blurred.

Time is the unit of measurement used to describe the adoption or diffusion of the innovation process. Time is used in three ways to measure the diffusion process. First, time can measure the gap between when a potential adopter first hears of an innovation and when he or she chooses to adopt it or not. Second, time can measure the relative position in the life-cycle of a product where the adopter picks up the product, process, or

service and begins to use it. Third, time can measure the total number of adopters in a social system that have adopted a product, process, or service (E. Rogers, 1995). Rogers used adoption over time to describe the 'Technology Adoption Life Cycle' (TALC) or the total number of adopters picking up an innovation over time (Brown & Venkatesh, 2005). As noted above, the technology adoption lifecycle describes the normal distribution (and cumulative distribution) of the types of adopters in the global marketplace for any product, process, or service (E. Rogers, 1995; Ryan & Gross, 1943).

Social systems are interrelated units that are engaged in joint problem solving to accomplish a common goal (E. Rogers, 1995). Members of social systems may be individuals, informal groups, organizations, and/or sub-systems (E. Rogers, 1995). They may interact indirectly via mass media, interpersonally face-to-face, or through some hybridized version such as an Internet forum or social media application (e.g., Twitter). Both system based norms and agents of change play strong roles in the diffusion process (E. Rogers, 1995; E. M. Rogers & Beal, 1958; E. M. Rogers & Kincaid, 1981). System norms help guide behavior patterns for groups across many levels. Agents of change or opinion leaders can exert their influence on others so as to guide or target communication about an innovation. Agents of change, including technology champions and gatekeepers, are important in all firms (including real estate and construction firms) as they can help push and pull their firms towards innovations that may help to create new competitive advantages (Egmond, et al., 2006c; C. Koebel & McCoy, 2006; Slaughter, 1998). These are also the types of individuals who tend to believe that problems can be solved in a multiplicity of ways and that a climate of innovation helps create the potential range of solutions (Hardie & Newell, 2011).

Innovation in Building Construction

The building construction industry, specifically the builder (or installer), is often viewed as a laggard, path dependent, and/or risk averse (Manseau & Shields, 2005; McCoy, Thabet, & Badinelli, 2009; Toole, 1998). A number of industry characteristics appear to suppress innovation and support this view. These characteristics include the relatively decentralized nature of construction firms (i.e., use of sub-contractors and the disconnects between product manufacturers and installers), property and construction

market cyclicality, volumetric production, building code requirements, and the fact that most building construction innovations are installed behind walls or exist under floors (Blackley & Shepard III, 1996; C. T. Koebel, 1999). However, just like many other industries, building construction is a cluster of related sub-industries including the commodities and manufacturing component pieces (e.g., lumber and door knobs), facility design, engineering, finance, and facility assembly (McCoy, et al., 2009). It follows, then, that various industry actors turn to innovation as they seek new competitive advantages over peer firms (Abbot, Jeong, & Allen, 2006; Manseau & Shields, 2005; Tatum, 1987). Describing drivers rather than barriers, Australian scholars have argued that firm resources, client and end-user influence, project conditions, industry networks, and the regulatory climate help to promote and facilitate innovation in small to medium sized firms (Hardie & Newell, 2011).

The construction literature has tended to investigate innovation by exploring the obstacles or barriers to the diffusion of innovation across different types of firms, building types, and products (Slaughter, 1993). As noted above, industry structure, the pace of regulatory change, and consumer's imaginations play a role in limiting the industry's desire to adopt innovations. Additionally, liability and warranty issues, fear of being a first user, cost, municipal policy, and lack of consumer awareness also play roles in limiting the spread of innovation in building construction (Choi, 2010; Galuppo & Tu, 2010; C. Koebel & McCoy, 2006; Manseau & Shields, 2005; Toole, 1998). Qualitative analysis of individual firms confirm many of these obstacles (van Egmond-de Wilde & Mohammadi, 2011). Conversely, empirical evidence indicates that investment in research and development, information transfer, builder education, incentives for adoption, and policies aligning innovator risks/benefits can accelerate diffusion of innovation in building construction (Enterprises, 2001).

Recently, the commercial building construction literature has shifted focus toward building technologies, construction management, and firm structures that facilitate adoption and diffusion of innovation (Habets, Voordijk, & van der Sijde, 2011; Kulatunga, Kulatunga, Amaratunga, & Haigh, 2011; C. Miller, Carr, & Cheung, 2001). Researchers have found that just as in the information technology industry, both product users and public policy can be substantial drivers of innovation adoption across products

from building information management software to road paving equipment (Wandahl, Jacobsen, Lassen, Poulsen, & Strensen, 2011; Wong, Wong, & Nadeem, 2011). This emphasis on construction technology has a number of parallels to the housing industry's deep dive into the evaluation of individual housing technologies via the Partnership to Advance Technology in Housing (PATH), a discontinued program sponsored by the Department of Housing and Urban Development (HUD). It also has significant ramifications for this dissertation, as it focuses on innovations in housing that are largely building technology related.

Innovation in Housing & Homebuilding

Homebuilding, a sub-component of the broader building construction industry is, like commercial construction, viewed as an innovation laggard. Unlike commercial construction, however, elements of this view can be traced back to the Great Depression. Responding to changing economic conditions in the 1930's, both the housing production industry and the housing finance industry implemented two substantial changes that forged the basic structure of the modern housing industry: 1) the standardized mortgage and 2) the use of dimensional lumber and advanced framing systems (Colton, 2002; C. T. Koebel, 2008). Beginning in 1932, the Roosevelt administration created the Federal Home Loan Bank Act, the Home Owners' Loan Corporation (HOLC), the Federal Housing Administration (FHA), and the Federal National Mortgage Association (Fannie Mae) (Colton, 2002). Though only operating for a short period of time, the purpose of the HOLC was to refinance existing mortgage credit to long-term fixed rates (Colton, 2002). Soon after, Fannie Mae was charged with providing mortgage market stability, which it did by purchasing loans made by FHA lenders (Hays, 2012). The sum of these agencies' actions constituted the first major underpinning force for the modern housing industry—the standardization of the mortgage market including the creation of the 30-year fixed-rate mortgage.

The second major supportive force from the Depression that has carried forward into the modern housing industry is the reliance upon balloon framing, which evolved into the modern light-frame (platform) construction (C. T. Koebel, 2008). Platform construction is construction conducted on the building site using dimensional lumber (C.

T. Koebel, 1999). Until the merging activity of the late 1990s and early 2000's, homebuilders typically were smaller firms that produced only a few homes using their own crews or subcontractors. This model tends to succeed with strong market knowledge and dynamic adaptation to the business cycle (C. T. Koebel, 2008). It also facilitates a rather fractured industry structure that makes sweeping change difficult despite the volumetric production requirements.

Reflecting on the “Laggard industry” assumption, Koebel et al. (2004) identified barriers and impediments to innovation for firms in residential construction. From these barriers and others, McCoy et al. (2012) consolidated uncertainty and risk into the following categories: site variability, one-off nature, longevity of warranties, supply chain variability, path dependency, and stakeholders. However, previous studies on innovative practices do not address the divergence of recent residential construction technologies. For example, in place of path dependency and resistance to innovation, numerous industry studies point to a widening awareness and likely use of innovative practices and techniques that support environmental goals (Bodie et al. 2008). Where homebuilding innovation has traditionally experienced slower rates of adoption, some green building technologies exhibit accelerated patterns (Nikhoo, Sanderford, McCoy, Koebel, & Frank, 2012).

Researchers suggest that industry is growing increasingly innovative over time (Blackley & Shepard III, 1996; Bradshaw, 2011; C. Koebel & McCoy, 2006; C. Koebel, Papadakis, Hudson, & Cavell, 2004; C. T. Koebel, 2008; Manseau & Shields, 2005; McCoy, et al., 2009; Nikhoo, et al., 2012; Sanderford, McCoy, & Koebel, 2012).

Evidence indicates that:

- Larger builders tend to be earlier adopters of innovations only when new materials provide potential cost savings, improvements in production processes, reductions in call-backs, and exposure to liability;
- Smaller builders tend to adopt new materials where consumer awareness of the product was high, the price of the new material was superior to its replacement, and where the home production process must be substantially altered; and
- Homes in geographic areas where increased awareness of innovative materials was high were more likely to adopt while areas where path dependency and resistance to new technology limited the potential for adoption (C. Koebel & McCoy, 2006).

This batch of more recent research confirmed earlier work that suggested that the primary barriers to the diffusion of innovation in the construction industry were the cyclical sales, a preponderance of small firms (vertical and horizontal fragmentation), institutional factors such as building and zoning codes, facility complexity, and unionization (Blackley & Shepard III, 1996; Slaughter, 1993, 1998; Toole, 1998). By extension, this work opened the door to study green building technologies and homes as innovations and catalyzed opportunities for scholarship about the adoption patterns of these innovations by builders (McCoy, Koebel, Rahmandad, & Frank, 2010; Sanderford, et al., 2012).

Green Housing as Innovation

Green homes and the performance enhancing building technologies they contain are innovations. In most cases, they are products, processes, or services that are both new to the builder/buyer and new to the housing market. Broad level housing data from Energy Information Administration confirm that over time, the US housing stock is becoming more efficient and using less energy per housing unit (Energy-Information-Administration, 2010). Scholars and trade organizations have also shown that the use of green materials and regulation is growing (Kontokosta, 2011; McCoy, Pearce, & Ahn, 2012). Further, both the US Green Building Council (USGBC) and the Department of Energy (DOE) report growth in the number of homes certified through both the LEED and Energy Star programs (EPA-DOE, 2012; USGBC, 2012b). However, green building, especially housing, remains ‘new’ and unfamiliar to most of its relevant markets.

With respect to increasing the environmental performance of a facility (houses included), green building encompasses different construction methods, strategies, and products that consume fewer resources and pollute or degrade the environment less (Muldavin, 2010; Yudelson, 2008). Different strategies and techniques include using less space and material, substituting conventional products for more efficient products (e.g. using efficient appliances and design strategies), using integrative design to benefit from site attributes (e.g. orient roof/windows to use the sun for lighting and heating), and exploiting the synergies among components such as reducing boiler size with better insulation (Hoffman & Henn, 2008).

Green building strategies to increase the environmental performance of new and existing homes have tended to focus on increasing system efficiency with respect to energy and water (Levermore, 2008; Stuart, 2012). To describe resource consumption and system efficiencies as well as other positive environmental benefits of facilities, the United States Green Building Council (USGBC) has provided and updated a suite of standards that rate a building's sustainability on different dimensions associated with the site, water, energy, atmosphere, material, indoor quality, design innovation, and regional priorities ("Usgbc programs: Leed," 2012). Additionally, the DOE created Energy Star, a certification for homes meeting energy usage parameters. Other green building certification systems such as the National Green Building Standard and Earthcraft also exist and tend to emphasize increased energy performance (see VCHR working paper on defining high performance in housing).

Increased environmental performance of buildings creates benefits on multiple fronts. Buildings consume 65% of total U.S. electricity and 36% of all primary energy (Loftness, 2004). Reducing consumption of resources and reducing Green Hous Gas (GHG) emissions will have positive local and global externalities (Pachauri & Reisinger, 2007). The fourth assessment report by Intergovernmental Panel on Climate Change (IPCC) estimates that 29% of building CO₂ emissions can be reduced at no cost by 2020 (Levermore, 2008). Green buildings are central to realizing these reductions as they both consume 25-30% less energy (Kats, Alevantis, Berman, Mills, & Perlman, 2003) and use alternative, emission-free sources including solar and geothermal.

Health and productivity benefits of green facilities are just as compelling, as Americans spend 90% of their time indoors (Fisk, 2000; Loftness, Hakkinen, Adan, & Nevalainen, 2007; US-EPA, 2008). Better indoor air quality, improved thermal control, healthy lighting, material selection, and access to public transportation reduce respiratory illness, headaches, sick building syndrome, skin and eye irritation, and obesity, among other ailments (Dainoff, 1991; Fisk & Rosenfeld, 2004; Hescong et al., 2002; Srinivasan, O,ÄôFallon, & Dearry, 2003; Wargocki, Wyon, Sundell, Clausen, & Fanger, 2001). These also contribute to increased productivity (Leeman, 2005), improved recruitment, and reduced turnover and absenteeism (Fitz-Enz, 2000).

Building science scholars are beginning to corral this complex body of

certifications and ratings into empirically measurable environmental performance standards (Price-Robinson, 2013; Stuart, 2012). Two tools with significant potential are RESNet's Home Energy Rating Score Index (HERS) and the DOE's Home Energy Score. The HERS index measures, on a scale of 0-200, the energy efficiency of a building as compared to the same building built using a standard reference design. A new home that performs equal to the standard reference design earns an index score of 100. A home performing 40% better than its standard reference unit would earn a score of 60. DOE estimates that the average existing US home would earn a score of 130 or perform 30% worse than RESNet's standard home. Similarly, DOE's Home Energy Score serves as a home's Miles Per Gallon rating and estimates the likely energy consumption of a home, then converts this into a Score on a scale of 1 to 10. Homes that are expected to use the least amount of energy score a 10, and homes that are expected to use the most amount of energy score a 1. The energy range underlying the scale varies from region to region to account for differences in climate (DOE). Between these two tools, developers, builders, homebuyers, homebuilders, lenders, and appraisers can begin to develop a more refined sense of a home's energy and environmental performance relative to other similar homes. With this information, they can begin to convert environmental performance into financial performance.

With respect to the financial performance of green buildings, real estate scholars have begun to peel back parts of the complex onion of green building values. They indicate that there is some evidence to support the claim that green buildings can be worth more than similar traditionally built buildings (Das & Wiley, 2013; P Eichholtz, Kok, & Quigley, 2011; P. Eichholtz, Kok, & Yonder, 2012; N. Miller, Spivey, & Florance, 2008; Pivo & Fisher, 2009; G Pivo & JD Fisher, 2010; G Pivo & J Fisher, 2010; Wiley, Benefield, & Johnson, 2010). Similarly, scholars have found evidence that buildings perform better financially following an upgrade using green materials and systems (Ciochetti & McGowan, 2010; Dermisi, 2012). This growing base of evidence of the increased financial performance of green buildings appears to be clearing the way for a conversation about their slow diffusion into the market place and perceived contrast with classic investment theory (Allcott, 2011; Allcott & Greenstone, 2012; Kok, McGraw, & Quigley, 2011).

Most of the scholarship about green facility price premiums has been devoted to commercial buildings, which are substantively different than residential buildings (except in the case of high rise multi-family housing which requires commercial construction techniques and processes). Another segment of this literature has been devoted to regulation and has explored the influence of public policies on green development patterns. Scholars have identified trends in the diffusion of green public policies (Kontokosta, 2011); positive spillover effects from green public procurement policy in California (Simcoe & Toffel, 2011); mandates, demonstration projects, and financial incentives can influence the market penetration of green buildings (Richardson & Lynes, 2007; Simons, Choi, & Simons, 2009); and policy ‘nudges’ can be useful in shifting occupant behavior (Costa & Kahn, 2010) .

The literature investigating similar value, diffusion, and policy questions for green housing is substantially less robust than the commercial literature. However, preliminary work on pricing premiums points towards similar findings in some markets for green homes (Bloom, Nobe, & Nobe, 2011; Rauterkus & Miller, 2011). Perhaps the most interesting of the residential real estate literature has focused on the quality of underwriting relative to green homes and innovations. Research in this area suggests that process innovations such as automated underwriting and credit scoring (Straka, 2000), risk based loan pricing, and securitization (R. G. Quercia & Stegman, 1992) have reduced financing costs and underwriting process time and increased underwriting accuracy as well as the range of buyers served. However, given the role of these tools in the credit crisis, it is possible to consider them as useful but dangerous innovations. Additional evidence indicates that buyers of high performance homes and locationally efficient homes are less likely to default on their mortgages (R. Quercia, Sahadi, Stellberg, Kaza, & Tian, 2013; Rauterkus, Thrall, & Hangen, 2010). Perhaps taken in tandem, underwriting programs could consider information about high performance homes as a way to increase the quality of loans made.

In much of the real estate literature, researchers have used the presence of green building certifications such as LEED and Energy Star as a measure of greenness. While not an inaccurate method, critics have suggested that it might be too easy to earn a green certification without using the systems and materials that will create increased

environmental performance (Thomas, 2012). Aroul and Hansz (2011) addressed part of this criticism by highlighting the presence of dual paned windows, a green window system, and the window's relationship with higher home values (Aroul & Hansz, 2011). Thomas' piece provides an opportunity for introspection and innovation for green housing advocates, designers, regulators, developers, builders, and scholars. It is far less robust than Sukhdev, who challenges the broader business community to reconsider its basic business structures to more adequately and aggressively confront the pressing issues of climate change, resource depletion, and rising consumption (Sukhdev, 2012). Both Thomas and Sukhdev's challenges point to new opportunities for green business and specifically for green housing.

Value Estimation

Placing the study of green homes and the broken down price discovery function into a diffusion of innovation framework should provide advantages for creating new knowledge about the problem's source and potential solutions. One advantage will come from the application of the theory of the chasm, based in the technology adoption life cycle, to the green housing market to analyze diffusion obstacles. On the surface, it seems that simply by bifurcating the major buyer groups of green homes into Moore's early market and mainstream market segments and acknowledging that they have disparate information needs relative to the value proposition of green housing, the problem is easier to comprehend and tackle.

On one side of the chasm, innovators and early adopters have been keen to buy homes with enhanced environmental performance. On the other, the pragmatic buyers are waiting until the increased environmental performance can be translated into increased financial performance that is measurable and can be included in the market value of a potential home. Crossing the chasm should be an act of identifying the gatekeepers of the chasm and creating or magnifying the flow of information such that the data heavy business of home appraisal and price discovery can take place. This flow of information is critical as it has a significant relationship with the reliability of pricing—a connection hypothesized by the Efficient Markets Hypothesis (Fama, 1970).

Efficient Capital Markets and Green Housing

The standard model for financial decision making assumes that managers and other decision-making actors have very similar, if not the same, information about a firm, its current cash flows, future risks, and existing liabilities (Brunnermeier, 2001; Fama & Miller, 1972; M. H. Miller & Modigliani, 1961). Often based on the idea of rational expectations, Muth argued ‘that expectations of firms (or, more generally, the subjective probability distribution of outcomes) tend to be distributed, for the same information set, about the prediction of the theory (or the "objective" probability distributions of outcomes)’ (Muth, 1961). Rational expectations allow for analysts to conduct their work using all available information—internal or external to the market place. To paraphrase several scholars, when all parties have the same information (symmetrical information), each party’s estimate of a firm’s price should be similar (Akerlof, 1970; Brealey, Myers, Allen, & Ross, 2006; Fama, 1970, 2012). It follows then that where various actors do not have the same information, there are asymmetrical perspectives of a firm or opportunity that can create different estimates of the firm or opportunity’s current market value (M. H. Miller & Modigliani, 1961). Akerlof’s thought experiment on the market pricing of used cars under asymmetric information helped provide additional nuance to the complex relationship between information, expectations, and pricing (Akerlof, 1970).

The market for houses, like the market for securities, is driven by the flow of information and transactions. Using the comparable sales method as the standard valuation tool, buyers and sellers constantly adjust their expectations for price based on recent sales of like-type or competitive homes (FHLMC, 2005; FNMA, 2006; Ratcliff, 1972; Vandell, 2007). Real estate appraisers are trained to value complex site and housing unit attributes using the comparable sales method, or its related technique, hedonic regression (AI, 2008; Donnelly, 1989; Kummerow, 1997). Guidance from the Appraisal Journal and related publications has covered the valuation of homes with attributes including finished basements, accessory dwelling units, views, and environmental liabilities (Andrus, 2012; Anselin & Le Gallo, 2006; Irwin, 2002; Patchin, 1994; Rodriguez & Sirmans, 1994). A critical component of each of these papers (and others like them) was the availability of data about both the attribute in question and a sufficient number of comparable homes against which analysis could be conducted.

Where there were data to analyze via a comparable or hedonic analysis, estimating the value contribution of each of these features was relatively straightforward.

However, as noted previously, green homes present appraisers with a unique set of obstacles. Where most MLS, do not track green home attributes or certifications, it is difficult for the appraiser to create a database measuring the value contributions of green building traits. A frustrating wrinkle in this problem is that in some instances, the data are catalogued but links between databases are obscure, impossible, or prohibitive in some meaningful way (Fuerst, McAllister, van de Wetering, & Wyatt, 2011). Based on this set of problems, it seems that a temporary method is needed to fill in during the period when an insufficient number of comparable properties exist and the time when a sufficient number of green homes exist from which comparable analysis can be conducted more readily.

Early research on the value contribution of energy efficient technologies in housing suggested a present valuation of their contributions on an after-tax basis (DeLisle, 1984). Using a present value method would integrate the income-capitalization method commonly used in commercial real estate with the comparable method—a topic that has recently surfaced again in the academic literature (Adomatis, 2010; DeLisle, 1984; Popescu, Mladin, Boazu, & Bienert, 2009; Runde & Thoyre, 2010). The integration of the cash flow and comparable model helps to reduce the number of comparables needed and fits within the guidance given on other cash flow generating home attributes (Andrus, 2012; Martin & Watkins, 2012). However, the accuracy of first cost and cost savings estimation, as well as the variability of interest or discount rates will all play complicating roles in creating this temporary solution.

Next Research Steps

As green homes are relatively early-stage innovations, diffusion of innovation frameworks offer a substantial intellectual backdrop for analysis. Given this, the next article analyzes this problem and responds to the question ‘what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?’ Further, it identifies the

problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations.

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Chapter 3: Establishing the Framework for the Green Housing Information Chasm

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Abstract

Green and energy efficient building certification and technology diffusion into the housing market could be significantly attenuated by limited or missing information. This article analyzes this problem and responds to the question ‘what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?’ This paper analyzes problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations. High performance homes reflect a type of green building innovations that involve non-trivial costs. As early-stage innovations, diffusion theory identifies the challenges faced by innovations including those faced as they move from early stage markets across Moore’s chasm into more mainstream markets.

Introduction & Summary of Problem

Despite three appraisals, Roger Normand remains confused. With his wife, the retired civil servant is building a highly energy efficient home outside of Portland, Maine. Normand’s home was designed and built to the *Passivhaus* standard, a more than 50% energy efficiency gain over standard 2009 code built homes of similar size. However, he believes the value created by the installation of green building technologies that generate operational efficiency has been consistently under-estimated by each of the three appraisals he’s received. He readily admits that green homes face substantial hurdles during appraisal and cites, the economic conditions of the past six years, the wide array of green building standards, a limited number of comparable units being built and sold, and limited data about green home attributes available to appraisers via the multiple listing service (MLS) or county assessor’s records (Normand, 2011).

Normand’s experience illustrates one of the central reasons why it seems green

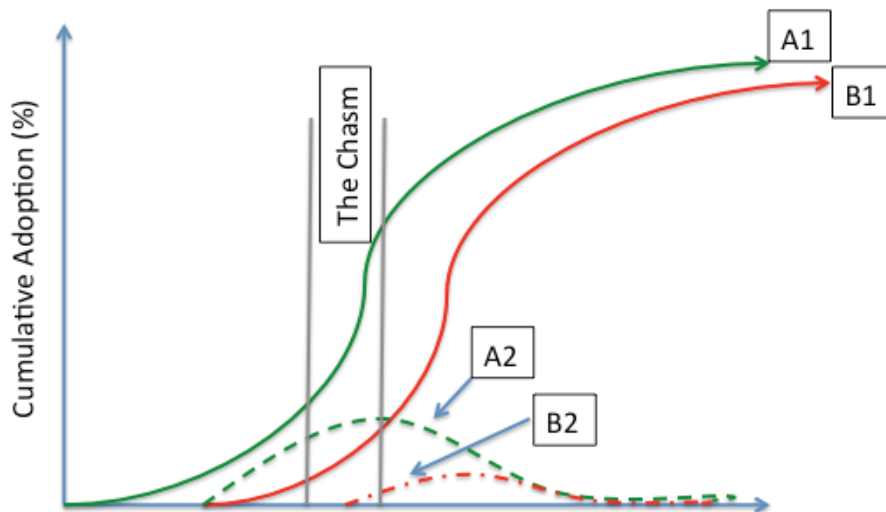
and energy efficient homes¹ have not diffused more widely into the housing stock—the limited availability of data on high performance housing attributes to include in the sales comparison appraisal method. This article analyzes this problem and responds to the question ‘what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?’ Further, it identifies the problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations. High performance homes reflect a type of green building innovations that involve non-trivial costs. As early-stage innovations, diffusion theory identifies the challenges faced by innovations including those faced as they move from early stage markets across Moore’s chasm into more mainstream markets.

Moore’s Chasm (the chasm) is a theory of innovation that consolidates the five market segments of the Technology Adoption Life Cycle (TALC), the distribution of potential adopters established by Rogers for new products, to two: the early market and the mainstream market. Most commonly, as the TALC is plotted on a normal distribution (or sometimes a cumulative sigmoid curve distribution), diffusion of products from one market segment to the next is assumed to be a continuous function. However, Moore’s work argues that between the innovators in the early market and the pragmatists in the mainstream market (at approximately 16% of total market adoption) lies a deep gulf (Grewal, Mehta, & Kardes, 2000; McCoy, Badinelli, Koebel, & Thabet, 2010; Muller, 2008). Where these two market segments consider the value proposition of innovations or new products very differently, crossing between the markets is an arduous journey—one that many innovations fail to complete.

Despite many years in the home building market, scholars still consider high performance home technologies and certifications as innovations (Greenhalgh & Rogers,

¹ For this paper, the terms green and high-performance housing are equivalent and will be used to describe any new home in which technologies are installed that have the capacity to create operational efficiencies such as reduced energy consumption and reduced water consumption. This stands in contrast to most attributions of green that require some degree of certification from a rating system such as EPA’s Energy Star (ES) or the US Green Building Council’s Leadership in Energy and Environmental Design (LEED). Very simply, houses that have the technological capacity to deliver upon the value proposition as green or high-performance whether or not they carry any official certification. Equally, those homes carrying a green certification without the technologies to realize the value proposition are also considered to be non-green.

2009; McCoy, Koebel, & Sanderford, 2013; Nikhoo, Sanderford, McCoy, Koebel, & Frank, 2012). Given their standing as innovations, we use the intellectual frameworks of the diffusion of innovation, specifically, Moore’s theory of the Chasm to analyze the missing attribute and performance information-valuation problem described above (Muller, 2008). C3_Figure 1 represents the authors’ conceptual estimations of the two different diffusion trajectories of high performance homes under the condition of inadequate information (A1 and B1) and under adequate information (A2 and B2). As with most explorations of the diffusion of a current innovation, it is difficult to know precisely what is happening given the quality and availability of the data.²



C3_Figure 1

- A1: Diffusion curve of the same housing units with complete value proposition information
- A2: Diffusion curve of green homes without full green information

² We took a cue from Shiller’s discussion of the missing data problem prompting him to develop what would become the Case-Shiller Index. In the *Subprime Solution* he writes, “When I was writing the second edition of *Irrational exuberance*—updating and expanding what had been a book largely about the stock market boom of the 1990s to cover the real estate boom of the 2000s as well—I wanted to include an analysis of the long-term performance of the housing market. To my surprise, everyone I asked said that there were no data on the long-term performance of home prices—not for the United States or for any country. Stop and think about that. If the housing boom is such a spectacular event, wouldn’t you imagine that someone would care if this kind of thing had happened before, and what the outcome had been? So I constructed my own index of U.S. existing-home prices dating all the way back to 1890.” (Shiller, 2008)

- B1: Number of re-sales for green homes that can be used to establish the market value for green features including certifications
- B2: Number of re-sales that can be used without green value information

The value proposition, or set of reasons why an investor should adopt one product over another product, for high performance buildings is based on the assumption that through the use of resource efficient technologies, an investor can reduce overall resource consumption creating lower operating costs. Lower operating expenses raise a building's net operating income that could then be capitalized, *certeteris paribus*, into a higher building value or simply increased cash flow to owners. Commercial real estate researchers have shown econometrically that in both commercial office and multi-family apartments, this value proposition holds in many markets. Further investors are able to realize premium rents for green certified and thermally efficient buildings than in similar facilities without those environmentally beneficial characteristics. Though there are many reasons that commercial property has been the focal point of green real estate research, perhaps one of the more important is the transparency by the disclosure and availability of data about building operations, leases, and building systems (Muldavin, 2010; Yudelson, 2008).³

High performance houses carry the same value proposition to homebuyers as green commercial buildings carry for investors. Where a high performance home contains building technologies designed to reduce operating costs, those savings could be reflected as construction quality upgrades, capitalized into higher home prices, or could provide an advantage over previously built homes. The residential real estate literature has begun to confirm this assumption, though the evidence is not nearly as robust as that found in the commercial literature. In the few markets where researchers have access to both high performance housing data such as the presence of energy related certifications (e.g., Green Point) or individual technologies (e.g., double paned windows) and a sufficient sample of homes, they have indicated econometrically that high performance

³ Data services such as CoStar, Real Capital Analytics, NCREIF and others help to provide professional analysts with increasingly transparent and accurate data. It is no surprise that the lion's share of the commercial real estate reaserach on green buildings has relied on CoStar and NCREIF data. Were these two services available for housing analyses (similar to the HEED database in the UK), this dissertation would have taken a radically different shape.

houses can sell at premium prices to comparable traditionally built homes (Aroul & Hansz, 2011; N Kok & Khan, 2012).

Unfortunately, the converse of information availability is also true. Where researchers and appraisers cannot find sufficient samples and/or the availability of performance data is missing, they are precluded from accurately estimating the contributory value of technologies and certifications in homes. This missing information market failure combined with the reliance on the comparable sales method creates a vicious cycle. Where appraisers do not have or cannot access information related to high performance homes to conduct a comparable sales analysis, they cannot differentiate between the high performance and non high performance houses and the price discovery mechanism breaks down.⁴ Where there is failed price discovery, developers and builders may not get the appropriate market signals about the desirability of these attributes; something which could substantially limit the diffusion pattern of high performance homes or the portfolio of high performance options.⁵ Whereas there are environmental and economic benefits created by high performance homes, and some have argued against a positive impact for innovativeness, the authors assume here that their increased diffusion is a desirable outcome for the industry and economy at large.

To analyze the missing information-valuation problem in the context of the diffusion of innovation theory, we review the diffusion of innovation literature including a summary and application of Moore's chasm. We also identify the most likely information gatekeeper relative to this diffusion problem. Further, we review the literature of value estimation focusing on innovation both in and outside of real estate.

Literature Review: Innovation

The Chasm: A Summary

Diffusion trajectories, the cumulative percentage of adopters, for innovations are expected to approximate a normal distribution (typically represented as an S-shaped

⁴ Price discovery is the act of determining asset prices based on the behavior of buyers and sellers.

⁵ Appraisers may use the cost method to make quality of construction or fully cost based adjustments in instances where insufficient comparable units exist with similar enough attributes to the subject property. While this has been shown to provide defensible value estimates, the efficacy of the method is attenuated insofar as cost does not always reflect what a competitive buyer would be willing to pay for the attribute—often a key point in the valuation of a green or high performance home.

curve) when the factors influencing adoption are normally distributed (Beal & Rogers, 1957; Beal, Rogers, & Bohlen, 1957; Bose, 1964; E. Rogers, 1995; E. M. Rogers & Beal, 1957, 1958; Ryan, 1948). While on the surface, the adoption of a product along this cumulative distribution (known as the Technology Adoption Life Cycle or (TALC)) appears continuous, research points out that there are gaps between each of the major adopter groups: innovators, early adopters, early majority, late majority, and laggards that constitute the TALC (Corrigan, 2001; Halevy et al., 2003; Levinthal & Rerup, 2006; Moore, 2002).⁶ These gaps represent the differences in attitudes about and needs for innovative new products and services (Femenias, 2009).

Technologist Geoffrey Moore condensed the five categories of adopters into two: the early market and the mainstream market. Within the early market, innovators tend to be venturesome (E. Rogers, 1995). They also tend to be technology enthusiasts and are often considered to be visionaries (Moore, 2002). They work to match emerging or breakthrough technologies with strategic opportunities (Egmond, Jonkers, & Kok, 2006c). In addition to innovators, early adopters make up the remainder of Moore's early market. Early adopters are often considered thought leaders or all well connected (Watts & Dodds, 2007) because they help to reduce adoption uncertainty about products through their early adoption and communication of their subjective evaluations (Egmond, et al., 2006c; Moore, 1991, 2002; E. Rogers, 1995).

Early majority adopters represent the leading edge of the mainstream market (Moore, 2002; E. Rogers, 1995). This group is composed of pragmatic purchasers who care about product quality, support, reliability and productivity gains from product use. Early majority adopters are deliberate and are keen to find products and services with strong economic value propositions—a distinguishing factor from the early market segments. This distinction is important in the context of green housing as early market adopters appear to have purchased these units aware of their environmental performance but with limited tools or need to substantiate their financial performance in many markets (Bernstein, 2007; Goodwin, 2011). This distinction between market segments has also been observed in the diffusion patterns of other types of consumer durable goods

⁶ Rogers used adoption over time to describe the 'Technology Adoption Life Cycle' (TALC) or the total number of adopters picking up an innovation over time (Brown & Venkatesh, 2005).

(Grewal, et al., 2000).

To provide innovations with the greatest chance for entry into and success within the mainstream market, developers of innovations must craft strategies that clearly communicate their product's value proposition(s) to both the early market and the mainstream market. Given that the early and mainstream markets have very different product attribute and information needs, Moore cautions that the "greatest peril in the development of a high tech market lies in making the transition from an early market dominated by a few visionary customers to a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation" (Moore, 2002). This gulf between markets is so wide that Moore called it the chasm (Moore, 1991). The theory of the chasm has not yet been used to study the diffusion of high performance homes. It is more typically applied to the study of information technology and related products. Here, we harness the procedural similarities of the diffusion of most innovations and attempt to differentiate our work by identifying how housing and housing related products differ substantively in their diffusion and chasm crossing processes from previously studied innovations.

Chasm As an Analytical Framework in Non-Housing Industries

The theory of the chasm has traditionally been applied to the study of marketing and new product development in information technology and related industries (Sroufe, Curkovic, Montabon, & Melnyk, 2000) specifically within fields of computer software and hardware (Cohen & McGee, 2004; Maurer & Melnik, 2007; Tantisiriroj, Patil, & Gibson, 2008). Medical researchers have also captured and applied it to the study of issues relating to the delivery of increased quality of patient care and education (America, 2001; Corrigan, 2001; Lorenzi, Novak, Weiss, Gadd, & Unertl, 2008; Rivas, Varela, & Scott, 2010). Additionally, scholars of entrepreneurship, management, marketing and education have used the concept of the chasm to analyze individual and organizational learning patterns, to create better e-commerce solutions, and to analyze the diffusion patterns of consumer durable goods (Kohavi & Provost, 2001; Levinthal & Rerup, 2006; Muller, 2008; Rasila, Sepps, & Hannula, 2002). Further, research in construction product

commercialization has used the concept of concurrent commercialization to measure the rate and timing of early and mainstream market adoption (McCoy, et al., 2010).

For high technology products, crossing the chasm often relies on a ‘high-risk, low-data’ strategy because of the difficulty in extrapolating information from early market product adopters (Moore, 2002). Moore cautions firms plotting their chasm crossing strategy to avoid the traps of micro-numeracy and statistical forecasting of markets and instead to develop scenarios using known data balanced by informed intuition to target key stakeholders and frame the value proposition (Moore, 2002). Explorations in effectuation, or the science of entrepreneurship, seem to bear out this argument (Dew, Sarasathy, Read, & Wiltbank, 2009; Read, Dew, Sarasvathy, Song, & Wiltbank, 2009; D. Sarasvathy, Simon, & Lave, 1998; S. D. Sarasvathy, 2008).

However, outside the high technology and effectuation research, much of the non-technology literature arrives at a slightly different conclusion than does Moore about the role of data in crossing the chasm. Instead of ‘informed intuition’ it appears that as the entrepreneur is too far removed from the adopter forcing non-technology industries to demand more data driven strategies. As real estate is a data intensive business and the purchase of homes a more than substantial transaction for an adopter, the diffusion of an innovation across its chasm should likely require a more data driven approach.

An additional distinction between high performance housing technologies and other industries is that most housing innovations do not stand on their own. They are typically analyzed as a portfolio of products or a system imbedded into a homes. Attempting to unbundle this group from the home or one high performance technology from its cluster of other high performance technologies would be analytically very difficult and could cause significant problems related to estimated energy performance. It would also influence their value proposition to the adopter.

High performance housing innovations also have non-trivial costs and installing the innovation in favor of their traditional economic substitute represents a significant choice by the homebuilder and homebuyer. The homebuilder’s choice to adopt these technologies can partially be explained a range of factors including the presence of public policies and incentives, climate, supply chain and skilled labor availability, price, and market demography (McCoy, et al., 2013). However, despite this and other survey data

from advocates describing the customer's interest in high performance innovations, the drivers of the homebuyer's innovation choices remain under-explored in the literature. For appraisers, this lack of information confounds price discovery, as cost and perceived demand cannot accurately measure market value.

Identifying an Information Gatekeeper

Previous research in housing, building construction, and information technology has identified the roles of technology champions and information gatekeepers in the diffusion of innovation (Egmond, Jonkers, & Kok, 2006a, 2006b; Egmond, et al., 2006c; Femenias, 2009; Koebel & McCoy, 2006; McCoy, Thabet, & Badinelli, 2009). Koebel and McCoy summarize the characteristics of construction firms that influence their choice to adopt innovations (Koebel & McCoy, 2006). They highlight the role of the innovation champion or an advocate within the firm that will help drive the firm towards more innovative practice and technology. This champion must be able to articulate the risk-reward profile for adopting an innovation as well as be willing to experiment and fail. The innovation champion within a firm is a rather important concept. However, the champion appears to be fully separate from the gatekeeper. The gatekeeper is the agent or process that holds the key to entering the mainstream market and broader diffusion. They play some pivotal role without which further diffusion is untenable.

With respect to the diffusion of high performance housing, a number of potential actors could be considered in the role of the gatekeeper; the builder, the realtor, and the lender could each play this role. However, given the interaction between information and its conversion to a value proposition, the most likely gatekeeper is the appraiser. Given the common use of debt to purchase homes, lenders must rely on appraisers to provide an objective, third party estimate of value as collateral for a mortgage.⁷ The appraisal is the first order process converting information about a home into an estimate of value. If the appraiser estimates a price for a home substantially differently than the contract purchase price, then the lender is likely to reduce the amount of their loan or not issue it at all. The

⁷ We recognize that as most residential real estate is purchased using some form of debt that the roles of the appraiser and the lender are deeply entwined, especially as it relates to the diffusion of innovations. We focus on the appraiser here as they are the agent responsible for the value estimate. We assume a rational lender accepts the value estimate leading to the issuance of a mortgage.

appraiser does not have a vested interest in whether or not the buyer adopts a high performance house. They are simply charged with analyzing the most probable price a reasonable buyer would pay for a home. To the extent that they cannot incorporate information about the innovative nature of the home into their work, they cannot relay substantiate the value proposition of the innovation. Without the appropriate information from the appraiser, the lender cannot signal the credit markets to most optimally allocate capital; potentially creating a negative feedback cycle that would generate curves A2 and B2 in figure C3_Figure 1.

Egmond et al (2009) argue that housing NGO's could play the gatekeeper role for municipalities adopting high performance housing policies in the EU(Egmond, et al., 2006a). Indeed, NGO's in the US have very recently adopted the role of information clearinghouses for green buildings launching programs such as the *Green Building Information Gateway*. The United States Green Building Council (USGBC) and other advocates have played a strong role in advancing the agenda to green the commercial building and housing stocks. Additionally, academic research has contributed to the greater empirical understanding of the business case for high performance commercial buildings and houses. However, both of these parties would likely be more likely to be classified into the role of an innovation champion or advocate rather than gatekeeper because their central task is not to substantiate the value proposition of an individual relative to its comparable market. If capital is to flow to buyers of these units and facilitate demand at market prices, neither the NGO nor the researcher can convert the presence of innovative technologies and their performance data into an estimate of its contributory or total potential market value. That remains the task of the appraiser.

Literature Review: Value Estimation

Efficient Markets Hypothesis Summary

The Efficient Markets Hypothesis (EMH) contends that financial markets are informationally efficient and that the prices of assets traded in financial markets represent

all information available to investors (E. F. Fama, 1970, 1998, 2012; Malkiel, 2003).⁸ The EMH further asserts that there is a continuum of information upon which asset prices can be based. Where the cost of information is low, the quality of information is high, the access to information is easy, and distribution of information is widespread, prices are easier to defend and to predict. Where these conditions are not met and information becomes less available and more expensive to obtain, variations in price estimates grow and prices become significantly harder to predict.⁹ For an in-depth review of the historical literature on the mathematics and history of the EMH see (LeRoy, 1989) and for counter-arguments see (Nicholson, 1968; Rosenberg, Reid, & Lanstein, 1985).

Because of the limited information available in the market place about leading edge products, processes, and services, innovations tend to disrupt investors valuation and make capital allocations more difficult (Baumol, 2010; Greenhalgh & Rogers, 2009; Harhoff, Henkel, & Von Hippel, 2003; Moore, 2002; Sahlman, 1990). Additionally, scholars suggest that the entrepreneur, with a deeper understanding of the value proposition of the product, must communicate that knowledge precisely to investors and to potential adopters or risk mis-pricing and under-investment (Akerlof, 1970; Harhoff, et al., 2003; Moore, 1991; Quan & Quigley, 1991). The role of the entrepreneur in communicating the value proposition of an innovation within the housing market is often blunted as the innovations are clustered and embedded into a home by a builder who, conceivably is responding to consumer demand. This wrinkle adds confusion to the missing information-valuation-diffusion problem defined in Chapter 1 and adds challenge to the appraiser's task identified above.

Valuation of Innovation In Other Industries and Products

How markets price the innovation of operating efficiency gains of new and used hybrid electric vehicles (HEV) or alternative fuel vehicles (AFV) (e.g., diesel and liquefied natural gas) may have reasonable similarities to the valuation of innovations in

⁸ It also contends that investors cannot regularly earn returns in excess of the total market return because they are constrained by the amount of information available.

⁹ The need for more widely distributed (and verified) information can be seen in the run up to the 1928 stock market crash and the enacting of 1933 Securities Act (Keller, 1988; Landis, 1959; SEC, 2010). Recent insider trading cases also illustrate the role of information in pricing and arbitrage ("U.S. V. Rajaratnam," 2011).

housing. Research suggests that buyers of HEVs or AFVs often inaccurately estimate discount rates (Greene, 2010) when analyzing fuel efficiency and make large errors in estimating fuel efficiency savings, discount rates, and fuel costs over time (Howarth & Sanstad, 1995; Turrentine & Kurani, 2007). Further, buyers appear willing to pay premiums for both HEVs or AFVs in spite of the difficulty estimating long-term costs of ownership (Furlong, 2011a, 2011b) and they are willing to pay these premiums during periods of increased fuel prices (Gilmore & Lave, 2013). The literature points to comparable sales methods and net present value calculations as consensus analytical methodologies for both buyers and research purposes (Erdem, Şentürk, & Şimşek, 2010; Krutilla & Graham, 2012; Saarenpää, Kolehmainen, & Niska, 2013).¹⁰

Estimating the value of eco-system services or the innovations produced by natural capital produced and managed by the planet's natural systems, like high performance homes, is a task limited by information availability (Costanza et al., 2007; Loomis, Kent, Strange, Fausch, & Covich, 2000). To overcome the information deficit, eco-system services scholars use *contingent valuation*, an econometric technique, that requires survey respondents to articulate the number of dollars they would be willing to pay or to accept to protect or lose some ecological service (Howarth & Farber, 2002). Ecological economists also use *hedonic valuation* to estimate the value of natural innovations such as bio-filtration (Postel & Thompson, 2005). In hedonic valuation, the known price of a good or service is regressed on a set of factors thought to contribute to the good or services' total value.¹¹

Financial analysts and researchers often estimate the unique value contribution of an innovative product to a firm using the *event study method* (E. Fama, Fisher, Jensen, &

¹⁰ With respect to the appraisal of high performance homes, appraisers do not commonly use cash flow capitalization or time value of money based methods. However, where high performance housing innovations create energy savings cash flows, accurately and quickly estimating the discount rate as well as the period of analysis and anticipated future utility costs should be a focal point in estimating their contributory value in single-family housing.

¹¹ Hedonic valuation has a deep history in urban and land economics as well as in real estate appraisal (for technical examples and further explanation see (Greiner & Thomas, 2013; Malpezzi, 2003; N. G. Miller, 1982; Tse, 2002)). For example, appraisers use this technique to measure the effect of air quality levels on home prices as well as measure the value of a unit's locational efficiency (Anselin & Le Gallo, 2006; Nelson, 1978; Rauterkus & Miller, 2011; Rauterkus, Thrall, & Hangen, 2010). It has also been applied to green commercial real estate to show that buildings with higher walkability scores have higher capitalized values and rents (Pivo & Fisher, 2009; Pivo & Fisher, 2010).

Roll, 1969). The event study method is an information intensive time series econometric method that measures the expected normal return of a firm and considers any additional return above that to be an abnormal return generated by some shift in information such as the announcement of a regulatory approval or approval of a patent (Binder, 1998; Lee, Smith, Grimm, & Schomburg, 2000).

Research from the US and UK has analyzed the relationship between equity returns and regulatory approval announcements for innovations from pharmaceutical and bio and information technology firms and discovered positive abnormal returns for approvals though too few negative announcements were made to confirm the opposite relationship (Ely, Simko, & Thomas, 2003; McNamara & Baden-Fuller, 2007; Sarkar & de Jong, 2006). Though not an exact substitution, Apple's equity return was observed to suffer abnormally following announcements about Steve Jobs' increasing health problems (Koch, Fenili, & Cebula, 2011). The results from both the drug and biotechnology industries appear to match findings from the software industry and other industries where innovation is used as firm and product differentiation strategy (Austin, 1993; Bayus, Erickson, & Jacobson, 2003; Chaney, Devinney, & Winer, 1991; Lee, et al., 2000).¹²

Real Estate Appraisal

Turning from the context and role of information in the valuation of innovation outside the property industry, we review the process of real estate appraisal and the role of information within it. We examine the central task of the appraiser, the regulatory environment, and summarize common appraisal methods for single-family homes. Our goal is to place the current state of appraisal practice into the context of the missing information-valuation-diffusion problem defined earlier.

¹² Commercial real estate scholars have applied the event study method to REIT return data, though not with an eye towards innovation, and with mixed certainty on the findings (Glascock, Davidson, & Sirmans, 1989; Rodriguez & Sirmans, 1996; Wang, Erickson, & Gau, 1993). It does not appear that there has (yet) been an investigation of any abnormal equity returns of member firms of the FTSE NAREIT Index Series-Green (the soon to debut green REIT index) following the release of Eichholtz et al's 2012 paper on the superior performance of REITs with green assets (P. Eichholtz, Kok, & Yonder, 2012).

Central Task of the Appraiser

In modern real property analysis, the real estate appraisal, or value estimate, is a process tool used to predict the market value of an interest in real estate. The Appraisal Institute defines market value as:

The most probable price, as of a specified date, in cash or in terms equivalent to cash, or in other precisely revealed terms, for which the specified property rights should sell after reasonable exposure in a competitive market under all conditions requisite to a fair sale, with the buyer and seller each acting prudently, knowledgeably, and for self-interest, and assuming that neither is under duress (AI, 2008).

In other words, the task of the appraiser is to estimate most probable price for specified real estate interests given existing market conditions, to the most probable buyer (J. R. DeLisle, 2001; Pagourtzi, Assimakopoulos, Hatzichristos, & French, 2003). The most probable buyer is an important nuance relative to green housing and its journey across the chasm from the early market to the mainstream market. Especially for a high performance home, an appraiser must evaluate the market in which the unit is located and the willingness of that market to accept green elements in their housing purchases (J. DeLisle, 1984; French & Jones, 2010; Graaskamp & Appraisers, 1970; Runde & Thoyre, 2010).

Runde and Thoyre (2010) suggest a method an appraiser can use to place a high performance building or home on a continuum from brown to green for the housing unit type and on a continuum from sustainability oriented to non-sustainability oriented for the market place. Their four quadrant model allows the appraiser to establish an analytical benchmark from which they can make more precise adjustments for various attributes (Runde & Thoyre, 2010). By more appropriately benchmarking the market the appraiser is forced away from making singular adjustments (Das & Wiley, 2013) such as the commonly cited Nevin gross energy modification that increases the value of a home for energy savings no matter the orientation of the market place, the buyer, or time since the high performance technologies were installed (Nevin, Bender, & Gazan, 1999; Nevin & Watson, 1998).

Additionally, in considering the most probable buyer of a green home the appraiser will have to make both objective and subjective inferences about the most

probable buyer pool from the data using both internal and external factors (Ratcliff, 1972). Internal factors could include the probable buyers' family structure, access to capital, and their ability to budget for household expenses including home operation. External factors could include the quality of and cost of innovative building technologies as well as market prices for power (gas, electricity, wind, or solar) (J. R. DeLisle, 2001). The examination of external factors, including the presence of high performance technologies, is also critical because it helps remove potential bias of the appraiser for or against green design from the value estimation process.¹³ Further, by growing more accurate in estimating the most probable buyer given the market place, appraisals of high performance homes should grow more precise and positively influence their diffusion into the market place. Goodwin (2011) identified three trends describing recent green home buyers: 1) Buyers of new homes appear to rank green attributes higher than buyers of existing homes, 2) buyers under 40 appear to rank green attributes higher than buyers under age 40, and 3) buyers with incomes over \$100,000 rank green attributes as less important than those making less than \$100,000 (Goodwin, 2011).

Appraisal Regulation

The appraisal of real estate is primarily guided by the Financial Institutions Reform, Recovery, and Enforcement Act of 1989 (FIRREA), the Truth in Lending Act (TILA).¹⁴ Recently, the Wall Street Reform and Consumer Protection Act (a.k.a Dodd-Frank) modified FIRREA and created the Consumer Financial Protection Bureau. Each of these complex sets of laws set the playing field for the State licensing of appraisers, the oversight of appraisal management companies, the issuance of mortgage credit and the collection of mortgage related fees (Frank & Dodd, 2010).

Title 9 of FIRREA provided for the creation of an oversight organization that would govern professional practices, standards, and qualifications (FIRREA, 1989). The Uniform Standards of Professional Appraisal Practice (USPAP), born out of this legislation (and collaboration between professional appraisal organizations), helped to

¹³ Not recognized in the literature as a significant factor, it stands to reason there could be negative interaction effects between the average age of members of the Appraisal Institute (52) and the types of green homes typically advanced as exemplary in training programs and design magazines.

¹⁴ See table 1 in the End Notes for a broader list of Federal regulations that influence the appraisal of real property.

standardize practice and ensure a minimum quality threshold for reporting. A further effort at reporting and data standardization came from Fannie Mae and Freddie Mac who introduced the Uniform Residential Appraisal Report (URAR) to standardize reporting of the appraisal of collateral pledged as security for a loan (FHLMC, 2005; FNMA, 2006).¹⁵

The URAR includes at least one section to describe the energy performance of a house. The URAR allows appraisers to note the inclusion, type, and resistance value (R-Value) of energy efficient technologies (FNMA, 2006). Fannie Mae requests that appraisers consider high performance technologies in value estimates as they reduce operating costs and vary substantially by climate zone (FNMA, 2013). Further, the Fannie Mae requires appraisers to compare energy efficient homes to other homes using a sales comparison grid to ‘ensure that the overall contribution of these items is reflected in the market value of the subject property’ (FNMA, 2013). However, despite the inclusion of a line on which to record these attributes on the URAR, their recordation is uncommon. This compounds the valuation challenge, as the sales comparison approach requires analysis of sales of homes containing similar attributes. Where high performance home comparables do not exist or are not well catalogued or searchable, estimating their contributory value is a significant challenge (Adomatis, 2010; Normand, 2012).

To advance the collection of energy related information about homes; Senators Bennett (D-CO) and Isakson (R-GA) have put forward a bill requiring lenders to assess potential borrowers’ energy costs as a component of the underwriting process. Known as the Sensible Accounting for Valuing Energy Act of 2011 (SAVE Act), federally sponsored loan purchasing firms such as Fannie Mae and Freddie Mac would begin to collect and catalogue expected energy use data as a tool to assess risk as well as reduce energy consumption (Bennett, 2011). At present the fate of the SAVE Act is uncertain.

Appraisal Methods

With respect to the appraisal of property and buildings, it is important to separate

¹⁵ In 2011, the FHFA began requiring appraisers to use the Uniform Appraisal Database (UAD) to enhance the accuracy and quality of loan data delivered to both Fannie Mae and Freddie Mac. The UAD standardizes inputs for many fields including condition and quality—two factors that can be used to adjust for high performance home technologies and certifications.

the discussion between those traditionally applicable to residential real estate and those applicable to commercial real estate. In commercial real estate appraisal, the appraiser may use all possible methods of valuation including the comparable sales, cost, and income capitalization or discounted cash flow methods. The latter methods have not historically been applicable to single-family residential property though to the extent that green homes operate more efficiently than other homes and create measurable cash flows that could be capitalized and valued, it appears time for a blending of these methods (for a review of capitalizing cash flows see textbook sections from (Geltner, Miller, Clayton, & Eichholtz, 2007)). For a more in-depth review of the history of real estate appraisal methods, see (Pagourtzi, et al., 2003; Vandell, 2007).

The most common and required method of valuation for single-family residential property is the comparable sales method (AI, 2008; Vandell, 2007).¹⁶ There are seven steps to conducting a comparable sales analysis:

1. Compilation of information into a database;
2. Acceptance of an appraisal assignment & definition of appraisal problem;
3. Quantification of the subject property;
4. Search for comparable units;
5. Adjustment of data to create equivalent comparables;
6. Correlation between comparables to obtain a final value; and
7. Issuing the final appraisal report (J. R. DeLisle, 2001; Jarchow, 1991).

Traditionally, to compile property information, the appraiser conducts a site visit and searches property tax records, plats, previous transfer deeds, and the local multiple listing service (MLS) to gather relevant property data (Pagourtzi, et al., 2003).

The comparable sales method for residential real estate identifies competitive homes that are comparable to the subject unit. Residential real estate appraisers identify geographically proximate and recently sold housing units or similar construction quality and condition that are both comparable to and would have been competitive with the unit being appraised. They then adjust the probable market value based on the differences between the comparable units and changes in market conditions (FNMA, 2006). Where an appraiser cannot find adequate comparables, they may turn to the cost method and

¹⁶ For the purposes of this article, residential property includes multi-family property so long as individual units are to be sold as condominiums. Where multi-family buildings contain rental units they will be considered as commercial income producing real property that should be appraised quite differently.

sum the cost of the home's attributes adjusted for the quality of construction (AI, 2008).

Appraisers are trained to estimate the value of complex and unique homes and sites (AI, 2008) even during periods of market volatility (French, 2011). Research shows that hedonic pricing models can estimate the contributory value of satellite imagery in an MLS listing (Benefield, Cain, & Gleason, 2012), proximity to open space (Irwin, 2002), views (Rodriguez & Sirmans, 1994), locational efficiency (Rauterkus, et al., 2010), traditional neighborhood design (Tu & Eppli, 2001), and the proximity to public transport (Bowes & Ihlanfeldt, 2001). Similarly, with respect to estimating the value contribution of unique building attributes such as the presence of finished basement bedrooms and accessory dwelling units, current appraisal practice guidance recommends converting the unique elements into individual costs or rent producing components, multiplying each by some cost factor or gross rent modifier (Nevin, et al., 1999; Nevin & Watson, 1998), and adding the marginal value created to the price of the home as appraised without them (Andrus, 2012; Martin & Watkins, 2012). This traditional plus marginal value gain method contains significant potential for the appraisal of high performance homes given the missing information problem.

During the comparable analysis of high performance homes, appraisers must ask important questions about the number and quality of comparables used to substantiate the theory of value described above (green value as the present value of the green components newly after-tax benefits). Where there is no comparable unit data available that describes the green features of a home, an appraiser could be forced to make less logical adjustments for value based on information not fully germane to their market (e.g., Nevin's modifier or application of premiums from other academic valuation studies not focused on the subject property's geography). If the appraiser makes illogical adjustments or cannot find data about the demand for high performance attributes, then the diffusion trajectory of high performance homes in that market would follow curves A2 and B2 of C3_Figure 1. There would not be enough data to meet the needs of the pragmatic buyers in the mainstream market and sales volumes would decline and fade. Noting this lack of or inaccessibility of information about green homes, the Appraisal Institute (AI) issued an addendum to modify the Uniform Residential Appraisal Report (Fannie Mae 1004) (AI, 2011). Much like the proposed Green MLS Toolkit, the

addendum provides a place to list information about green attributes for any appraisal assignment (AI, 2011). To the extent that tools like the AI Addendum can help bring more data into the comparable analysis of green homes, the diffusion curve of green homes should look closer to curves A1 and B1 of Figure 1. However, at present, once an appraiser collects the information into the AI addendum, the data is not warehoused such that it can be used again by others in the same market place (or other markets for that matter).

Current Green Valuation Methods

Real estate scholars have used exact pair matching, fixed-effect regression, and other econometrically sophisticated techniques to identify the value premiums associated with green office and apartment buildings (Dermisi, 2009; P Eichholtz, Kok, & Quigley, 2011; Feige, McAllister, & Wallbaum, 2013; Fuerst & McAllister, 2008; N. Miller, Spivey, & Florance, 2008; Pivo & Fisher, 2009; Wiley, Benefield, & Johnson, 2010). Similar methods have been used on (in most cases) much smaller sets of single-family housing data to estimate green premiums (Aroul & Hansz, 2011; Bloom, Nobe, & Nobe, 2011; N Kok & Khan, 2012; Mandell & Wilhelmsson, 2011; Nevin, et al., 1999; Nevin & Watson, 1998; Rauterkus & Miller, 2011; Rauterkus, et al., 2010). However, both practical experience and recent research suggest that premiums from this body of work should not be applied uniformly to all green buildings (Das & Wiley, 2013). So, how should appraisers (or researchers) work where there is limited, missing, or inaccessible information about green and high performance homes (Fuerst, McAllister, van de Wetering, & Wyatt, 2011)?

There are two common methodological approaches appraisers can use to estimate the contributory value of high performance home technologies and certifications under the condition of missing information: 1) a present value calculation of the after tax benefits created by energy savings (Adomatis, 2010; J. DeLisle, 1984; Popescu, Mladin, Boazu, & Bienert, 2009); and 2) a quality of construction based approach where matched pairs are used to account for as many adjustments in value as possible. Where there remains unexplained variation in the estimated value of a high performance home, the final adjustment is attributed to the superiority of construction quality related to high

performance innovations (Watkins, 2011).

Though there have been theoretical suggestions on how to account for the present value of the energy savings, (Adomatis, 2012; Bostic et al., 2012; Leopoldsberger, Bienert, Brunauer, Bobsin, & Schetzenhofer, 2011; Lutzkendorf & Lorenz, 2006; Popescu, et al., 2009) few if any empirical studies exist (Bostic, et al., 2012). Further, the literature offers a wide range of guidance on assumptions to make on the present value calculations. For example, some suggest using the mortgage constant of the buyer while the SAVE Act recommends a 20 year period and the same discount rates as recommended by OMB for Federal projects for high performance technology analyses (Bennett, 2011; Browning & Romm, 1995; Fowler & Rauch, 2008). Others suggest building residential property analysis assumptions from the US Real Estate Investment Trust market (DeWeese, 2009). While each has their merits, practitioners do not appear to have coalesced around a common method.

For a cluster of technologies that have varying useful life-cycles innovations that attach to the house and not the buyer, this advice risks being too generic and could under or over estimate the value contribution of high performance technologies. If high performance homes are to cross the chasm into the mainstream housing market, appraisers need greater access to data to feed the more traditional methods of analysis. They also appear to need a practical temporary tool to help them in markets where there is missing information about the attributes high performance homes that would preclude the use of comparable sales analysis. The next section describes a location adjustable method of selecting a discount rate, period, and costs for a net present value analysis that fills the above gaps. Its goal is to fill the gap and to help increase the diffusion trajectory of high performance homes.

Limitations

Perhaps the most substantial limitation of this essay is its lack of consideration for the role of the Great Recession in stymieing innovation. Here, the authors focused on the role of missing information and the conceptual or theoretical effects it could have on the adoption and diffusion of high performance homes into the market place. By asking about expected diffusion patterns, the problem of missing information could be

considered outside of the on the ground problem of the credit crisis. Indeed, much has been written about the seizure of the mortgage markets and that seizure's effect on any number of issues (e.g., commercial loan portfolios, employment, etc). However, little has been penned on the relationship of energy efficiency and the building stock during this period. Two recent articles from the real estate finance literature offer conflicting analyses of the data. Kok et al (2011) suggest that the diffusion of energy efficiency in office buildings increased during the crisis period in markets with strong fundamentals (N. Kok, McGraw, & Quigley, 2011). On the other hand, Das and Wiley (2013) show evidence that building owners hedged towards energy efficiency as commercial office market fundamentals softened (Das & Wiley, 2013).

Relative to housing, it could be argued that process innovations such as the automated underwriting models that were developed in the late 1990's and refined into 2006 plus the demand for increasing numbers of securitized loan portfolios and derivatives helped to curtail the adoption of physical innovations related to the energy efficiency of new houses. This would be a logical argument. However, from the NAHB Builder's Practice Survey, there is evidence that suggests that, among a subset of high performance housing technologies, there was an increase in the proportion of builders installing these technologies in new homes. As the data doesn't suggest the extent to which these homes were self-funded, funded by pre-purchase agreements, or funded via debt instruments, it is difficult to get a clear picture vis a vis new homes. Clearly, what is clear here is that the capital markets play a role in the diffusion of homes into housing markets—traditionally built or otherwise. More econometric research is needed here to uncover the deeper links and relationships between the diffusion of high performance housing and the credit crisis of 2007-2009.

Conclusions and Next Research Steps

The diffusion of high performance single-family homes into most US regional housing markets has been hamstrung by missing data about the presence and performance of innovative energy efficient technologies. Where appraisers do not have data on these attributes to conduct their required analyses, they are blocked from making accurate

estimates of the contributory value of those innovations. When contributory estimates of value cannot be made with reliable accuracy, the price discovery process breaks down lowering (or halting) the diffusion trajectory of high performance homes. After exploring this missing information-valuation problem in the context of the diffusion of innovation and Moore's theory of the chasm, the authors identified real estate appraisers as the most likely information gatekeeper. Appraisers are responsible for estimating the market value of homes for mortgage lenders and other exogenous parties to the homebuyer. They are the first order agent of the missing information problem. To the extent that the appraiser cannot search for, find, and analyze data about the presence and relative efficiency of high performance systems, technologies, and designs, there is likely to be mis-valuation of high performance homes. Where there is mis-valuation, the price discovery cycle is likely to become less reliable and slow down—sending increasingly unclear but negative signals to the market place about the value proposition of high performance homes relative to traditional homes.

To jumpstart the price discovery cycle for housing, to help high performance homes cross the chasm, and to begin to use existing data to distinguish the value contribution of the high performance attributes, appraisers need a reliable and temporary tool. Such a tool should borrow liberally from the corporate finance literature and its practice to provide structure and guidance to appraisers as they generate assumptions relative to time value of money calculations. Additionally, as the appraisal literature is has under-explored the methods of valuation for high performance homes, future research should investigate the current methods of analysis practitioners are using and how they are grappling with the missing information problem.

Just as McCoy's work on commercialization in construction product supply chains and Koebel's analysis of the internal champion for innovation within homebuilding firms, this paper provided a basis for applying a diffusion of innovation and chasm theory framework to high performance homes. In identifying the appraiser as the most likely gatekeeper for the missing information problem, the authors confirmed that the chasm as an intellectual framework could be readily applied to analysis of high performance. Moreover, it could potentially be easily applied to analyze other forms of

innovation in housing making it perhaps one of the more important conceptual contributions of the paper to the literature.

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End Notes

C3 Table 1(AI, 2008)

Federal Legislation Influencing Appraisals	
Title	Key Elements
Truth In Lending Act of 1968	Requires copy of appraisal be made available to consumer.
Uniform Relocation Assistance and Rel Properties Acquisition Act of 1970	Requires just compensation for displaced owners and tenants affected by land acquisitions for Federally funded projects.
Real Estate Settlement Procedures Act of 1974	Requires lenders to give borrower an estimate of closes costs within three days of applying for a loan.
Competitive Equality in Banking Act of 1987	Required appraisals for S&Ls to be conducted under same policies and procedures as those for commercial banks.
Federal Land Exchange Facilitation Act of 1988	Created tools for valuting parcels exchanged between Federal agencies and state agencies.
Financial Institutions Reform, Recovery, and Enforcement Act of 1989	Required appraisal independence, refined selection criteria for appraisers, created minimal appraisal standards, and updated USPAP.
Homeowners Protection Act of 1998	Provides for cancellation of private mortgage insurance.
Gramm-Leach-Bliley Act of 1999	Sets requirements for use of non-public personal information by lending institutions and third parties.
Internal Revenue Service Regulation 1.170A-13	Describes reporting requirements for appraisals done for income tax purposes.
Pension Protection Act of 2006	Provides guidance on appraisal of non-cash charitable contributions as well as for estate and gift tax purposes.
Dodd-Frank Wall Street Reform and Consumer Protection Act 2010	Amends FIRREA, adds new categories of mortgages that require appraisal, provides for oversight and fee setting of Appraisal Mgmt Companies.

* *The Appraisal of Real Estate*

Green building practices to increase environmental performance have tended focus on more efficient resource consumption (e.g., energy and water) and the reduction of emissions. Increased environmental performance of buildings creates benefits on multiple fronts. Buildings consume 65% of total U.S. electricity and 36% of all primary energy (Loftness, 2004). Reducing consumption of resources and reducing GHG emissions will have positive local and global externalities (Pachauri & Reisinger, 2007). The fourth assessment report by Intergovernmental Panel on Climate Change (IPCC) estimates that 29% of building CO₂ emissions can be reduced at no cost by 2020 (Levermore, 2008). Green buildings are central to realizing these reductions as they both consume 25-30% less energy (Kats, Alevantis, Berman, Mills, & Perlman, 2003) and use alternative, emission-free, sources including solar and geothermal.¹⁷

A complex web of tools and techniques exist to understand (Ellison & Brown, 2011), rate, certify, and assist analysts with decision-making relative to greening the design, construction, and analysis of a new home or existing home renovation (for a full review of the residential green building rating systems, please see (Price-Robinson,

2013; Stuart, 2012). While Stuart does not classify these tools further, some degree of grouping clarifies their goals, utility, and usability. Here, we distinguish between prescriptive ratings systems, building performance measurement tools, and decision-analysis tools for clarity and increasing the precision of future use and adaptation to valuation.

Prescriptive green building rating systems create checklists for designers and homebuilders that include green techniques, building technologies, and site conditions that can be included or leveraged to earn points ("Usgbc programs: Leed," 2012). The checklists of market leading rating systems including USGBC's LEED for Homes, the DOE's Energy Star, the National Association of Homebuilders' National Green Building Standard, and Passive House provide designers, builders, and the third party rating technicians with a 'build to' specification for certification. Real estate scholars have investigated the value signals created by these rating systems and can show links between certification or public policy and increased transaction values (Bloom, et al., 2011; Dastrup, Graff Zivin, Costa, & Kahn, 2012). However, as should be expected from prescriptive systems without enforcement mechanisms, criticism has emerged citing the ease of green building certification without the requirement for commercial facility performance or the under-performance of certified facilities (Menassa, Mangasarian, El Asmar, & Kirar, 2011; Thomas, 2012).

In addition to the prescriptive green building rating systems there are several tools designed to measure the performance of homes. The most empirically rigorous is the Home Energy Rating System index or HERS index developed by RESNet, a home energy research and standard setting non-profit firm. HERS index values measure the relative performance of a green home to the same home's standard design and construction. A score of 100 indicates that the home performs at parity with a newly built home with respect to energy consumption. A score of 70 indicates that the home being tested performs 30% more efficiently the standard reference design and construction techniques. DOE suggests that most existing homes in the US should score 130 on the index indicating that they are 30% less efficient than the same home built today (insert reference). Circling back to the build up discount rate, using the HERS index for each home's discount rate would allow new homebuyers to use a value of 100 basis points. If the home were already rated at below 100, then they would earn a better rate driven by greater efficiency. The converse is also true.

A recent analysis of HERS index hypothetical homes relative to various iterations of the building codes including IIEC 2006 and 2012 has helped to validate the predictive and descriptive abilities of the HERS index (Fairey, 2013). DOE is also in the process of developing a Home Energy Score on a scale of 1-10 that serves as a home's energy miles per gallon rating (controlled for climate zone). Homes scoring 10 are considered highly energy efficient while those scoring 3 or less could be politely described as energy obese. The Home Energy Score follows the European Union's push to label consumer products for energy consumption—including homes (EUC, 1992). A study home sales in the Netherlands revealed that homes with higher energy ratings sold for a premium compared to non-labeled homes and further that homes with the lowest end ratings sold at a discount to non-labeled homes (D Brounen & Kok, 2010). Similar evidence was found by a similar group of researchers when investigating green labeled homes in California (working paper draft).

In addition to green building rating systems and performance measurement tools, there are a number of information processing and decision making tools that analysts can access and use in the study of green homes. As described above, green building rating typologies and energy consumption scores are rarely tracked in multiple listing services preventing appraisers from analyzing the value contribution of these metrics on most probable home values. However, both the Appraisal Institute (AI) and the National Association of Realtors (NAR) have created new tools forward to help close this information gap and work to solve the information collection problem. AWEAddendum 820.23 is an appraisal report template that functionally modifies Fannie Mae's Uniform Residential Appraisal Form (1004) (AI, 2011). This addendum allows appraisers to expand upon the information provided in Forms 1004/70 to describe the green features, rating systems, and energy consumption metrics associated with a green home. Appraisers in markets where this form is used consistently and the data is stored accessibly should begin to be able to conduct more comparable analysis sooner rather than later.

The NAR Green MLS toolkit provides local boards of realtors with templates and other tools that can be added to their MLS systems to allow the input of green features for new listings (NAR, 2011). Further, the USGBC's Capital Markets Partnership recently released a decision making tool for lenders that integrates much of the above information and converts the weighted scores for data into the number of basis points by which the lender should consider discounting the loan constant. Despite each of incentives and normative pull by these certification systems, tools for measuring, and decision-making frameworks, the lack of regulatory push from behind appears to be a key missing ingredient and hampers our residential energy literacy (Dirk Brounen, Kok, & Quigley; Desiderio, 2012).

Concurrent Strategies to Help Increase Green Home Diffusion

In addition to the temporary valuation solution, the remainder of the green housing industry must also push forward on its present an agenda to increase the amount of, access to, and availability of data about green and high performance homes and their attributes. At present, advocacy groups including the USGBC, the Appraisal Institute, and the National Association of Realtors are developing and getting new data tools into the hands of lenders, brokers and appraisers.

One group of strategies for developing data streams should focus on the investment of public and private funds into demonstration projects in targeted markets. As the NAR has made the Green MLS Toolkit available for modification to individual markets, both the Federal and State governments as well as real estate interest groups such as the Urban Land Institute and the Appraisal Institute should consider funding the adaptation and operation of this tool in several reference markets. As a condition of funding such a demonstration project and to help catalyze further market action, donors could require that the projects become open source tools to be used by other potential adopters. (Need to insert findings from Eng Star regression analysis to help prioritize locations of demonstration projects.)

Such partnerships have already yielded success in the housing industry. For example, the Partnership to Advance Technology in Housing (PATH), a voluntary partnership between HUD's Office of Policy Development & Research (PD&R), the

Federal housing and finance agencies, and a host of private firms created a vehicle to fund, conduct, distribute research findings on innovative housing technologies. It also created an encyclopedia of innovative technologies that could be accessed by builders, developers, and other stakeholders in the housing production industry. A modified example that also holds merit is Tony Malkin's open source project developing the Empire State Building's energy services company. In buying and renovating the Empire State Building, Malkin opened all of the energy management tools for the facility to the public so that any lessons learned could be levered by other building owners at significantly lower costs.

A derivative of this strategy is to use the purchasing and regulatory power of the government to drive the creation of data. Evidence from California indicates that there are positive spill over effects into commercial markets where local governments have green procurement policies and green building policies (Simcoe & Toffel, 2011; Simons, Choi, & Simons, 2009). Shifting private action through public procurement policy is built on the notion of stimulating market supply, noting that "and a significant demand from public authorities for 'greener' goods will create or enlarge markets for environmentally friendly products and services...[and] stimulate the use of green standards in private procurement" (Simcoe & Toffel, 2011). Application of this method to real estate appraisals could be easily managed as a part of the Federal Land Exchange Facilitation Act of 1988 which sets out the appraisal boundaries for exchanges of publicly owned land (BLM, 1988). Where any transaction involving the purchase or sale of publicly owned land requires an appraisal, that appraisal would have to collect information about green buildings on the parcels being transacted. Similarly, the Government Services Administration, to meet the standards imposed by Executive Order 13423, adopted USGBC's LEED program and made green building central to its operation and mission (Bush, 2007). Though the GSA is a commercial land lord and this paper is focused on a residential specific problem, it appears that the same logic could be applied to HUD managed residential property to see what, if any, data streams can be leveraged forward into the housing market.

It is important to note that much like the proposed valuation method, any data development strategy that involves a public subsidy must be temporary. This paper is not an argument for the creation of new public subsidies. Instead, where public subsidies and programs can be leveraged temporarily to help catalyze market change, incentives, markets and firms must drive the process towards full market efficiency. To that end, it will be critical to request some analysis from the primary private market actors and their trade associations. What costs would they be willing to bear to implement more accurate pricing? What tools do they currently possess that they could leverage? What would they need? How big do they estimate this market could be? To some extent, threads of this have been started in the commercial property markets and should be continued to the residential markets (see (Deutsche-Bank, 2011; Kats, Menkin, & Dommu, 2011) for greater details on estimating the market for energy efficiency improvements and investments in buildings).

The strategy with the largest potential effect on the creation, collection, storage, and accessibility of data should focus on the secondary mortgage market actors such as Fannie Mae and Freddie Mac. Despite the rocky history and uncertain futures of these firms, their power over the direction and velocity of the mortgage markets will likely

continue to be substantial for some time. If these two firms were to begin requiring that appraisers and mortgage originator collect data about green homes, the majority of the housing industry would be pulled along quickly. Such a requirement has historical ties to the 1933 Securities act, and its policies that mandating (and creating special exemptions for) the disclosure of certain types of information relative to the sale of securities (Landis, 1959). These disclosures and standards for exemption contributed significantly to the information efficiency of the US capital markets. Today, much of the information dissected by analysts stems from required public disclosures made available by the firms and the Securities and Exchange Commission (SEC).

Chapter 4: Towards a Temporary Solution for Estimating the Contributory Value of High Performance Housing Technologies

**Andrew Sanderford
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Introduction & Problem Statement

Given the extant scholarship on the contributory value of high performance attributes to green homes, it seems logical to argue that until sufficient comparables exist in individual markets for high performance housing, appraisers should adopt a temporary method of valuation. One of the more common methodological suggestions from regulators and practitioners both seems to be an integration of the comparable sales method with the income method to capture the cash flows generated as energy savings from energy efficiency (Adomatis, 2010, 2012; Bennett, 2011). However, as there does not appear to be a consensus path forward on the hybridization of methods, the authors posit that appraisers should borrow conceptually from corporate financial analysis and valuation to help bring standardization to appraisal practice to create a more dynamic and potentially more accurate method than that articulated by the Sensible Accounting to Value Energy Act (SAVE) (Bennett, 2011). This paper uses the simple research question, “Is it possible to develop an alternative valuation methodology to the SAVE Act using best practices from corporate finance?” To test this, the authors advance a method of valuation that considers the value contribution of high performance attributes of green homes as the total present value of the energy savings discounted by a market and collateral specific discount rate. This present value of the energy savings can then be appended to an estimate of the value of a home created in the absence of its high performance features. The proposed method is designed to provide appraisers with a temporary solution that appraisers can use to mend the broken price discovery cycle caused by missing information about and few comparables that include high performance attributes in new homes.

In moving towards a temporary tool that integrates the present value of operating

savings with the comparable sales method, appraisers can leverage the growing suite of tools and rating systems that describe green homes and their costs and benefits (Kats, Alevantis, Berman, Mills, & Perlman, 2003; A. Pearce, 2001; A. R. Pearce, 2008; Price-Robinson, 2013).¹ This method will also help future appraisers to triangulate calculations and use their robust methods of value estimation based on existing home sales data (Graaskamp & Appraisers, 1970; Kauko, 2004; Kummerow, 1997). By focusing on the present value of operating cash flow savings and then appending those to a value developed using the comparable sales model, appraisers are not forced to change their practice but instead simply apply best practices from a related discipline into an existing appraisal framework (Adomatis, 2010). The key practical differences in this suggested method relate to the discounting of future energy savings (Fuller, 2008; Jaffe & Stavins, 1994). Where previous high performance valuation suggestions have emphasized the present value of energy savings, they have not focused on the following four factors: 1) the nuances of first cost estimation, 2) the length of the period of analysis, 3) the reliability of the estimated energy savings generated by the cluster or group of technologies included in the home, and 4) the selection of a discount rate.

Obstacles To A Solution

First cost estimation with respect to green building is typically described as the traditional cost for a facility plus some premium for the differential costs of the green product and system substitutions (A. R. Pearce, 2008; Winiarski, Shankle, Hail, Liu, & Walker). However, when comparisons of materials are right sized, whether or not all high performance systems and technologies will continue to constitute a cost plus scenario for construction or appraisal analysis remains uncertain as the literature is divided in its forecast and discussion (Browning & Romm, 1995; Consulting; Kats, et al., 2003; A. Pearce, 2001; A. R. Pearce, 1997, 2008). For the purposes of this section, the authors assume that first costs of high performance innovations are superior to their

¹ It cannot be stressed enough that the method suggested here is a temporary patch to be used until such time as sufficient comparable units can be created. This temporary solution should assist appraisers working in markets where limited data about the attributes of high performance homes are available for use in comparable sales analysis.

traditional economic substitutes.²

The first cost estimation problem creates a methodological challenge for appraisers, as often it is difficult to compare the precise high performance technologies included in the home with their traditional economic substitutes. This problem is directly linked to the missing information problem described above and in the previous essay; traditional databases used for search and analysis do not typically include specifics or searchable fields describing high performance attributes included in the subject property or high performance building certifications. To overcome this obstacle, the proposed method urges appraisers use a two-step process. First, the appraiser can conduct a traditional comparable sales analysis for the subject property as if it did not have high performance attributes. This will allow the appraiser to create a base value estimate for the subject property. Second, the appraiser can assume that the high performance subject property has a superior quality of construction to its cohort and select additional comparables to create a quality adjustment. The quality adjustment will serve, in a sense, as the marginal cost of construction difference between the high performance home and its traditional counterpart. Though there is variation that could creep into this two-stage process, the method facilitates an efficient estimation of the cost differential between a high performance and traditional home. Additionally, when paired with the present valuation of the estimated energy savings of the subject home, it prevents the appraiser from double counting costs.

Substantially more work is needed in this area from both building scientists as well as from designers to help develop a more accurate method of estimating the marginal cost difference between a traditionally built home and a high performance home. The *Marshall and Swift: Residential Cost Handbook*, the dominant cost tool used by appraisers, can be used in the above process or independently to calculate the traditional-high performance marginal cost on a per square foot basis. The trouble with such a detailed analysis is that it requires the appraiser to gain a significant amount of design and construction knowledge and to be able to appropriately select an economic substitute for a high performance technology. For example, a double paned window with

² However, as adoption of high performance homes increases, and technology prices change over time, price parity or price advantage may be achieved.

and a low-emissivity coating can be easily considered economic substitutes. However, attributes with systems effects such as more efficient HVAC units require smaller ducts and other related features so simply measuring the cost difference between a two ton and four ton HVAC system are not right sized calculations. The proposed method is not a full remedy for this problem but instead is a stopgap and a challenge to all stakeholders to increase research on the topic.

The second obstacle for the appraiser is the period of analysis for the present value calculation. The Sensible Accounting to Value Energy (SAVE) Act, a piece of legislation that has been recently re-introduced for discussion in the US Senate suggests a fixed period of analysis at twenty years. Suggestions from the appraisal literature and anecdotes vary from the common period of home ownership (seven years) to the common buyer's mortgage period (thirty years). A tight building envelope is a hallmark of high performance construction. As the envelope tightens, less air and moisture can move across the building components. Conceptually, this should increase the longevity of the materials and expand the economic life of a home by a substantial amount. However, conversations with building science professionals revealed little consensus on precise increases. Here, the proposed method suggests the use of a time period that matches the useful economic life of the building given its superior construction techniques that limit the amount of air and moisture flow through its systems (limiting degradation). Appraisers are asked to use their best judgment as whether the standard estimate of twenty-five to fifty years is sufficient or whether the window needs to be extended.

It is worth noting that, green commercial property owners are eligible for accelerated depreciation on energy efficient capital systems in many states and on Federal tax returns. In some cases, homeowners are eligible for the same depreciation benefits. Where none of the green real estate literature has addressed the role of depreciation, two related findings from transportation research provide insight into how building science and appraisal scholars could advance knowledge on valuation of energy efficient technologies in housing: 1) higher fuel economy passenger cars have better resale prices (i.e., lower depreciation) at higher fuel prices and 2) resale prices generally exceed the expected discounted future fuel costs (Gilmore & Lave, 2013). The suggested present method can easily be altered to include Gordon's model to increase or decrease expected

costs, savings, or depreciation.

Until recently, the reliability of energy savings estimation models varied widely and helped illustrate Jaffe's notion of the efficiency gap—a gap between estimated energy savings and actual energy consumption (Jaffe & Stavins, 1994). The credible level of accuracy and confidence for simulation results of energy consumption predictions in residences has been estimated to have a margin of error between 25% and 70% of homes (Institute & Group, 2009) also see (Polly, Kruis, Roberts, & America, 2011; Roberts et al., 2012). The high level of variation among energy consumption estimation protocols is frustrating and ultimately limits the precision of an appraiser's calculation. However, until building science can address the variation and find ways to bring it down, appraisers must use the best available models to estimate the efficiency of potential technology upgrades to homes. At present, that model is the Home Energy Rating System Index (HERS) from ResNet. The HERS index measures the relative performance of a green home to the same home's design and construction using the 2009 International Energy Conservation Code as the reference. A score of 100 indicates that the home performs at parity with a newly built home with respect to energy consumption. A score of 70 indicates that the home being tested performs 30% more efficiently than the standard reference design and construction techniques.

In addition to first costs, useful life estimates, and efficiency estimates, the selection of a discount rate for evaluating energy efficiency technology decisions plays a key role in the present value of the associated energy savings. As of 2010, the National Institute of Standards and Technology indicated that for all Federal projects relating to energy efficiency, analysts were to use a conservative nominal discount rate of 4% (Browning & Romm, 1995). However, research indicates that consumers tend to overestimate (e.g., use rates such as 40%) the discount rate when analyzing savings generated from energy efficient durable goods (Greene, 2010; Howarth & Sanstad, 1995). Where there is a lack of consensus and practice on how to select an appropriate discount rate for the analysis of energy efficiency in housing and the finance of high performance technologies, the build up method can provide reasonable, conceptually defensible, and temporary solutions until a more appropriate method can be created.

The build up method, common in securities and firm valuations, describes a

method to calculate the minimum rate of return an investor would require based on the common and idiosyncratic risks associated with some cash flow stream (Brealey, Myers, Allen, & Ross, 2006; Morningstar, 2013). The build up method is typically represented by the following equation:

$$\text{Discount Rate} = R_{\text{Risk Free}} + R_{\text{Equity}} + P_{\text{Small Firm}} + P_{\text{Industry}} + P_{\text{Firm}}$$

where R = describe required returns and P= three different types of premiums.

To apply the build up method to the analysis of high performance housing the following assumptions could be used:

- The yield on a US Treasury Security such as the 10 Year Bond; and
- (The prevailing LTV ratio for a good credit buyer in the market area) * (The 10-year moving average of FHFA Home Price Index for the same area.³)

With respect to the premiums we suggest substituting:

- A constant of 1 basis point for the small firm premium. This could be an holding place for additional risk relative to the subject property;
- The intensity of the climate in basis points measured as ((sum of heating degree days and cooling degree days for the study property climate zone)/1000); and
- The subject property's HERS score (range: -50 to 200) in basis points in place of firm's risk premium;

These substitutions would be deviations from typical practice in financial analysis though would be useful to make the technique applicable to building performance analysis.

This method produces similar results and tracks with the manual for evaluation of energy efficient technologies published by the National Renewable Energy Lab (Short, Packey, & Holt, 1995). The method would be relatively easy for an appraiser to calculate and is independent of the attributes of the buyer—the most important of its features. Selecting a discount rate for the analysis of high performance housing technologies should, for new homes, focus on the estimated performance of the home independently from its future occupant. Later forms of analysis can analyze expected versus actual energy performance and could be tied to occupant behavioral characteristics.

³ Where the home falls outside the data set covered by the FHFA price index, appraisers will need to conduct traditional market studies, already part of their market research, to determine the average equity return on housing in the subject home's market. Further, the appraiser can use MLS data within a particular neighborhood to develop this expectation for an equity premium. They could compare it to the CBSA number for an even more accurate discount rate.

Proposed Present Value Solution

With more appropriate estimates of efficiency, discount rates, first cost estimates, and weighted average life-cycles of the groups of technologies included in a green home, an appraiser should be able to more precisely estimate the value contribution of these green elements on top of the price of home priced as a traditional unit using a present value (PV) calculation. Traditionally, PV is calculated as:

$$PV = Cash\ Flow \left[\frac{1 - 1/(1 + r)^t}{r} \right]$$

With respect to the appraisal adjustment, the cash flow would represent the annual energy savings estimate generated as part of a HERS report.⁴ R would represent the discount rate constructed from the build up rate discussion above, and T would represent the weighted average useful economic life of the systems. To estimate the present value of energy savings, an appraiser can:

1. Calculate Home Efficiency: Multiply (HERS Index score/100) x (DOE BTU usage for same size home in climate zone);
2. Calculate the energy savings: Subtract the results of step 1 from the DOE BTU usage figure used in step 1;
3. Convert BTUs saved to Kilowatt Hours: Multiply Step 2 result by 0.00029307107;
4. Multiply the KWHs saved for each period by the average price of residential electricity or gas as provided by the Energy Information Agency in Table 5.6A or substitute local data (insert reference); and
5. Discount the monetized energy savings over the weighted average expected life of the technologies in the home and sum.

An alternative strategy would be to use the outputs from the HERS Index report (Architectural-Energy-Corporation, 2013) for a home to conduct the same calculation:

1. Calculate Home Energy Efficiency:
 - a. Locate the estimated energy cost of the home from HERS 'Energy Cost and Features' report produced by REM/Rate software;

⁴ Note: this method relies on the builder providing a HERS index score for the unit. HUD estimates the cost of testing and rating the home between \$300 and \$800. Who pays for this cost should be a negotiated item though likely the builder should have the home scored at completion and pass the cost on to the buyer in the sales price.

- b. Multiply the Estimated Energy Cost by $1 + (1 - \text{HERS Index Score}/100)$ to obtain the Energy Cost for the standard reference unit;
 - c. Subtract the estimated energy cost from the standard reference energy cost to obtain energy savings on an annualized basis⁵; and
2. Discount the monetized energy savings over the weighted average expected life of the technologies in the home and sum.

This solution (both the discount rate selection and present value calculation) addresses several of the gaps in the existing literature and provides a method that appraisers can use in practice to estimate the value contribution of the unique technologies installed in the high performance house. It does not require that the appraiser use comparable sales data to make a value adjustment but instead relies on the HERS index score and then publicly available data that can be adjusted for individual market geographies and utility prices.

The tables below show the use of the building up method and the present value of estimate energy savings applied to the same new house built in three different Virginia markets. Variation 1 describes a time period where the analysis period is set to that of the SAVE Act—20 Years. Variation 2 describes the same scenario where we used Solver to identify the difference in the number of years required to generate the same estimate of value using the SAVE Act assumptions and the assumptions methods suggested by the authors (time difference is between .8 and 1.5 years). Variation 3 illustrates the differences in value when the analysis period is extended to 30 years.

⁵ This assumes that REM/Rate uses the most up to date utility prices for the region in which the subject home is located.

Variation 1

Assumptions	Value
HERS Index Score	70
Standard Ref Design	100
Efficiency	70%
Analysis Period	20
Annual Energy Use Estimate	\$1,500
Standard Ref Design Eng Use	\$1,950
Annual Energy Savings	\$450

Build Up Rate	Blacksburg	Charlottesville	Virginia Beach
Annual Energy Savings	\$229	\$229	\$229
Risk Free Premium	2.5	2.5	2.5
Equity Premium	0.61	0.878	1.034
Small Firm Premium	0.01	0.01	0.01
Climate Premium	0.472	0.464	0.295
HERS Index Premium	0.7	0.7	0.7
Build Up Discount Rate	4.29%	4.55%	4.54%
SAVE Act Assumption	4.00%	4.00%	4.00%
Capitalized Value of Savings/ Build Up	\$10,485	\$9,886	\$9,914
Capitalized Value of Savings/Save Act	\$11,250	\$5,723	\$5,723
PV Build Up Method	\$5,961	\$5,827	\$5,834
PV SAVE Act (4%--20 years)	\$6,116	\$6,116	\$6,116

C4_Variation1

Variation 2 (Solver VA Beach=SAVE)

Assumptions	Value
HERS Index Score	70
Standard Ref Design	100
Efficiency	70%
Analysis Period	21.614331
Annual Energy Use Estimate	\$1,500
Standard Ref Design Eng Use	\$1,950
Annual Energy Savings	\$450

Build Up Rate	Blacksburg	Charlottesville	Virginia Beach
Annual Energy Savings	\$229	\$229	\$229
Risk Free Premium	2.5	2.5	2.5
Equity Premium	0.61	0.878	1.034
Small Firm Premium	0.01	0.01	0.01
Climate Premium	0.472	0.464	0.295
HERS Index Premium	0.7	0.7	0.7
Build Up Discount Rate	4.29%	4.55%	4.54%
SAVE Act Assumption	4.00%	4.00%	4.00%
Capitalized Value of Savings/ Build Up	\$10,485	\$9,886	\$9,914
Capitalized Value of Savings/Save Act	\$11,250	\$5,723	\$5,723
PV Build Up Method	\$6,257	\$6,109	\$6,116
PV SAVE Act (4%--20 years)	\$6,116	\$6,116	\$6,116

C4_Variation2

Variation 3 (Analysis Period 30 Years)

Assumptions	Value
HERS Index Score	70
Standard Ref Design	100
Efficiency	70%
Analysis Period	30
Annual Energy Use Estimate	\$1,500
Standard Ref Design Eng Use	\$1,950
Annual Energy Savings	\$450

Build Up Rate	Blacksburg	Charlottesville	Virginia Beach
Annual Energy Savings	\$229	\$229	\$229
Risk Free Premium	2.5	2.5	2.5
Equity Premium	0.61	0.878	1.034
Small Firm Premium	0.01	0.01	0.01
Climate Premium	0.472	0.464	0.295
HERS Index Premium	0.7	0.7	0.7
Build Up Discount Rate	4.29%	4.55%	4.54%
SAVE Act Assumption	4.00%	4.00%	4.00%
Capitalized Value of Savings/ Build Up	\$10,485	\$9,886	\$9,914
Capitalized Value of Savings/Save Act	\$11,250	\$5,723	\$5,723
PV Build Up Method	\$7,513	\$7,285	\$7,296
PV SAVE Act (4%--20 years)	\$6,116	\$6,116	\$6,116

C4_Variation3

Conclusion & Next Research Steps

The method of valuation proposed above provides evidence that it is conceptually possible to create a method of valuation distinct from and more dynamic than the SAVE Act. This method adapts the build up method and the present value of an annuity formula to provide appraisers with an easy to use and easy to understand tool to use when estimating the value of a high performance home where a sufficient number of comparable high performance homes does not exist. In the context of missing data about the presence of high performance housing attributes and certifications, appraisers cannot use the comparable sales analysis as it was originally intended to estimate the value of high performance homes. Where they cannot use comparable sale data to drive estimates of value, the mechanism of price discovery slows or could potentially stop. Here, the authors offer a temporary valuation strategy that can help appraisers to break the vicious pricing cycle by capturing information that can be pulled, with the exception of the HERS report, from a variety of public sources. The proposed present value strategy should be considered temporary, as the traditional methods of single-family residential

comparable sales analysis are sufficiently accurate when there is sufficient data to populate the calculations.

This temporary method harnesses the logic of discounted cash flow modeling used in corporate finance and commercial real estate analysis, borrowing the build up method to generate an appropriate discount rate. It also attempts to make adjustments for problems related to first cost estimation and also to correct for the significant variation shown to be present in the energy savings estimation models across the industry. The logic of the suggested method assumes that the present value of the energy savings generated by a high performance house are cash flows that can be valued the same way as one would value an annuity. As the energy savings attach to the home and are not portable, the buyer is essentially buying these cash flows at time 0 or their present value.⁶ For new homes, this process is relatively straightforward though it can be applied to existing housing through the use of additional calculations to adjust for time.

The method suggested here attempts to provide reasonable and actionable solutions to recognized frictions in the appraisal of new high performance homes. However, the method has some limitations. Most specifically, the marginal cost differences between traditional and high performance homes are not simply the dollar for dollar differences to purchase and install the technologies. There are systems based differences that can cause cost extrapolation to be difficult. The suggested method proposes a rough solution to this problem. The authors recognize that this is akin to selecting the cleanest dirty shirt from the laundry basket and anticipate further analysis on this and the problem of selecting an analytical time period. To follow this temporary strategy, future research should also investigate how appraisers are, at present, working to overcome the obstacles related to the comparable sales-limited data problem. Such work should attempt to locate consensus on the methods being used and to identify where additional research may assist practice.

⁶ The present value of energy savings as an annuity concept relies on the notion that the cash flows are net of the cost of achieving them. We've accounted for the net aspect of these cash flows by suggesting that the appraiser should make a quality of construction adjustment to offset any pricing differences and avoid double counting them via a net present value calculation.

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Chapter 5: The Appraisal of High Performance Single Family Homes

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Abstract

Builders and developers are increasingly using high performance construction materials in new homes. However, problems with the availability of data to describe and differentiate traditional homes from high performance homes in appraisals appear to be a significant obstacle limiting further market adoption. This paper reports on data generated from a series of semi-structured interviews with sixteen real estate appraisers who have appraised a high performance home or have received training to do so (or both). The paper describes the methodological approaches used by this group of geographically and experientially diverse appraisers and analyzes the supporting elements these practitioners need to more precisely estimate the value contribution of high performance technologies within homes.

Introduction

Real estate and building construction research suggests that developers are greening (Bradshaw II, 2011) and that builders are using more high performance building technologies over time (McCoy, Koebel, & Sanderford, 2013). Additionally, studies indicate that homes with these technologies or energy efficient home certifications can command a premium over similar homes without the high performance features or certifications (Aroul & Hansz, 2011; Bloom, Nobe, & Nobe, 2011; Dastrup, Graff Zivin, Costa, & Kahn, 2012; Kok & Khan, 2012). However, it is not uncommon to hear horror stories from builders or homebuyers seeking to finance a high performance home. These stakeholders perceive that appraisers under-value, incorrectly value, or exclude the value contribution of the high performance building technologies and design of the home (Desiderio, 2012; Normand, 2012). As the lender uses the appraisal to guide their allocation of capital to the loan applicant, these errors in value estimation relative to the collateral could have significant effects on lending practice and the diffusion of high performance homes into the housing market.

Prima facie, this problem appears linked to the principal method of analysis appraisers use to estimate the value of single-family homes, the comparable sales method, and the availability of data used in comparable sale analyses. The comparable sales method relies on data from the transaction of similar homes to create adjustments for the differences between the subject property and the recently sold comparable properties. However, as there are approximately one and a half million green certified homes in the US¹, or 1.5% of the housing stock, identifying and using comparable transactions to value new high performance homes in many markets could prove difficult and force appraisers to innovate.

To gain insight into this problem, this paper seeks to answer the research questions, 1) at present, how do residential appraisers with green valuation training or experience estimate the contributory value of high performance building technologies within high performance homes; and 2) how are the methods and processes used substantively different from those used to appraise non-high performance homes? To answer these questions, the authors first review the appraisal literature, interspersing findings from the construction and real estate literature where necessary. Next, the authors analyze data and make observations about a series of semi-structured interviews conducted with residential real estate appraisers from across the US with green appraisal training and/or experience.

Literature Review

The central task of a real estate appraiser is to analyze various sets of market and property data to provide a client with an informed estimate of the market value of some interest in real property (Pagourtzi, Assimakopoulos, Hatzichristos, & French, 2003). The valuation process is a series of procedures that appraisers use to inform their opinion of value (AI, 2008). The valuation or appraisal process for nearly any subject property is most commonly described and taught as an eight-step process. After accepting the assignment, the Appraisal Institute trains appraisers to 1) identify the problem and type of value to be estimated; 2) determine the scope of work to be done; 3) collect data about

¹ This estimate captures the total number of homes certified through the three major green building rating systems: Energy Star, LEED, and NGBS. There are a number of major regional rating systems such as Earth Craft and Green Point that add approximately 25,000-50,000 more homes.

the subject property, comparable properties, and the market place; 4) analyze the data; 5) generate an opinion of the value of the site; 6) generate an opinion of the value of the improvements using the sales comparison, cost, or income capitalization methods; 7) reconcile variations across the different value estimates generated by different methods; and 8) issue a report describing and defending the appraisers' value estimate (AI, 2008).

Within the valuation process for single-family homes, the most common and required method of analysis for generating an estimate of value is the sales comparison method (Kummerow, 1997). The sales comparison method relies on the economic principle of substitution— the concept that absent major differences, consumers can substitute one similar product for another. In the sales comparison method, the appraiser uses the price differences observed among the transactions of similar homes and the subject property to define and make adjustments to the estimated value of the subject home (Pagourtzi, et al., 2003). To make his or her final estimate, the appraiser relies on the degree of comparability between properties, the quantity of information available about the comparable properties, and the authenticity or reliability of the data (AI, 2008; Colton, 2002).

In the markets where data on property attributes is available and reliable, researchers have used various regression techniques linked to the principles of comparable sales to analyze the contributory value of an array of home and site complex attributes including: proximity to mass transit (Bowes & Ihlanfeldt, 2001), traditional neighborhood design (Eppli & Tu, 1999), proximity to open space (Irwin, 2002), the presence of trees (Dombrow, Rodriguez, & Sirmans, 2000), environmental contamination (Patchin, 1994), views (Rodriguez & Sirmans, 1994), the presence of a basement (Andrus, 2012), homes in rural markets (Walker, 1994), the presence of satellite imagery in MLS listings (Benefield, Cain, & Gleason, 2012), and the presence of accessory dwelling units (Martin & Watkins, 2012). Research also provides guidance for the use of statistical methods (e.g., Monte Carlo simulation) to augment appraisal during periods of economic uncertainty (French, 2011).

These findings suggest that where appraisers have the data available to conduct variations of comparable sales analysis, the building blocks of the method itself are robust. Instead, it appears that with respect to high performance homes, appraisers might

be asking the method to answer a question that it cannot, because they are not providing the appropriate inputs. Further, there seems to be confusion as to what the appropriate inputs are when estimating the value of a high performance home.

The primary difference between a traditional home and a high performance home is the value proposition of each unit type. In addition to the constellation of reasons individuals and families purchase homes, high performance homes also include design and construction innovations that create superior environmental performance and translate into superior economic performance for the occupant. Relative to a similarly sized home in the same location but before occupant behavior, high performance homes are estimated and modeled to create significant measurable energy savings. Just as in agriculture, viticulture, consumer appliances, and forest products, builders attempt to summarize their product's value proposition with an eco-label. There are a significant number of eco-labels; the most common include Energy Star, Leadership in Energy and Environmental Design (LEED), the National Green Building Standard, Green Point, and Earth Craft.

Researchers confirm that price premiums exist in certain markets between eco-labeled homes and non-labeled homes, as well as in homes where data on presence of a high performance technology is available. Across California, eco-labeled homes have been observed to have sold at a 9% premium compared to non-labeled homes (Kok & Khan, 2012). In Fort Collins, Colorado, Energy Star labeled homes sold at a \$8.66/sf premium over non-labeled homes (Bloom, et al., 2011). In Texas, homes with higher efficiency windows command a 3% price premium over those with less efficient windows (Aroul & Hansz, 2011). In Sacramento and San Diego, homes with solar panels sold for 3.5% more than those without from 2003 to 2011 (Dastrup, et al., 2012). These findings confirm earlier research that showed the extent to which energy savings can be included in the value of high performance homes (Nevin, Bender, & Gazan, 1999; Nevin & Watson, 1998).

Despite the growing evidence base for the superior environmental and economic value proposition of eco-labeled homes, scholars have shown that residential energy literacy is low (Brounen & Kok, 2010), that buyers of innovations that create energy savings typically misestimate discount rates (Howarth & Sanstad, 1995), and that

occupant energy behavior is susceptible to types of social pressure (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). Further, research indicates that data used for the valuation and underwriting of green buildings are fragmented and can be a significant obstacle for appraisers and lenders (Fuerst, McAllister, van de Wetering, & Wyatt, 2011). In addition to these problems and the limited numbers of eco-labeled units, each label conveys a different emphasis on attributes including building performance, material selection, and location. It is also difficult for an appraiser to compare across eco-labels.² Further, premiums associated with an eco-label from one market are not portable to other markets (Runde & Thoyre, 2010), so appraisers must develop and use data unique to their market to appraise high performance homes (AI, 2008).

To combat problems related to the limited availability of comparables in a market place and to create an alternative method to reconcile estimates of value for high performance homes, the appraisal literature suggests that practitioners use a hybridized version of the comparable sales and income methods. Relying on the energy savings estimated for each new high performance home, appraisers can consider these energy savings as cash flows that can be capitalized into the value estimate (Adomatis, 2010, 2012; DeLisle, 1984; Lopez, 2013; Popescu, Mladin, Boazu, & Bienert, 2009; Watkins, 2011). However, some caution that cash flow based approaches can be affected by poor assumptions (Runde & Thoyre, 2010). This method could also fall out of the task of the single-family residential appraiser who is asked to consider what a knowledgeable buyer would pay. With low residential energy literacy, a propensity to mis-estimate discount rates, and variation present in the tools used to generate estimates of future energy performance (Durak, 2011; Institute & Group, 2009), it is plausible to suggest that the average buyer does not or cannot use this type of analysis, and therefore it shouldn't be used in appraisal. It is also plausible to interpret this variation as a lack of trust for estimated energy savings tools.

The hybridized income-comparable sale method tracks with the commercial real estate underwriting literature that points towards the use of discounted cash flow analysis

² Green Energy Money, a firm based in Austin, Texas, has pioneered a tool that plots each of the major green building rating systems and their sub-categories (e.g., LEED silver and gold) onto the HERS index. Additionally, the Virginia Center for Housing Research is analyzing the three national green building rating systems to develop a 'right sized' comparison between systems to help advance this conversation.

as a method for incorporating high performance features of buildings (Finlay, 2011; Muldavin, 2010). For commercial real estate firms, estimating a discount rate is a straightforward process. Each firm must discount cash flows at a rate at least equal to their weighted average cost of capital. In housing, homebuyers don't often know what their analogous discount rate could be. Within the residential appraisal literature, there does not appear to be a consensus on how an appraiser should select a discount rate or how to select the term of analysis. Recent research advises appraisers to assess the sustainability uptake within the market and place the subject property in that context before making any adjustments to their value estimate (Runde & Thoyre, 2010).³ This advice is particularly germane in the context of research on commercial real estate underwriting that points to the challenges of conducting property analysis when the data is disaggregated and difficult to access (Fuerst, et al., 2011).

In addition to the comparable sales method, appraisers can use the cost method to estimate the value of a home (AI, 2008). The cost method allows the appraiser to sum the published construction costs and depreciation of various technologies to generate an estimate either for reproduction or replacement cost. Reproduction costs represent the cost to re-create the house using temporarily specific materials and techniques; it is not as commonly used as replacement cost. Replacement cost describes the sum of the present costs of present materials and labor to replace the subject property with as similar a structure as can be created. The cost method is hamstrung by both geographical variation in cost data, the accuracy of first cost estimation strategies (A. Pearce, 2001; A. R. Pearce, 1997, 2008), and the conceptual disconnect between cost and market value. In other words, costs and values may vary, but they also must be placed in the context of market norms. Anecdotal conversations with builders reveal this to be a significant problem, as the builder must purchase and install all of the high performance technologies, but the market (buyers) may not recognize or give credit for the full cost of those technologies in the transaction prices of homes.

Related to costs of green homes and facilities, construction researchers have found that stakeholder perceptions of the initial cost of green projects continue to be a

³ This also prevents the appraiser from making singular adjustments such as Nevin's multiplier. Nevin's multiplier, similar to a price-earnings multiple, capitalizes every dollar of energy savings at a rate of \$20.

barrier to their implementation (Ahn & Pearce, 2007; Klotz, Horman, & Bodenschatz, 2007; Wilkinson, James, & Reed, 2009). These responses demonstrate that the construction industry still believes that green building costs significantly more than conventional construction, despite the growing body of evidence to the contrary (Bartlett & Howard 2000). It is possible that these perceptions could have influenced appraisers, as many of these perspectives have been widely discussed in the popular and practitioner literature.

Despite the costing and premium research, there still remains a significant amount of missing information that appraisers confront when conducting an appraisal of a high performance home. Much of the data appraisers need for their work are found in the multiple listing services databases provided by boards of realtors. Typically, these databases under describe high performance technologies. However, there is change afoot. To help encourage the collection of high performance home data, both the National Association of Realtors (NAR) and the Appraisal Institute (AI) have created process tools. NAR has advanced a toolkit for greening the multiple listing services (MLS) (NAR, 2011). The Greening the MLS toolkit provides MLS service owners with strategies and tools to use to allow users to input and search for various types of data describing green and high performance homes. The AI has created an addendum to the Uniform Residential Appraisal Report (URAR) known as the Residential Green and Energy Efficient addendum (form 820.03) (AI, 2011). The addendum modifies the URAR documents from Freddie Mac and Fannie Mae (FHLMC, 2005; FNMA, 2006) and creates space for describing the green and energy efficient attributes and technologies of the subject property being appraised. Each of these tools will help to provide more data for use in estimating the value contribution of high performance systems and technologies. These tools will also allow appraisers and researchers to observe what buyers are paying versus construction costs.

Semi-Structured Interviews

To gain further insight into current appraisal practice relative to high performance homes, the authors conducted a series of semi-structured interviews with licensed

residential real estate appraisers from across the United States. The eighteen interviews took place by phone or in person from May through July of 2013.

Sample Description

At the end of 2012, there were approximately 82,000 licensed appraisers practicing in the United States (AI, 2013). According to the AI, an appraisal trade organization, most appraisers were male, had 20+ years of experience, were licensed to practice in a single state, and worked in residential appraisal (AI, 2013). Within AI membership, there are 61 members that have passed the *Valuation of Sustainable Buildings Professional Development Program* and 74 members who claim Green Home Valuation as a core competency in their membership profile. Beyond the AI data, 119 individuals have completed the *Certified Residential Green Appraiser* course through Earth Advantage, a green building non-profit organization. Earth Advantage also offers a shorter course titled *Appraising Green Homes*—completed by 352 appraisers.⁴ To distinguish between the two levels of training, both the *Valuation of Sustainable Buildings Professional Development Program* and *Certified Residential Green Appraiser* program were considered higher-level training courses due to their length and areas of emphasis.

The first step in generating the sample of appraisers for this paper was to contact members of the Appraisal Institute that listed green training in their online profiles. One respondent came from this effort, though nearly all who wrote back suggested a number of responses encouraging us to contact other appraisers. We were able to snowball a

⁴ It is difficult to accurately estimate the universe of residential appraisers who have green or high performance home valuation training. Within the AI data, many of those who have taken and passed the *Valuation of Sustainable Buildings Professional Development Program* focus their appraisal practices on commercial buildings. We include all of those individuals in the denominator for our sample description calculations as the AI database returns their names when using the search designation ‘Valuation of Sustainable Buildings: Residential’. There is likely to be some overlap between those appraisers who have taken a course from Earth Advantage (EA) and those Appraisal Institute (AI) members who claim a green home valuation competency, as Earth Advantage is one of the only other organizations providing training specific to green homes for appraisers. Organizations like the Building Performance Institute also provide continuing education for real estate professionals though participation by appraisers has been quite rare. As it is difficult to estimate the degree of overlap between the EA and AI data, we consider there to be none to avoid under-counting.

group of respondents from the leads provided by AI members. Following this effort, we attended an edition of *Certified Residential Green Appraiser* training in Virginia and were able to interview four residential appraisers following the training. Some of these individuals provided recommendations that led to an additional cluster of respondents. Finally, the authors used their collective professional networks within the residential construction and real estate services industries to connect to the remainder of the respondents. All in, there were 18 appraisers in the sample; 16 with green training and 2 without who helped provide the guideposts for typical appraisal practice.

The characteristics of the sample of appraisers interviewed for this research project generally aligned with the demographic characteristics of the appraisal industry. All appraisers interviewed were licensed to practice in a single state. Nearly all had more than 20 years of appraisal experience and primarily focused their practice on residential property. Six (or 33%) of the sample were licensed to practice in Virginia (including one specializing in the Washington, DC market area) while the remaining respondents were licensed to practice in California, Connecticut, Idaho, New York, North Carolina, Oregon, Texas, and Wisconsin. Of notable difference between the sample and the national data, 44% of the respondents were women, slightly higher than the percentage of women in the national data (AI, 2013).

Within the sample, sixteen individuals had appraised at least one green home in the last year (many had appraised more than 1), had taken a continuing education or certification course from AI or EA on the appraisal of green homes, or had both appraised a high performance home and completed valuation training. The two appraisers who had neither appraised a green home nor taken a green valuation-training course were familiar with the concepts due to their tenure in the business. These two appraisers provided significant insight into the decision-making practices of the ‘rational’ appraiser estimating the value of the traditional home. They also provided substantial guidance on where high performance home appraisal methods might need to differ from those used to appraise traditionally built homes.⁵ Assuming no overlap within the Appraisal Institute data and further assuming no overlap within the Earth Advantage data, the sample of

⁵ To gain more context about valuing high performance homes, the authors also had an extensive conversation with a member of a private equity firm specializing in the valuation and acquisition of sustainable commercial assets. We used this conversation as background and context during data analysis.

appraisers interviewed for this paper represents approximately 9% (16/180) of the total number of appraisers who have completed higher levels of green home appraisal training and approximately 3% (16/606) of the number of appraisers who have some form of green appraisal training.

Methods of Analysis

This study investigated the differences in appraisal practice between high performance new homes and traditionally built new homes. As this was principally an exploratory research project, the authors relied upon semi-structured interviews as the primary method used to collect data. Interviews typically lasted 45 minutes and were largely conducted via telephone. Interviews were not audio recorded. Instead, handwritten field notes were taken during the interviews and were typed immediately following the interview. The authors used the transcription of the field notes as an opportunity to expand upon anything not fully captured within the field notes. Where qualitative methods are less common in real estate and construction research, they help to provide tools for researchers where large samples are impractical and/or where nuance in practice can more easily be analyzed via interaction with practitioners (Pink, Tutt, Dainty, & Gibb, 2010).

To provide some structure for the interviews, the authors created a short list of general, probe, and clarification questions (Rubin & Rubin, 2011) designed to mimic pair-wise comparison between a traditionally built new single-family home and the same home including variations of high performance building technologies and eco-labels.⁶ First, the respondents were asked how they would conduct the appraisal of a traditionally built home and then asked how that process would differ when assigned two high performance variations of the same home. For illustrative assistance, we created MLS

⁶ For these interviews and analyses, the terms green and high-performance housing are equivalent and will be used to describe any new home in which technologies that have the capacity to create operational efficiencies such as reduced energy consumption and reduced water consumption are installed. This stands in contrast to most attributions of green that require some degree of certification from a rating system such as EPA's Energy Star (ES) or the US Green Building Council's Leadership in Energy and Environmental Design (LEED). Very simply, houses that have the technological capacity to deliver upon the value proposition as green or high-performance, whether or not they carry any official certification. Equally, those homes carrying a green certification without the technologies to realize the value proposition are considered to be non-green.

listing sheets for three variations of the same hypothetical home to control for location, size, and other non-high performance attributes (see Appendix). The base of the hypothetical home model was a new code built home in a generic subdivision. The first high performance variation included a number of moderately high performance technologies and a green building certification. The second variation included very high performance technologies but did not carry a green building certification. This packet of hypothetical home listings was sent to the respondent prior to the interview. Given the geographic diversity of the sample, the authors amended the hypothetical home variations for regional changes in technologies. However, in many instances, appraisers were substantially better at providing specific examples of individual homes or technologies that they had analyzed than the amended hypothetical listing templates.

The interview questions were designed to prompt the respondents to discuss and compare how they have appraised or would appraise a high performance home (e.g., the hypothetical variations) differently, if at all, than a similar traditionally built home. Given the comparative nature of the questions, as well as the fact that we were examining a multi-step process, we used an interpretive framework to analyze the data generated during the interviews (Gubrium & Holstein, 2002; Warren, 2002). The interpretive framework allowed for comparisons of procedural and analytical methods akin to the more mathematical tools of process mapping (PM) or fault tree analysis (FTA) (NASA, 2002). Though respondents were not asked to create a process map that could be analyzed with FTA, the interview questions were organized to allow for comparisons of both procedural aspects of appraisal as well as analytical tools used within the appraisal process.

To assess the data, we first read through the interviews and ‘listened’ for recurring broad themes using interpretive techniques summarized in Rubin & Rubin (2011) (Rubin & Rubin, 2011). Next, we re-read the interviews and focused within those broad themes that arose around procedural and analytical differences for sub-themes and nuance (Britten, 1995). Finally, we analyzed groups of interviews in clusters to assess whether geography, experience, or other factors might be associated with the development of themes (Gubrium & Holstein, 2002).

Findings

Based on several different assessments of the respondents' data, there does not seem to be a substantial procedural difference between the appraisal of a new high performance home and the appraisal of a new non-high performance home. Appraisers in this sample tended to follow the same procedural steps for both traditionally built and high performance homes. These steps tended to match those steps described as high quality practice by the two non-green appraisers in the sample. The steps described by the respondents also tended to match those steps enumerated in both the Appraisal Institute textbook and other publications (AI, 2008).

In the absence of procedural differences, each respondent described large and small differences in analytical methods used to estimate the value of high performance homes—or the contributory value of their technologies. Similarly to the appraisal literature, respondents articulated modified versions of each of the traditional methods of estimating value: comparable sales, cost, and income capitalization. In general, respondents described using both the comparable sales and cost methods with adaptations for construction cost and quality of high performance technologies. Many also described a method of analysis that modified the income capitalization method, a method not typically used in single-family residential appraisal, to capture the energy savings cash flows generated by high performance technologies. Embedded in the discussions of these differential methods of analysis were several sub-themes supporting appraisers' work on high performance homes: 1) vocabulary, construction, and awareness of substantive differences between green and non-high performance homes; 2) role of and availability of high performance housing data; 3) appropriate estimation of the potential buyer; and 4) the complex role of appraisal management companies (AMCs).

Key Differences in Analytical Tools

Within the sample, all of the appraisers detailed modifying at least one of the three primary analytical strategies when considering the appraisal of a high performance home: the comparable sales, cost, or the income method. None of the sixteen respondents with green valuation training described using an un-modified version of methods of analysis. While the authors did not ask respondents to express a preference

for a method of analysis, neither the respondents' experience or number of high performance homes appraised appeared to be associated with the method they spent the most time discussing. Instead, those respondents that noted commercial real estate experience or more extensive financial analysis training appeared more disposed to discussions about the modified income approach discussed below.

Both the comparable sales and cost methods are accepted in common appraisal practice for non-high performance homes; the comparable sales method is the method of analysis required when submitting the Uniform Residential Appraisal Report. Descriptions of the modifications to these two methods appear to be logical extensions of the base methods that allow appraisers to leverage their most familiar tools and strategies and mitigate risk in submitting reports to underwriters. Not surprisingly given the primary area of practice of the respondents, there was greater consensus on how to modify and apply the hybrid comparable and cost methods than the hybrid comparable-income method. As the income method is not traditionally applied during single-family residential property appraisal, respondents described, with less agreement, several variations that converted energy savings into estimates of contributory value.

With respect to the comparable sales method of analysis, respondents principally described adapting the method to make an adjustment for the perceived increase in construction quality of high performance homes. On a traditional home, respondents depicted the typical method using competitive comparables to create a series of range bound adjustments based on the superiority/inferiority of the comparables relative to the subject home. Respondents noted that the traditional method could be made more accurate through the use of matched pairs, a grouping technique that allows an appraiser to gain insight into the per-unit cost of an attribute (e.g., a comparable home and subject home are similar in all attributes except location—indicating that the difference in price is related to the difference in location). With respect to high performance homes, one respondent noted that she would prefer to use matched pairs for high performance appraisal but she rarely found matched pairs outside of subdivisions with limited numbers of home models. She then went on to suggest that finding a high performance matched pair was more akin to a needle in a haystack—at least in her market.

Once the typical adjustments were identified, the consensus from respondents was that they then went on to make an additional adjustment based on the increased quality of the materials associated with and included in high performance homes. In other words, respondents were able to use comparable sales to estimate the value of a high performance home largely in the absence of its high performance attributes. They added an incremental positive value adjustment based on the difference between the quality of the comparables and the subject property. All who described this method cited a perception of the superior quality of high performance building materials as well as a perception of increased attention to design as the basis for the adjustment. Three respondents explained further by saying they considered tightening of the building envelope and the decrease in air and moisture moving across walls, roofs, and basements to be the basis for their quality adjustments and extension of the home's economic life. With less air and moisture crossing through the systems, the building materials will not degrade as rapidly as a home with a looser envelope.⁷

Respondents also described a modified version of the traditional cost method that could be used to estimate the value of a high performance home. Using data from the Marshall and Swift Residential Valuation Handbook, an annual publication describing the per-unit costs of all manner of construction materials with adjustments for levels of quality and geography, appraisers can estimate the replacement cost of any structure. After establishing the value of the lot, an appraiser can use the Marshall and Swift's handbook to sum the per unit or per square foot cost of building materials into the total cost for improvements—both for traditional homes and high performance homes. None of the sample respondents suggested using the cost method as the primary method of analysis. They noted the differences between estimates of cost and value and illustrated their statements with examples of high performance homes that cost far more to build than the local market would seem to bear in sales prices. Often, these examples fell at the extreme end of high performance technology use where the prices of the building materials were quite high due to rarity of use or low market penetration (e.g., geo-thermal heating systems). The cost method was most often cited as a method of triangulating or

⁷ An increase in economic life factored into both of the other commonly used analytical tools.

reconciling the estimate of value generated as part of the comparable sales or hybridized income-comparable sales methods.

In addition to the comparable sales and cost methods, over half of the respondents described using a hybridized income valuation and comparable sales method.

Traditionally used in commercial real estate valuation, the income method capitalizes a stream of property-based cash flows into an estimate of what an investor might pay for the income generated by the building. The income method has not regularly been applied to single-family residential appraisal unless the property is owned by an investor and rented to a tenant. However, respondents cited the energy savings generated by high performance building technologies as cash flows that they could value using the income method. They described consensus around the notion that the present value of the estimated energy savings could be appended to the value of the home appraised in the absence of the high performance attributes—conceptually, a similarity to the methodological adaptation made to the comparable sales method. Two respondents suggested that they had been able to use the method slightly differently. Instead of making adjustments from non-high performance comparables, they estimated what each high performance subject property would rent for and then capitalized that rent stream using a gross rent modifier. These two then appended the present value of the energy savings to the capitalized rent stream. Nearly all respondents endorsing the hybrid method suggested that it could be used in situations where fewer potential comparable sales existed or where they felt that the comparable sales adjustment might not reflect what a typical buyer might pay.

While the present valuation of energy savings was the common refrain, there was little agreement among respondents on standard practice for discounting these cash flows. Respondents offered a range of discount rates from the current rate available for 30-year fixed-rate mortgages (currently ~4%), the rate prescribed in the Sensible Accounting to Value Energy (SAVE) Act (4%), a risk free rate such as the yield on the 10-year US Treasury bond (~2%), or some risk loaded rate that was based on a base rate plus a premium for the extra risk of the investment type. Additionally, there did not appear to be consensus on the period of the analysis for discounting the energy savings. Some advocated for the average period of time a home in the market area is typically held by an

owner; others suggested using the average of the useful lives of the combined high performance technologies. Still others argued for a thirty-year period—matching the term of the thirty-year fixed-rate mortgage. The lack of consensus on discounting assumptions and wider variation in accuracy formed the basis of several respondents' criticisms and lack of trust of this method. Among this sample, none raised the issue of trusting the energy savings data as a concern--a topic from the literature review that seemingly might have posed a larger obstacle.

Beyond the range of assumptions used to discount the energy savings, there did not appear to be an agreement on whether or not the present value of the energy savings calculation was to be added directly to the appraisal estimate or whether the present value figure was to be added net of the high performance-traditional technology cost differential. In other words, there was a bit of divergence around whether the calculation was one of present value versus or net present value. Perhaps, this divergence was due to the questions used during the interviews to catalyze conversation about these methods. However, regardless of the reason for the divergence, it will be important for future practitioners to determine whether a net present value calculation is superior or inferior to the simple present value of the energy savings.

Vocabulary and New Knowledge + Role of Data

To support the use of the modified methods of analysis described above, both the respondents in the sample and the green appraisal literature point toward the need for a more standardized vocabulary to differentiate between high performance and non-high performance homes (Adomatis, 2010, 2012; Fuerst, et al., 2011; Normand, 2012; Runde & Thoyre, 2010). The respondents also noted that an increase in accuracy of vocabulary would help distinguish between high performance technologies when submitting reports to underwriters. Respondents also articulated needs for searchable and more readily available data describing the performance and presence of technologies included in high performance homes. In many instances, these needs were contextualized by stories about knowledge bases and the defense of methods of analysis to underwriters. Very simply, without the ability to describe or search and find data using commonly defined or even

more technical terms, it appeared that the ability to produce an accurate and defensible value estimate declined.

Reflecting on his first high performance home appraisals, an appraiser from the East Coast indicated that he was underprepared and likely made some mistakes analyzing the house and estimating the home's value. However, he noticed that as he took green appraisal courses and developed a greater sensitivity to the differences in value propositions between the high performance houses and traditionally built houses, he was able to more accurately capture the logic and nuance that underwriters would accept in appraisal reports. A respondent from the West Coast recalled an assignment where she discovered that the subject home was constructed using structurally insulated panels (SIPS), a structural building system for roofs and walls that sandwiches rigid foam between sheets of oriented strand board. SIPS panels have a higher thermal resistance than do code built and insulated walls and are considered to be high performance building technologies (Bostic et al., 2012). The presence of the SIPS panels was not listed in the property data advertised within the local MLS's by the listing broker. Had this individual not recognized the presence of SIPS, her estimate of value would have been lower.

In a similar vein, several appraisers had conducted recent searches of their MLS' for eco-labeled homes. In one instance, the respondent's search for Energy Star certified homes returned several hundreds of listings. In reviewing the listings, the appraiser discovered that most homes simply included Energy Star certified appliances and did not carry whole house certification—particularly striking in that in preparation for the interview with this appraiser, the authors discovered that the market in which this respondent worked boasted several hundred homes with HERS index ratings. Those with similar stories expressed frustration at the inability to search their MLS databases for high performance attributes and noted the difficulty in developing comparables as the reason for moving towards one of the three innovative valuation methods described above. Where most had considered the lack of data to indicate a limited, if not non-existent, market for high performance attributes, one appraiser stressed his opposition. He made it clear that missing market data for an innovation didn't automatically indicate the market did not value the attribute. Instead, it prompted him to search for different types of data such as contracts between builders and buyers detailing attribute choices.

In an anecdote illustrating the complex interaction of vocabulary, data, and methods of analysis, an appraiser of a Net Zero home, or home that produces the same amount of energy it consumes, suspected that his extensive documentation of technological terms, assumptions, and descriptions of present value estimation methods helped move his report smoothly through the underwriting process. Other respondents shared similar stories about different types of high performance houses where a logical and carefully documented report assisted greatly with acceptance of the report by an underwriter.

Within discussions about knowledge base, vocabulary, and data supporting the modified methods of analysis, many respondents focused on the difference between the presence of high performance building technologies and the presence of a green building certification. There appeared to be consensus that certifications were helpful from a statistical perspective facilitating increased accuracy in market analysis and coarsely grouping potentially comparable houses. However, like the warnings from the literature, many cited the variability of focus within the green building rating system certifications and expressed preference for such things as a single scale such as the HERS index score on which all certifications can be plotted, a binary energy certification such as Energy Star, or MLS databases that included high performance attribute based searching.

Several respondents shared unique methods of working around data shortages. Two described keeping a separate file holding all of the green housing information available in their markets. When they appraised a home with high performance features, they would turn to these files as they contained data on transactions of other high performance homes. Interestingly, another respondent suggested that the common demand from underwriters for three comparables within ½ mile within the last 90 days was just that—a goal and not a rule. Instead, he noted that comparables that describe the market for the subject property are the standard and in some cases those comparables do not meet the distance, proximity, and temporal demands of the underwriter. Each of these three respondents argued that when sufficient data existed to identify comparables, the classic methods of analysis would work well.

Estimating the Potential Buyer

The Appraisal Institute's procedural guide for the valuation process highlights the creation of a scope of work and definition of the type of value to be estimated. Additionally, the classic comparable sales analysis technique requires appraisers to identify competitive comparable homes to the subject property. In other words, these steps and requirements compel the appraiser to estimate who the most probable buyer of the subject property would be and to estimate what they might pay for it under typical market conditions. Typical market conditions include appropriate market exposure, an arm's length transaction, and an assumption that both the buyer and seller are acting prudently and knowledgeably. The task of estimating the most probable buyer of a high performance house did not appear to have significant procedural or methodological differences for most respondents. As there is variation amongst the different types of single-family homes, there doesn't appear to be a great push towards a high-performance home specific method of estimating a buyer.

Although there was not a great deal of variation in response around this sub-theme, three respondents provided insight into some alternative perspectives. One questioned whether or not most buyers, even the most probable buyer type for a high performance home, met the criteria for acting prudently and knowledgeably. Linking back to the hybrid income-comparable sales method, another suggested that he was not yet convinced that the average buyer was sophisticated enough to conduct a version of a discounted cash flow analysis and therefore the method should be lightly used—if at all. The third respondent raised the related issue of whether or not the appraiser's personal bias about the design of some types of high performance homes had the potential to both positively and negatively influence the estimate of value and most probable buyers. He acknowledged that all appraisers must do their best to strip away their own biases about architecture, construction, and neighborhoods—doing their best to anticipate what the most likely buyer of the subject house might offer to pay. However, he cited the age, lifestyle, and tendency towards path dependency among his colleagues as potential reasons bias against high performance products or design might creep into practice. This individual volunteered that the possibility of under-estimating the contributory value of high performance technologies and certifications by someone with a negative bias was

equal to the probability of the over-estimating for someone with a positive bias towards increased home energy performance.

Appraisal Management Companies

With several exceptions, respondents tended to suggest that Appraisal Management Companies (AMCs) created a net negative force on the more complex types of appraisals, including those of high performance homes. Created to protect consumers from collusion by lenders and appraisers, AMCs provide a firewall between the parties and serve as an intermediary for the lending institutions in creating a bidding process where appraisers can bid to provide appraisal services. In concept, the AMC is designed to increase appraiser independence and to prevent creation of relationships between lenders and appraisers based not on the value and accuracy of the services provided but on volume or preconceived outcome (e.g., asking an appraiser to deliver an estimate of value equal to the price to be paid by the borrower).

In general, the sample respondents were pessimistic that AMCs would lead to better appraisal practice relative to high performance homes. Many talked about the tendency of AMCs to accept the lowest bid for an appraisal and also their tendency to ignore geographical and product type competency requirements when accepting a bid by an appraiser for an assignment. One Virginia appraiser noted that AMCs seem to create a rush to the bottom in terms of price, speed, and quality of the outcomes. Together with a respondent from California, he was perplexed that given the added increase complexity and time required to conduct the appraisal of a high performance house, the AMC's have not demanded appraisers provide proof of competency before accepting a bid to conduct an appraisal.

Two appraisers from Texas shared that they had been asked to review and redo AMC assigned appraisals conducted on a high performance house because the lender had several significant questions. Using the hybridized income approach reconciled by the cost approach, the review appraisers felt that their revised appraisal more accurately reflected the high performance attributes of the home. The two noted that the review appraisal cost the lender a significant premium, but that the lender seemed pleased and was able to issue the loan on the home.

Limitations & Next Steps

One of the primary limitations of this research is the size of the sample. Given the pricing and time pressures facing most practicing appraisers, creating a sample of this size was a significant challenge. Further, where the universe of residential appraisers who have appraised a green home or are trained to do so is difficult to estimate, it is difficult to know whether or not the sample size is sufficiently large from which to make observations. Based on the publicly available information, it appears that the sample of appraisers who participated in interviews represents approximately 8-9% of the total number of residential appraisers that have higher level green home valuation training and 3% of the total number of appraisers that have at least a basic level of green home valuation training. To be clear, the findings presented represent the data from the sample and should not be quickly generalized to the broader population of appraisers. Further, they do not allow us to make comparisons about how non green-trained appraisers would tackle the hypothetical assignment. Additionally, given the sampling procedure, it is possible that there was some similarity in responses related to interviewing individuals that had attended the same training program.

Given these limitations, it seems appropriate that one next research step would be to explore the variance in outcomes produced by the range of inputs for each method of analysis described above. One actionable way to collect a larger sample of data and potentially to validate this work would be to integrate the research into future sessions of green appraisal training courses. Participants could be asked to estimate the value of a hypothetical home using both methods and the value estimates as well as the ranges of inputs could be catalogued and analyzed given characteristics of the appraiser. An additional next step could be a more detailed survey of the methods of analysis appraisers are using to estimate the value of green and high performance homes. Data from a larger sample where respondents answer a standard set of questions (as opposed to the conversational basis of a semi-structured interview) could be analyzed using traditional quantitative analytical techniques. A survey distributed to a larger group would also help to eliminate, or at least mitigate, potential limitations related to snowballing and researcher bias. However, given the time constraints of practicing appraisers, execution

of the survey would need to rely on innovative distribution channels and be supported by a known topic champion.

Conclusions

Despite the growth in the use of high performance technologies in new single-family housing over the last ten years, estimating the contributory value of high performance technologies and certifications remains a difficult task for appraisers. Traditionally, appraisers use the comparable sales method to estimate what the most probable buyer would pay for a new home, often drawing on the principles of hedonic regression to establish prices for individual attributes of a home. However, with respect to high performance homes, much of the information upon which comparable units could be established or hedonic regression conducted is missing from common data sources such as MLS and county tax assessment databases. Without some significant modification, this missing data creates a substantial problem for appraisers as it short-circuits their most common method of analysis. Based on the sample of appraisers interviewed here, respondents trained to value or with experience valuing high performance homes indicated that they used two analytical strategies: 1) a quality of construction adjustment or 2) an adjustment for the present value of estimated future energy savings. These two methodological amendments to the comparable sales method allow appraisers to overcome the obstacle of limited comparable sales data and to generate a logical estimate of market value.

Though there was limited variation in the construction quality adjustment method, there was substantial variation in the assumptions that drive the present value method. This variation suggests a lack of consensus in practice that should be addressed by national organizations representing appraisers and other homebuilding or real estate interests. Policy makers have re-introduced the Sensible Accounting to Value Energy (SAVE) Act to the Senate as a way to help standardize these assumptions. However, hard-wiring those assumptions into appraisal models such that every high performance home will be analyzed using a discount rate of 4% and a period of analysis of 20 years fails to meet the criteria for estimating what an informed buyer would pay for a home. Instead of the fixed discount rate and analysis period, advocates should determine a

method of selecting assumptions that allows the appraiser to adjust for market and unit conditions as well as market based expectations. Recent draft guidance issued by the Appraisal Foundation's Appraisal Practices Board, the committee that provides legal oversight for professional practice, indicated that value estimates could be negatively influenced by insufficient or unsupportable assumptions. They advise amending the Uniform Standards of Professional Appraisal Practice (USPAP) competency requirements to ensure that those appraising high performance homes have sufficient training to recognize market data (in a range of forms) and convert it into value estimates.

Appraisers in the sample described this competency problem in the context of Appraisal Management Companies (AMCs) and the perceived race to the bottom of fees bid for complex assignments. Following the Great Recession, policy makers have been focused on creating lender-appraiser firewalls to benefit the homebuyer. In doing so, they appear to have created a system where AMCs have a perverse incentive to accept the lowest bid to conduct an appraisal. Many respondents believed that low bids were accepted while competency requirements were disregarded. It appears that their calls to the appraisal advocacy organizations have been heard. On July 15th, the Appraisal Practice Board recommended the development of competency standards for the appraisal of high performance homes. The push for a competency standard would promote a number of solutions to the problems referenced in the above interviews. Competency would demand training to recognize systems, technologies, and their relevant market data points. As these data points would then be catalogued they would begin to transform the valuation landscape and address data and vocabulary problems referenced by appraisers above.

In addition to the Appraisal Foundation, public policy makers could play a strong role in helping to solve the missing information problem. Though they do not have much influence over local MLS databases, they can demand the collection of various data about high performance homes as part of the builder permit and tax assessment process or as a part of the process to obtain a GSE guaranteed mortgage. The collection and storage of data in the tax assessment or GSE records would allow appraisers to search for comparable units more easily as the data would be both public and, in many cases allow the data to become mapable using GIS. The ability to use GIS would allow researchers

to assist appraisers in analyzing the market effects of high performance technologies but also their geographic diffusion over time. The missing information problem also creates some significant hurdles beyond the domain of appraisal. It has the potential to influence all parts of the mortgage underwriting decision from credit scoring a borrower through the securitization chain.

Traditionally, lenders have relied on credit scoring models to help them understand a borrower's likelihood of defaulting on mortgage and based on that probability to price the loan. While this practice has been widely accepted by the mortgage industry, it has some shortcomings. Primarily, credit-scoring models are created to examine a borrower's past—analyzing the extent to which they have repaid loans and other forms of non-mortgage commercial credit such as auto loans, credit cards, or other unsecured personal loans. The literature suggests that most models rely conceptually on the notion that past behavior will be correlated to future behavior. To that end, lenders and mortgage researchers have used credit scores (FICO or other) as surrogate variables to measure a borrower's ability to repay and the proposed Loan to Value ratio to help understand the probability of the borrower defaulting (and the extent to which the lender could suffer losses). At present, there is no way to distinguish, within a credit scoring model, the extent to which a borrower's probability of default is influenced by the energy efficiency of their home—models are not designed to assess this type of situation. Given the higher net cash flows to the borrower associated with high performance homes, it seems useful to consider versions of credit-scoring models that analyze a buyer's existing cash flow before and after purchase to help understand their probability of default. Quercia et al (2013) modeled the likelihood of default on a sample of 30,000 mortgages including a significant portion where the data stream included a HERS score (R. Quercia, Sahadi, Stellberg, Kaza, & Tian, 2013; R. G. Quercia & Stegman, 1992). They found strong evidence that borrowers on higher performance homes were less likely to default than the rest of the sample. They also showed a positive association between lower default and higher income and the negative association between loan to value ratio at origination and the potential for default. It seems, based on this strong initial evidence that where underwriters can collect data about the relative energy performance of the collateral underpinning a mortgage loan and include it as a

variable in a default or credit model, the predictive power of default models can be increased—which leads us to also consider Automated Underwriting tools.

Automated Underwriting (AU) models rose to prominence in the late 1990's replacing manual underwriting (software replacing humans). AU provided lenders with the ability to customize the credit scoring model and mortgage underwriting models used as well as discover ways to interact them. Studies of AU programs suggest that LTV and FICO scores are the key variables that predict future default. Straka (2000) suggests that as firms moved from manual underwriting to the process innovation of automated underwriting they increased the accuracy of their work (also increased efficiency and created time, servicing, and funding cost reductions) (Gerardi, Rosen, & Willen, 2010; Straka, 2000). By adopting AU as a process innovation, firms were able to incorporate better forms of data into their analyses. Adopting firms were more adroitly capable of analyzing a borrower's collateral, capacity to repay, and credit worthiness. It stands to reason based on Straka's review as well as Gerardi et al's (2009) findings on the role of deregulation and innovation in the mortgage market, that the missing data problem related to high performance housing could also be addressed via changes to AU and credit scoring models (Gerardi, et al., 2010). AU models could be adapted for high performance loans, like they have been for affordable home loans or high-risk borrower loans, with the inclusion primarily of a relative energy performance variable such as the HERS index. Additionally, the models could include categorical variables for eco-labels or a long-term moving average variable for reported energy performance relative to estimated performance. The credit and underwriting literature suggests that there are two ways to generate better analytical outcomes: 1) create substantively different models that seek to analyze problem in some new way; or 2) include some new piece(s) of information in existing models. Overstreet and Beiling's yet unpublished working paper on the Flat Maximum effect indicates while new models may create better results, better information yields more consistently generates superior modeling results. Bellotti & Crook (2009) confirms that radical types of information such as macro-economic variables can be included in credit scoring models and can increase their predictive abilities (Bellotti & Crook, 2008). Given these and other findings, future research should start to examine the role of high performance homes in the lending and underwriting

process as well as in the securitization chain. At present, this literature appears, on summary review, to be under-explored and a natural path forward for this and other related work.

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C5_Appendix A

C5_HypoHome1

HypoHome 1

Unit Description: Size, Bed, Bath, Year Built	
Sub Type:	Single Family
Baths:	2.5
SF Bsmt Fin N/Egr/In:	0
SF Garage:	648
Bedrooms:	3
Total SqFt Livable:	2,230
SF Bsmt - Unf:	0
Studio/Loft:	0
SF Bsmt-Fin w/Egress:	0
SF Asry Dwell Det:	0
SF Deck:	250
Yr Remodeled Complete:	N/A
SF Per:	Assessor
Waterfront:	No
Year Built:	2012
Furnished:	
Agent Owned:	No

Public Remarks: Detailed Unit Description	
Public Remarks:	This home is in a wonderful convenient location. Great lot with incredible amenities nearby.
Realtor Remarks:	
Legal	Eagle's Landing Subdivision Lot 7
Directions	
Zoning	Residential-4 (4units/acre)
Land Ownership Type	Fee Simple
Construction Type	Site-built (Stick)
Style	2 Story
Specialty Rooms	Dining; Foyer/Entry
Heating & Air Conditioning	Electric Heat Pump
Features Interior	Cable TV; Gas Log
Items Included	All Ktchn Appliances
Exterior Finish	Brick, Wood
Features Exterior	Deck; Landscaping; Sprinkler Blw Ground; Undergrnd Utilities
Roof	Asphalt Single
Energy Related Features	None
Green Certification	None
Driveway	Asphalt
Road Surface	Paved
Road Access	Public
Water	City Connected
Garage	2 Car

C5_HypoHome2

HypoHome 2	
Unit Description: Size, Bed, Bath, Year Built	
Sub Type:	Single Family
Baths:	2.5
SF Bsmt Fin N/Egr/In:	0
SF Garage:	648
Bedrooms:	3
Total SqFt Livable:	2,230
SF Bsmt - Unf:	0
Studio/Loft:	0
SF Bsmt-Fin w/Egress:	0
SF Asry Dwell Det:	0
SF Deck:	250
Yr Remodeled Cmplete:	N/A
SF Per:	Assessor
Waterfront:	No
Year Built:	2012
Furnished:	
Agent Owned:	No
Public Remarks: Detailed Unit Description	
Public Remarks:	This green home is in a wonderful convenient location. Great lot with incredible amenities nearby. Built according to green building specifications.
Realtor Remarks:	
Legal:	Eagle's Landing Subdivision Lot 7
Directions:	
Zoning	Residential-4 (4units/acre)
Land Ownership Type	Fee Simple
Construction Type	Site-built (Stick)
Style	2 Story
Specialty Rooms	Dining; Foyer/Entry
Heat	Electric Heat Pump (SEER 13)
Features Interior	Cable TV; Gas Log
Windows	Double-Paned, Low-E/Argon Filled
Items Included	All Ktchn Appliances
Exterior Finish	Fiber-Cement (hardi-plank Wood Deck; Landscaping; Sprinkler Blw
Features Exterior	Ground; Undergrnd Utilities
Roof	Asphalt Shingle
Energy Related Features	HERS Index: 90, Energy Efficient Heat Pump, Energy Star Appliances, Double-Paned, Low-E Windows, Programmable Thermostat
Green Certification	None
Driveway	Asphalt
Road Surface	Paved
Road Access	Public
Water	City Connected
Garage	2 Car

HypoHome 3

Unit Description: Size, Bed, Bath, Year Built	
Sub Type:	Single Family
Baths:	2.5
SF Bsmt Fin N/Egr/In:	0
SF Garage:	648
Bedrooms:	3
Total SqFt Livable:	2,230
SF Bsmt - Unf:	0
Studio/Loft:	0
SF Bsmt-Fin w/Egress:	0
SF Asry Dwell Det:	0
SF Deck:	250
Yr Remodeled Complete:	N/A
SF Per:	Assessor
Waterfront:	No
Year Built:	2012
Furnished:	
Agent Owned:	No

Public Remarks: Detailed Unit Description	
Public Remarks:	This green home is in a wonderful convenient location. Great lot with incredible amenities nearby. Built to LEED specifications.
Realtor Remarks:	
Legal:	Eagle's Landing Subdivision Lot 7
Directions:	
Zoning	Residential-4 (4units/acre)
Land Ownership Type	Fee Simple
Construction Type	Site-built (Stick)
Style	2 Story
Specialty Rooms	Dining; Foyer/Entry
Heat	Geothermal (Need Efficiency Rating)
Features Interior	Cable TV
Windows	Triple Glazed/Argon-Filled Low-E Windows
Items Included	All Ktchn Appliances-Energy Star
Exterior Finish	Fiber-Cement (hardi-plant), Wood Composite Deck; Landscaping;
Features Exterior	Sprinkler Blw Ground; Undergrnd Utilities
Roof	Low-E Coated Standing Seam Metal HERS Index: 50, Geo-thermal heat pump, Triple Glazed/Argon-Filled Low-
Energy Related Features	E Windows, Programmable Thermostat, 3KW Photo-voltaic array, Icynene Spray Foam Insulation
Green Certification	LEED
Driveway	Permeable Concrete
Road Surface	Paved
Road Access	Public
Water	City Connected
Garage	2 Car

Chapter 6: Conclusions & Future Research

Andrew Sanderford

Research Problem Summary

According to the US Environmental Protection Agency and Department of Energy, more than 1.5 million homes have been Energy Star certified since 1996. The USGBC's database indicates that more than 13,000 homes have earned some degree of LEED certification over the same time period. Adding regional systems such as Greenpoint and Earthcraft the total number of eco-labeled homes in the US can roughly be estimated at 1.5 million units. Within individual markets, the ratio of Energy Star homes to the total number of homes in any CBSA remains below 12%; the majority of markets have ratios below 3%. In the context of the increasing volume of the national and global discussion about green consumer durable goods, corporate social responsibility, hybrid-electric vehicles, climate change, and the volatility of energy prices, it seems that green and energy efficient home certifications are lagging—or at least suffering from slow diffusion in many markets. Perhaps some of this can be explained by residential construction's status as an innovation laggard, but certainly not all of it can.

This dissertation generated research questions to explore the frictions and obstacles to the broader diffusion of high performance, energy efficient homes into the US housing market. Specifically, the research investigated what diffusion patterns markets might expect under the condition of missing information about the value proposition of high performance homes and in the context of the comparable sales valuation method. Further, the dissertation explored current real estate appraisal practice for existing methods of analysis used to overcome obstacles to high performance home valuation. Finally, the dissertation offered a temporary valuation tool to help break the vicious cycle of limited data—> mis-pricing of high performance homes—> limited diffusion.

Where previous research focused on the diffusion of green and energy efficient building technologies into homes or building certifications into the commercial property

markets, this dissertation focused on the unit of analysis of the high performance house. The dissertation appears to be the first to analyze high performance homes in the context of Moore's Chasm, a tactic that allowed the authors to address McCoy's request in his 2008 dissertation to identify and explore the role of champions or gatekeepers of innovation within residential construction. By using Moore's Chasm as an intellectual framework for analysis, the authors identified the real estate appraiser as the most likely gatekeepers of information. Further, the research differentiated itself by using qualitative methods of analysis to analyze current appraisal practice vis-a-vis high performance single-family homes. In doing so, the authors were able to confirm that among real estate appraisers, there is not a common analytical framework for estimating the value of high performance homes. Further, this lack of consensus has bled over into a sub-method of analysis where the authors discovered that that appraisers do not hyperbolically overestimate discount rates relative to energy savings cash flows the way they appear to do relative to other products.

Research Questions and Methods of Analysis

The first article of the dissertation analyzed the problem of limited diffusion and responded to the question 'what diffusion patterns would we expect based on the problem of valuation of green homes in the absence of comparable attribute data supporting their value proposition?' Further, it identified the problem in the context of the diffusion theory and the condition of inadequate information about the performance of these innovations. High performance homes reflect a type of green building innovations that involve non-trivial costs. As early-stage innovations, diffusion theory helps researchers to identify the challenges faced by innovations including those faced as they move from early stage markets across Moore's chasm into more mainstream markets.

The authors employed literature review across several disciplines to develop a new theoretical understanding of the effect of valuation on the diffusion of innovation. First, the authors reviewed the diffusion literature focusing on definitions of innovation to understand the extent to which high performance homes met existing definitions of innovation. After confirming that high performance homes met the definition of early-stage innovations, they reviewed the diffusion of innovation literature focusing on

diffusion patterns of consumer goods and services across a range of industries including building construction and real estate. Following this review, the authors identified the real estate appraiser as the most likely gatekeeper in the diffusion process for high performance homes. Building from this, the authors reviewed the literature to analyze how scholars have estimated the value of innovations across the automobile, biotechnology, securities, and property industries and identified the need for a temporary valuation tool to break the vicious cycle caused by missing information.

The second article responded to the findings of both the first and second articles and offered a temporary valuation method based on a net present value formula. The solution is only temporary, as the traditional methods of appraisal should work well once there is sufficient data available in the market place to conduct comparable sales analyses. At the point in time where a market has documented a sufficient number of high performance homes from which to conduct comparable sales analyses, then the temporary method could be converted into a method of reconciliation. Following this article, the authors analyzed data generated from a series of semi-structured interviews conducted with residential real estate appraisers from across the US with green appraisal training and/or experience.

The third article sought to answer the research questions, 1) at present, how do residential with green experience and training appraisers estimate the contributory value of high performance building technologies within high performance homes; and 2) how are the methods and processes used substantively different from those used to appraise non-high performance homes? To answer this question, the authors first reviewed the appraisal literature, interspersing findings from the construction and real estate literature where necessary. They then conducted eighteen semi-structured interviews with real estate appraisers and discussed how they would or have conducted the appraisal of high performance homes and how that differed (if at all) from the appraisal of traditionally built homes.

Conclusions

Using the intellectual framework of Moore's Chasm to analyze the diffusion patterns of high performance homes showed evidence to support the claim that high

performance homes have not yet crossed from the early market into the mainstream market. The literature review across the innovation, finance, and appraisal literatures identified the real estate appraiser as the most likely gatekeeper for increased high performance home diffusion. Identifying a gatekeeper is important insofar as gatekeepers are individuals, firms, or processes (e.g., policy) that funnel, filter, and block the transfer of information about the value proposition of various innovations.

The appraiser as gatekeeper logic is primarily supported by the fact that most home purchases rely upon the use of mortgage debt. As such, lenders require a third party, the appraiser, to estimate the value of the collateral upon which they are making mortgage loans. Where the appraiser cannot gain access to, discover data, or substantiate the value proposition of a performance of a high performance home, they cannot substantively differentiate the value of a traditional home from a high performance home. As high performance homes contain technologies and systems designed to operate more efficiently than their traditionally built counterparts, this could seriously blunt broader diffusion.¹

The review also indicated that appraisers appear to need a temporary solution to help them break the vicious cycle. The SAVE Act, proposed and rejected several times over the last three years has recently gained new traction in the US Senate. It proposes to convert energy savings from energy efficiency at a discount rate of 4% over a 20-year period of analysis. Research from other industries where energy saving innovations exist suggest that using some version of a present value calculation can help estimate the value of these innovations. However, the literature noted that buyers typically are unable to accurately estimate discount rates to use to present value energy savings based cash flows. So, given the static nature of the SAVE Act methodology and the lack of consensus among practitioners on the selection of a time period or discount rate, the

¹ Though we conclude that the most likely gatekeeper is the appraiser, we perhaps give them too much primacy and instead should consider the Lender as an alternative gatekeeper. The Lender could encompass any actor in the capital allocation process from mortgage origination (the step that includes initial credit scoring of the buyer, analysis of potential loss given default, appraisal of the collateral, and pricing of the loan) to securitization. Each of these analyses are influenced by the availability and completeness of information about their subject. Lenders with greater access to high performance housing information would gain a competitive advantage over their competition and also likely be able to underwrite and issue better loans for securitization. Suspecting the Lender as a potential gatekeeper does not challenge the original conclusion of the dissertation but instead broadens it and allows future research to move in a wider trajectory.

temporary solution should suggest an easy to use but disciplined method of generating assumptions.

The data from interviews with appraisers indicated that while there were few, if any, procedural differences between the appraisal of a traditional home and a high performance home, the methods of estimating value within the appraisal process were markedly different; despite the fact that within the sample, there was limited consensus as to what methods were most useful. In practice, most appraisers used two methods. The first was a modified version of the comparable sales method that made an adjustment for the quality of construction and increased economic life of high performance building technologies and systems. The less air and moisture moving across the building components, the longer the house would last. Further, as these systems and technologies were considered more difficult to install, they were perceived to be of higher quality. The second approach focused on discounting the estimated future energy savings of the home to create a cash flow based adjustment of value to the home appraised in the absence of the high performance technologies. Despite consensus that these two methods were useful in low data environments, there was limited consensus on the details of use. For example, there were nearly as many variations of the method respondents used to estimate a discount rate as there were respondents in the sample. This variation can lead to significant variation in price adjustments.

Finally, building from the findings of both the first and third articles, we created a temporary solution to appraisers for the valuation of high performance homes that addresses some of the problems highlighted by the literature review and interviews. The method uses the build up method to select an appropriate discount rate. The build up method for a high performance home includes a risk free rate, an equity premium for the market, a climate adjustment, and the HERS index of the subject property. The method then estimates the cash flow savings generated by the high performance technologies by converting the HERS score of the property from BTUs into KWHs using a tool from the Department of Energy. These two elements are then combined into the present value of an annuity formula. The method we advanced in this article attempted to provide some guidance from other industries such as securities and firm valuation where discount rate construction is a regular and structured process. Further, the proposed method draws on

the present value of an annuity formula that can be adjusted for taxes and depreciation or changes in the growth rate of the cash flows over time. In suggesting that appraisers use these two tools, we contributed to the conversation of high performance valuation a method that appears to be superior to the method prescribed by the SAVE Act and helps to bring some consensus on inputs to practitioners.

Future Research

There are a number of future directions that this work could take to make a more significant contribution to the fields of housing, planning, and real estate. Perhaps the lowest hanging fruit is an analysis of the economic factors, policy instruments, and market attributes that influence the diffusion of energy efficiency in housing. At present, several papers have explored the factors associated with increased diffusion of energy efficiency in the commercial property market. However, at present, no work has been completed on those factors associated with increased efficiency within the housing market. Policy makers, builders, and developers would likely be interested to know more about the levers that have been pulled successfully or the market factors that help explain how diffusion has occurred to date. They may also be able to interpret this research to identify future opportunities to deploy policy or leverage market factors to increase future diffusion of energy efficiency within the housing stock.

An additional direction future research could take would be to expand the analysis of current appraisal practice into a survey allowing for more quantitative analysis of the methods of analysis appraisers are using to overcome high performance home appraisal obstacles. Existing practitioners and policy makers would benefit from the nuanced understanding of practice and could use the data and analysis to inform iterations of methods of analysis and policy.

Future research could also expand the analysis of gatekeeper to investigate the role of the mortgage underwriter in broader diffusion of high performance homes. The appraisal and the appraiser sit within the mortgage lending process and provide a service that is integral to its success. By expanding research into the lender as a gatekeeper, I would be able to address a number of additional frictions associated with high performance homes including the role and shortcomings of existing automated

underwriting systems and credit scoring models with their use surrogate variable models in place of more empirical cash flow based variables. Additional frictions include agency issues related to home ownership (e.g., owner as investor/tenant), the concept of loss given default for a high performance home versus a traditional home, and finally the role of capital availability via the securitization process. Under the topic of securitization of high performance home mortgages, there has been little research to suggest how the flow of capital has created a more stable pathway for innovation into the housing market as it allows buyers to express demand and builders to build to it (and occasionally suggest what new features might look like). This topic is likely to be important given two critical mis-matches: the mis-match of the duration of capital (e.g., lenders tend to fund mortgages with short term capital though they are longer term assets) and the mis-match of the flow of capital to buyers who do not need the benefits of energy efficiency and the lack of capital available to lower income buyers where increased cash flow from energy savings could prove most valuable given a trigger event such as job loss or illness.