Market Mechanisms for Financing Green Real Estate Investments

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1 Introduction

U.S. buildings consume almost 39% of the total U.S. total energy consumption, making real estate the largest consuming sector by a considerable margin; see Table 1.1. In comparison, the industrial consumption share is about 33% of the total and the transportation share is about 28% of the total. Within the real estate sector, the share of total energy used is almost equally split between residential (20.9%) and commercial (18.0%) buildings.

Table 1.1: Buildings Share of U.S. Primary Energy Consumption (Percent), 2006

Residential Buildings	Commercial Buildings	Total Buildings	Industry	Transportation	Total	Total Consumption (quads)
20.9%	18.0%	38.9%	32.7%	28.4%	100%	99.5

Source: U.S. Department of Energy (2009)

The energy consumption of U.S. real estate appears, furthermore, to be substantially less efficient than comparable European buildings, even after controlling for such factors such as climate, GDP, and population.[1] There is no mystery as to the reason: U.S. costs for electricity and heating oil range from 50 to 75 percent of the levels in most European countries; see IEA (2009). This indicates there must be feasible technologies that would allow the energy consumption of U.S. buildings to be reduced significantly. Such investments could arise as the result of building codes and comparable requirements, or as a voluntary response to high and volatile energy prices.

Most economists would agree that the "first-best" solution to reducing U.S. energy consumption, across the three major uses of real estate, industry, and transportation, is to raise

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[1] IEA (2008) and (2004) provide comparisons of residential energy use in the U.S. and Europe corrected for climate and measured per unit of GDP or per capital. McKinsey (2007) also shows substantially higher U.S. energy consumption compared to Europe after controlling for GDP and population. Rand (2009) provides a discussion comparing energy use in the U.S., Australia and the European Union.

the U.S. price of energy through appropriate fiscal instruments. While this may occur in the future, the timing of this change in policy remains highly uncertain. So it is sensible, even critical, to look for alternative, accelerated, mechanisms to reduce U.S. energy consumption. Indeed, if and when U.S. energy prices do rise, the economic adjustment will be easier and faster if the transformation toward a more energy efficient technology is already well along. Facing inadequate energy-efficient investments in real estate, governments in both the U.S. and Europe have intervened to provide additional incentives. To date, three approaches have dominated theses interventions: expanded building codes, energy-efficiency certifications, and direct fiscal subsidies.

Expanded building codes have been the primary mechanism to ensure energy-efficient structures in Europe and are likely to expand over time in the U.S. as well. Building code requirements, however, have their primary impact on new construction, and given the long durability of most buildings, new construction annually represents a very small percentage of the existing building inventory. Most building codes, furthermore, are prescriptive rather than performance-based, which limits the incentive they provide for new innovative solutions.

Disclosure certificates at the time of building sales have also become an important mechanism in Europe. The 2002 EU Energy Performance in Buildings Directive requires an energy performance certificate based on either the building's design or usage characteristics. While such disclosures might well have an impact on the sales prices, it is unclear to what extent such disclosures motivate either the seller or buyer to initiate energy efficient investments. In the U.S., certifications such as Leeds and Energy Star are available, and such certifications are sought by builders and developers who are planning to create energy efficient buildings. But these certifications primarily apply to new buildings, and it is unclear to what extent the certifications are the factor actually motivating energy-efficiency in these buildings.[2]

Direct subsidies provided by either government agencies and public utilities may provide economic stimulus to energy efficient investments. In these times of harsh fiscal budgets, however, direct subsidies are unlikely to be a major driver of new energy-efficient investments.

Given the limitations of building code requirements, energy-efficiency certifications, and direct subsidies, it is critical to consider whether there are other solutions to the private market failures that are contributing to the underinvestment in U.S. building energy efficiency. It is possible, of course, that the available technology is just not profitable in net present value (NPV) terms. However, it appears that NPV positive energy-efficient investment opportunities already exist, and that further innovations and cost-savings from scale economies are literally in process. In this paper, we focus on loan market frictions as a market failure that raises the cost and limits the availability of mortgage funding for energy-efficient investments. Given the large ratio of the existing stock to new investment, our proposed solutions emphasize market mechanisms to eliminate the frictions that inhibit energy retrofits in existing structures. These same solutions will also expand the incentives to embed the best technology in new construction. In either case, we can identify three steps that must

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[2] Eichholtz, Kok, and Quigley (2009) show that buildings with certifications obtain higher sales prices, which provides a motivation for obtaining such certifications. However, it is unclear whether the existence of the certifications motivates energy efficient investments that otherwise would not have been carried out. The existence of higher sales prices on certified buildings also does not indicate whether the initial energy-efficiency investments were NPV positive; to show that, the investments costs must be compared with the sales prices.

occur if building owners are to invest voluntarily in energy saving equipment:

1. Identification of worthwhile investments, Building owners must be able to identify those energy-efficient investments that meet at least a minimal standard of profitability. As a simple example, for any investment to add value, it must at least provide a non-negative NPV when evaluated with a zero interest rate. In other words, the investment must pass an internal rate of return (IRR) hurdle of zero, which is to say that the sum of the actual cash flow benefits must exceed the investment costs.

2. Computation of the true NPV. Investment decisions, of course, will be based on a NPV > 0 criterion, where the NPV is evaluated at the owner's true opportunity cost of capital. For many real estate investments, this opportunity cost will equal the interest rate that is applied in financing the investment. The NPV criterion also allows the property owner to prioritize alternative investments, giving the highest priority to the highest NPV projects. This is particularly relevant if there is a cap on the total amount of available funding.

3. Identification and removal of financial frictions. Frictions in the lending market raise the discount rate and lower the NPV computations, thus limiting the set of feasible investments and acting as a deterrent to those investments with the longest payoff structures. Or to put it in a positive vein, the removal of such frictions can stimulate the aggregate amount of energy efficient investments, and provide particular benefits to those investments with the longest-term payoffs. The identification of these frictions and proposals to remove them is the direct focus of this paper.

The agenda of this paper is as follows. In Section 2, we describe the loan market frictions that currently inhibit energy-efficient investments in the commercial real estate sector. In Section 3, we describe our proposals to help eliminate these frictions. Our proposals in Section 3 require a mechanism through which firms can compute the NPV of their proposed energy investments and convince their lenders of the benefits of funding these investments. Thus, in Section 4, we provide a feasible method to compute the net present value of alternative energy-efficient investments. The key innovation here is to use Monte Carlo simulations to incorporate stochastic energy prices into the valuation process. In Section 5, we provide a summary and conclusions.

2 Commercial Mortgage Market Frictions that Inhibit Energy-Efficienty Investments

Commercial property mortgage lending in the United States traditionally focuses on two key risk measures for underwriting mortgages: the loan-to-value ratio (LTVR, the ratio of the mortgage balance to the value of the building), and the debt-service-coverage ratio (DSCR, the ratio of the propertys net operating income to the principal and interest payments on the mortgage debt). These ratios are also monitored by bank regulators, including the Federal Reserve, the Comptroller of the Currency, and the Office of Thrift Supervision, because they are important indicators of the quality of commercial bank underwriting and the mortgage-related default-risk exposure. Sound underwriting standards typically require a LTVR no more than 65% and a DSCR no less than 1.25, although, of course, other factors such as the quality and timing of tenant leases will have an impact on these ratios. These ratios are important because mortgage performance data have shown that mortgage borrowers are more likely to default as the LTVR rises toward 1.0 or as the DSCR falls toward 1.0.

The key role of the DSCR and the LTVR for underwriting commercial mortgages has become a critical impediment for the recognition of volatile energy costs as an additional and major source of mortgage default risk for commercial buildings. Net operating income (NOI, the net rental income associated with a commercial structure) is the key input in computing both the DSCR and the LTVR. NOI appears directly in the numerator of the DSCR. The present value of NOI is also the fundamental input in determining the property valuation that appears in the denominator of the LTRV. In practice, the forecasted net operating income of a commercial building is constructed by:

1. Aggregate the forecasted contractual rental income from the tenants' leases;
2. Subtract the forecasted building operating expenses, including the costs of energy; and
3. Adding back the forecasted energy-use reimbursements from the tenant to the landlord, as required on triple net leases that are the most common commercial lease contracting structure.

The triple-net lease, and the software package, ARGUS, which is widely used to organize and display the information, thus "nets" out the energy risk exposure of buildings, other than those energy costs borne solely by the landlord due to vacancies, joint costs associated with common areas such as lobbies, and incomplete energy reimbursements from the tenants to the building owner. The result is that mortgage lenders typically do not account for the risks created by a commercial buildings energy costs. In particular, commercial mortgage underwriters currently have no validated system to score the default risk created by energy-cost volatility in a manner similar to their use of the DSCR and the LTVR to score the overall default risk.

Of course, with triple-net leases, tenants in more energy-efficient buildings should benefit from lower energy bills, and thus should be willing to pay higher rents for space in such buildings. Three conditions have to be realized, however, if the result is to be more energy-efficient investments:

1. Tenants must validate the lower expected energy costs before they accept the higher rents;
2. Landlords must confirm the higher rents before undertaking the energy-efficient investments;
3. The actual investments must be NPV positive in order to ensure that a true net benefit exists.

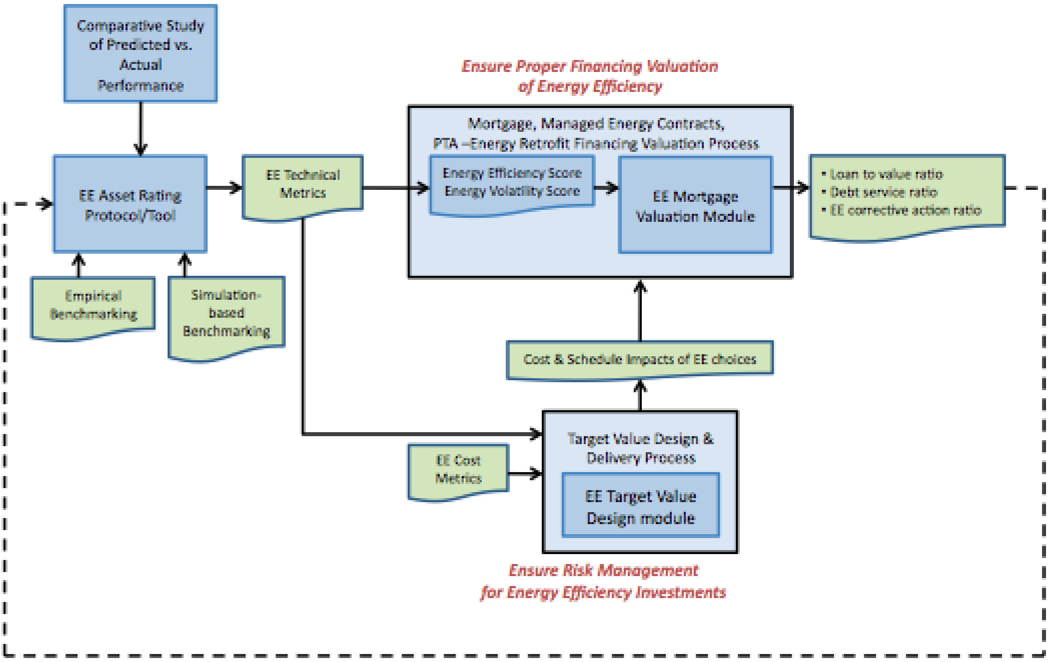
Imperfect information regarding future energy costs and the efficacy of energy-efficient investments makes each of these steps problematic. The result is that the existing systems for commercial mortgage lending and property leasing inhibit energy-efficient investments in this sector.

The positive news is that our proposed tools for evaluating and disclosing energy efficient investments, to which we next turn, can play an important role in mitigating the frictions that currently constrain both owner-lender mortgage contracts and owner-tenant lease contracts.

3 Mitigating Financing Frictions for Commercial Real Estate

The unsatisfactory situation for the financing of energy-efficient investments in commercial real estate can be potentially mitigated by energy efficiency metrics and disclosures for mortgage underwriting and tenant leasing. These metrics allow the comparison of energy-related costs and risks across building types, building qualities, and tenanting structures. Just as LTVR and DSCR are informative about the potential default risk of newly originated mortgages, so too our proposed Energy Efficiency Score (EES) and Energy Volatility Score (EVS) provide default risk metrics based on the impact of energy-cost savings on a building's net operating income. The benefits include both a higher net operating income as a result of lower energy costs and a more stable net operating income in the face of volatile energy costs. The goal is that the two new energy efficiency metrics will be used by commercial loan underwriters to provide more favorable loan terms to loan applicants with energy-efficient buildings.. The two scores will also provide property owners with a means to determine the most cost-effective energy-efficient investments, and tenants with a means to estimate their savings in energy costs as a result of renting space in an energy-efficient building.

Figure 3.1: Asset Valuation



3.1 Energy-Efficiency Metrics to Facilitate Commercial Mortgage Lending

Figure 3.1 provides an overview of how our proposed energy efficiency (EE) mortgage underwriting rating system would work. It uses both engineering-based simulation methods focusing on an integrated analysis of whole building systems to benchmark the relative energy consumption of lighting, HVAC, and plug-load functions in commercial buildings of differing types and qualities; and performance-based empirical benchmarking using statistical estimation methods. The output from our coordinated energy efficiency benchmarking analyses will be technical metrics that are summarized in the proposed scoring metrics for mortgage underwriting: the EES and EVS. These two scores are related to the level and volatility of the net operating income of commercial buildings. The scores can also be incorporated as inputs into mortgage valuation models that are based on the dynamics of interest rates and asset prices.

As shown on the right-hand side of the flow diagram, the mortgage valuation technology can be used prescriptively to determine the appropriate interest rate to be charged, and/or the maximum loan size to be granted for buildings with differing EES and EVS. This prescriptive exercise takes the energy efficiency scores as given and solves for the actuarially fair mortgage contract terms (e.g. by setting lower mortgage rates, higher LTVRs, and lower DSCRs as compensation for a higher energy efficiency score or a lower energy volatility score). The scores may also be used to induce renters to pay higher rents in exchange for the benefit of lower energy costs.

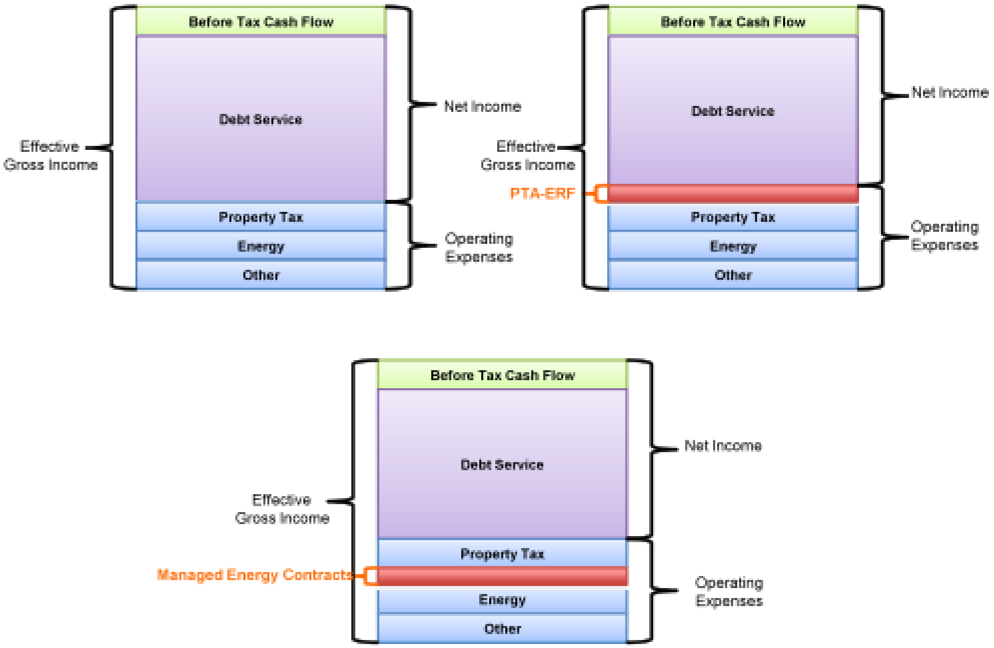
By measuring the EES and EVS that result from alternative energy-efficient investments, we can also derive a third measure, the Energy Efficiency Action Ratio (EEAR). As shown in the flow diagram, this third ratio allows a decision maker to rank order the cost effectiveness of alternative investments to change the energy efficiency of buildings. This analysis is a particularly important if mortgage lenders are going to recognize that energy-efficient investments in commercial buildings can directly reduce their mortgage default risk by raising the property's NOI and by reducing the sensitivity of the NOI to future energy cost volatility.

In Section 4 below, we take the first steps to implement this program by carrying out dynamic Monte Carlo valuation of the possible future energy costs of a representative building based on alternative stochastic paths for energy costs. Future work will then expand this tool to compute the energy efficiency and energy volatility scores and the energy efficiency action ratio for buildings with any actual or simulated physical and environmental characteristics.

3.2 Alternative Methods to Facilitate Commercial Mortgage Lending

Figure 3.2 introduces two alternative green financing instruments–Managed Energy Contracts and Property Tax Assessed Energy Retrofit Financing and compares them with a straight commercial mortgages. Managed Energy Contracts (MEC) are privately provided leasing contracts in which an energy service provider commits to provide all energy related services to a property owner, typically a Real Estate Investment Trust or large real estate portfolio operator, in exchange for the payment of the property operators historical energy costs. The energy service provider profits if it achieves energy cost savings in excess of the

Figure 3.2: Location in the “Cash Flow Stack” of Commercial Real Estate Mortgages (CREM), Managed Energy Contracts (MEC), and Property Tax Assessed Energy Retrofit Financing (PTA-ERF) for Commercial Real Estate Assets



present value of any investments it makes. At the end of the lease term, typically ten years, the energy efficiency improvements remain with the building, thus enhancing the value of the building owner’s asset. Since the MEC lease payments are equivalent to the historical utility fee structure of the property, the full utility fee structure remains fully recoverable from tenant reimbursements. While energy efficiency gains are achieved through MEC, the full cost savings of these investments are captured by the tenants or the building owner only at the lease maturity date.

Property Tax Assessed Energy Retrofit Financing (PTEF) is a very recent innovation in green energy financing pioneered by the city of Palm Desert, California through the Palm Desert Energy Partnership, and subsequently was codified into California State Law in July, 2008 with the passage of Assembly Bill 811. The goal of AB811 is to allow California cities to finance permanently fixed renewable energy generation improvements in private property including commercial real estate assets. Although the financing strategies may differ by city, the bill allows for the creation of special tax assessment districts in which individual property owners can opt for energy retrofit project loans with long maturities (e.g. 20 years for the CityFIRST program in Berkeley, California). These loans have a contractual payment structure that is similar to loans, except that they are paid back using a fully amortizing installment payment that is added to the property taxes of the asset. In addition, the PTEF loan liability is a tax lien with priority over mortgage liens and it is attached to the property in contrast to a mortgage loan which is the liability of the borrower and is collateralized by the property.

As shown in figure 3.2, the three types of commercial real estate green financing are attached at different positions in the cash flow stack of commercial real estate assets. All three options, usually involve a commercial real estate mortgage (CREM) and therefore a substantial fraction of the net operating income, the primary mortgage underwriting cash flow, is allocated to the debt service on the loan subject to the limitations of the debt service coverage ratio. The relative energy risk exposure of the CREM would, however, differ across the three structures represented in figure 3.2. The straight commercial mortgage presents the lender with the maximal energy risk exposure. In contrast, the PTEF increases the property tax liability of the property and thus reduces both the size and risk of the commercial mortgage loan through the cost savings achieved by an energy-efficient retrofit investment. Even further, the use of a MEC largely eliminates the energy risk of the commercial real estate loan because the property's energy costs are fixed at the historical expense level.

Although MEC and PTEF have different payment priorities, the commitment of the building owner is similar across the two contracts (technically MEC are lease financings). Both of these commitments represent forms of fixed income securities in which an initial investment by the lender, or lessor, is paid back with a set of installment payments by the borrower, lessee. For this reason, they both can be underwritten for risk and priced using the same form of financial modeling techniques that we develop in Section 4 below. Alternatively, the market prices of these two contract types can be directly related to our two energy efficiency scores, and the preferred investments will be identified our the energy efficiency corrective action ratios.

Table 3.1 provides a further comparison across these three green financing instruments. For one thing, currently there are no standardized energy efficiency metrics or valuation tools to underwrite or price any of these financing alternatives. Without an organized capital market for MEC and PTEF instruments, valuation occurs on a case by case basis. Both CREM and PTEF involve loan contracts, or promissory notes, whereas the MEC involves a lease contract which is simply another form of fixed income security. The seniority of these instruments, as previously discussed, also differs with PTEF instruments having the most secure interest.

The U.S. commercial real estate mortgage market, based on its size and long history, does have well developed and standardized methods for valuing the risks that arise from macro-fundamentals such as interest rates and asset price dynamics. In contrast, the valuation standards applied in MEC and PTEF markets are currently entirely private and proprietary. The CREM market also currently services all sizes and types of commercial building, whereas MEC usually require larger scale to achieve energy efficiency gains and thus they are used primarily for Real Estate Investment Trusts or large real estate operating companies.

Two further limitations arise with regard to the MEC and PTEF mechanisms. With regard to the MECs, there is a potential principal-agent problem in that the energy-saving innovations introduced by the service provider could have a negative impact on the building's serviceability. In fact, this may be an important factor that has limited the use of these contracts. With regard to PTEFs, most commercial mortgages have a covenant that constrains the property owner from creating new liens senior to the mortgage lien. The mortgage lender's permission is thus required to use the PTEF mechanism. In principal, the mortgage lender would benefit and thereby grant permission– if the energy-efficient investment were NPV positive, since the increase in property value (i.e., the loan collateral) would then exceed the value of the new, senior, property lien. The method we develop in Section 4 below would provide the lender with the necessary information to make the decision.

Table 3.1: Alternate Financing Methods Comparison

	Commercial Real Estate Mortgage (CREM)	Managed Energy Contracts (MEC)	Property-Tax Assessed Energy Retrofit Financing (PTA-ERF)
Standardized Energy Efficiency Metrics	No	No	No
Energy Efficiency Valuation Tools	None	Net present value of agent's energy efficiency investments and pass-through of existing utility payments	Net present value of energy retrofit investment and amortized loan payments
Security of Interest	Mortgage lien on Property	Commitment on utility fees	Tax Lien on Property
Contract Type	Promissory Note	Utility provision lease.	Promissory Note
Valuation Standards	Actuarial and regulated	Private	Private
Installment Payment Structure	Long amortization (15 to 20 years) due in 7 or 10 years	10 year renewable contracts	Add-on to Property Taxes with 20 year payback
Ownership of Energy Related Investment	Building Owner	Building Owner	Building Owner
Capital Market Funding Sources	Commercial Banks, Commercial Mortgage Backed Securities, Insurance Cos., Pension Funds	Private Companies (e.g. Transcend Equity Development Corp.) - if scale sufficient potential for lease securitization capital markets	Private Companies (e.g. Renewable Funding Financial Partners) if scale sufficient Municipal Bond Market
Commercial Real Estate Applications	All commercial property types and building sizes	Real Estate Investment Trusts, Large Real Estate Operating Companies	Residential only, authorization exists for commercial real estate
Market Penetration	$2.37 Trillion Capital Market	Small Private Operating Companies (e.g. Transcend - MESA)	Small Private Operating Companies (e.g. Renewable Funding Financial Partners)
Performance Risk	Default and Prepayment Risk of Borrowers	Agent's failure to render energy services, property owner's failure to pass-through utility fees	Property owners non-payment of property taxes
Energy Retrofit Expenses Recoverable (Escalatable) from Tenants	Yes, if operating cost, repairs/maintenance, or cost reducing. No, if capital improvements.	Lease payment is an escalatable operating expense. Accounting opinions exist.	Tax payment is escalatable, no accounting rulings.

Finally, CREM, MEC, and PTEF share comparable default risks due to the failure to make payments per the contractual agreements, by the borrower, lessee, or taxpayer respectively. Finally, the ability of the building owner to pass energy efficiency related expenses through to the tenants depends on the language of the tenant leases and whether the investments are related to fixed capital improvements or to maintenance and repairs. MEC and PTEF may blur this distinction, however, since there are no definitive FASB rulings. What is clear from the summary presented in Table 3.1 is that all three green financing strategies could benefit from the development of suitable energy efficiency metrics, the topic to which we now turn.

4 Monte Carlo Simulation to Compute NPV for Energy Investments

As previously introduced, summary statistics, or scores, for the energy efficiency and energy volatility of commercial real estate assets are critical if we are to achieve private market solutions to the mortgage market frictions that currently inhibit energy-efficient investments in commercial buildings. The key is to quantify the impact of possible future energy costs on a building's NOI. NOI is, in turn, a critical component in computing the property's DSCR and LTVR, the financial ratios used to determine the mortgage contract terms and amount. Thus NOI is the critical statistic through which energy cost variability is linked to the mortgage lending decision.

We next provide a prototype model that allows us to compute the impact of energy price volatility on the NOI (net of energy costs), for a representative building. We use a Monte Carlo simulation methodology in which alternative future paths of energy prices are generated as the output of a stochastic process. We then compute the impact of the alternative energy paths on the property's NOI.

4.1 Stochastic Modeling of Energy Spot Dynamics

The classical stochastic process for the spot dynamics of commodity prices was developed by Schwartz (1997) who specified the process as the exponential of an Orenstein Uhlenbeck (OU) process. Mean reversion has been identified as an important empirical regularity of the price dynamics of natural gas and electricity. There is also a growing literature considering improvements on the Schwartz model such as incorporating jumps to handle the empirical spikes in many commodity prices, such as electricity, modeling the seasonality of commodity prices over heavy and lighter consumption months, and fitting the correlation structure of commodity prices and exogenous factors such as temperature dynamics.[3]

For our modeling of energy price dynamics, we will also use an Schwartz-type OU process. We implement our simulation model as flexibly as possible to allow for inclusion of important empirical characteristics of electricity such as mean-reversion, seasonalities in price levels

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[3] Recent work in modeling energy dynamic processes include: Benth, F. E., Cartea, A., and Kiesel, R. (2006). Benth, F. E., Koekebakker, S., and Ollmar, F. (2007), Bessembinder, H., and Lemmon, M. (2002), Cartea, A. and Figuerosa, M. G. (2005), Deng, S. (2000), Eberlein, E. and Stahl, G. (2003), Geman, H. and Roncoroni, A. (2006), Karlis, D. and Lillestl, J. (2004), Weron, R. (2000), Weron, R. (2004), Weron, R. (2005), and Weron, R., Kozlowska, B., and Nowicka-Zagrajeck, J. (2001). For excellent surveys of modern energy modeling techniques see Weron, R. (2006) and Benth, F.E. and Benth J.S., and Koekebakker, S. (2008).

and volatility, heteroscedasticity, co-variation with fuel prices, and high frequency (daily or intraday) jumps. Natural gas spot prices also have mean reversion, seasonalities and heteroscedasticity. Thus, the price dynamics for the natural log of electricity and natural gas prices, dp_{e_t} and dp_{g_t},[4] can be represented by generic equations of the form:[5]

$$\begin{aligned} dp_{e_t} &= \alpha^e[\theta^e(t) - p_{e_t}]dt + v^e(p_{e_t}, t, \ldots)dX_t^e \\ dp_{g_t} &= \alpha^g[\theta^g(t) - p_{g_t}]dt + v^g(p_{g_t}, t, \ldots)dX_t^g \end{aligned}$$

where the local volatility functions, $v^e(p_{e_t}, t, \ldots)$ and $v^g(p_{g_t}, t, \ldots)$, can be constant, deterministically dependent on time t, or deterministically dependent on any other relevant state variables. The Brownian motion increments, dX_t^e and dX_t^g, have historically been highly correlated for electric power and gas.

Most commodity option pricing models assume that the risk neutral dynamics have the same qualitative characteristics as the objective dynamics. The parameters of the risk neutral dynamics are then determined using a mixture of statistical calibration (using time series data from the spot market for natural gas and electricity, such as the Henry Hub natural gas spot prices shown in Figure 4.1) and implied calibration of the volatility parameters from the natural gas and electricity futures and options markets in the monthly block market. The table in Appendix I gives the data used for the electric power and gas derivatives markets and for the term structure of U.S. Treasury securities in April 2008.

In this paper, we model the actual resource costs of natural gas and electricity, not the utility power company regulated pass-through of these resource costs. We focus on two distinct markets in which energy is traded. These markets differ in the “time granularity” of the underlying variables and types of optionality traded and in their market participants.

1. The first market is the relatively liquid over-the-counter (OTC) market for futures and options on monthly blocks (i.e., portfolios) of daily flows of electric power and gas (e.g., 1 MW of electricity each hour for each day over the delivery month or 1 mmBTU of gas each day over the delivery month). Prices are quoted on a 1 megawatt hour (MWH) or 1 mmBTU basis. Some of this trading occurs on exchanges (e.g., NYMX) and some is OTC. We will call this the monthly block market. Since a capability for physical delivery is not necessary in this market, parties without the capacity to handle energy physically can simply close out their positions via offsetting trades to avoid delivery. The future and options markets have the broadest investor participation.

2. The second market is also an OTC market in which same-day blocks of spot electric power (or spot gas in daily blocks) are bought and sold in real-time. In this spot market, trades occur through a decentralized search/negotiation process. Nevertheless, a daily spot price index is publicly reported based on surveys of transactions by electric power broker/dealers. Agents that trade in this market must be able to deliver/receive electrons or gas physically in real time.[6]

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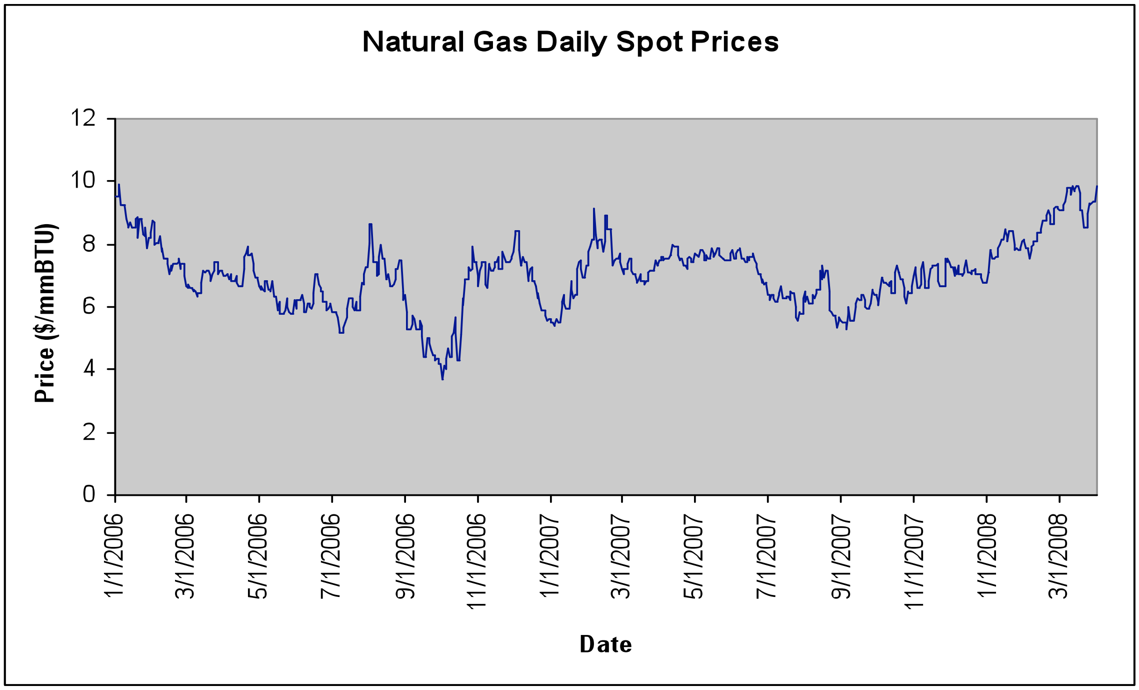
[4] Where $p_{e_t} = lnP_{e_t}$ and $p_{g_t} = lnP_{g_t}$.

[5] For simplicity, in this version of the paper we will ignore Poisson price jumps in both the gas and electricity modeling. In future versions of our simulations we intend to model these Poisson processes as a function of temperature dynamics.

[6] For simplicity in this version of our simulations we are making some significant simplifications about

Figure 4.1: Henry Hub Spot Price



Source: Bloomberg, Henry Hub spot prices

We calibrate our OU processes to the futures and options prices reported in Appendix I for April 2008 and to electricity and Henry Hub spot price dynamics.[7] We use a simple deterministic volatility specifications $v^e(t)$ and $v^g(t)$ and fit an empirical value for α^e of 5.2 for electricity and an α^p of 4.4 for natural gas and an electricity/gas correlation of 0.9 for their respective Brownian motions. We fit the $\theta^e(t)$, $\theta^g(t)$, $v^e(t)$, and $v^g(t)$ to the futures and options data using least squares. We are thus fitting the OU dynamics to the observed term structure of forward prices for electricity and natural gas as of April 1, 2008. We then simulate five years of monthly spot price dynamics using 1000 Monte Carlo simulations. Representative price paths using a fixed correlation structure of 0.9 for our fitted OU energy dynamic processes are reported in Figures 4.2 and 4.3.

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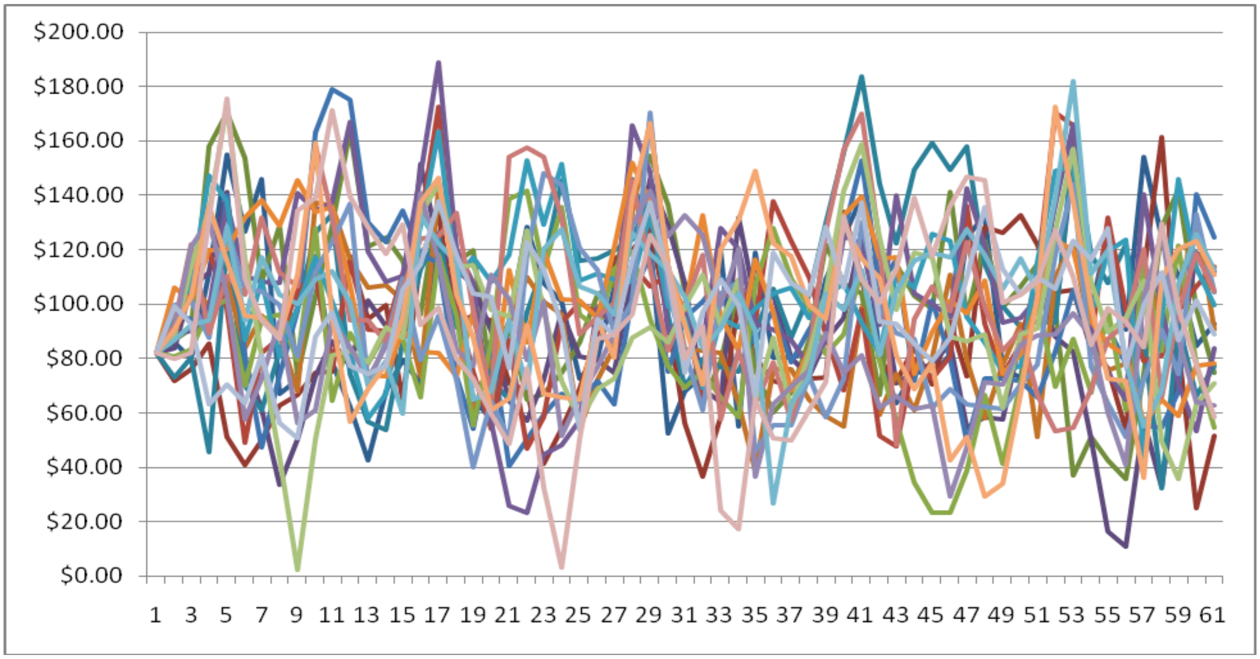
energy markets. First, the spot market actually trades hourly rather than daily blocks of power in real time. Thus, the spot price energy is literally the price of energy over the shortest operational decision intervals: one hour for power and one day for gas. Second, there is one more important market which is ignored in our current simplified simulation strategy. This is an OTC market for one-day ahead forward contracts on one day's worth of power (or gas). For example, on Tuesday an investor can lock in the price for a day-long flow of a 1 MW of electricity (or delivery of 1 mmBTU) on Wednesday. Because physical delivery is required, this market is also limited to parties with contractual or operational control over actual power or gas. There is no term structure information for daily deliveries since there are no daily forwards for maturities longer than one-day ahead.

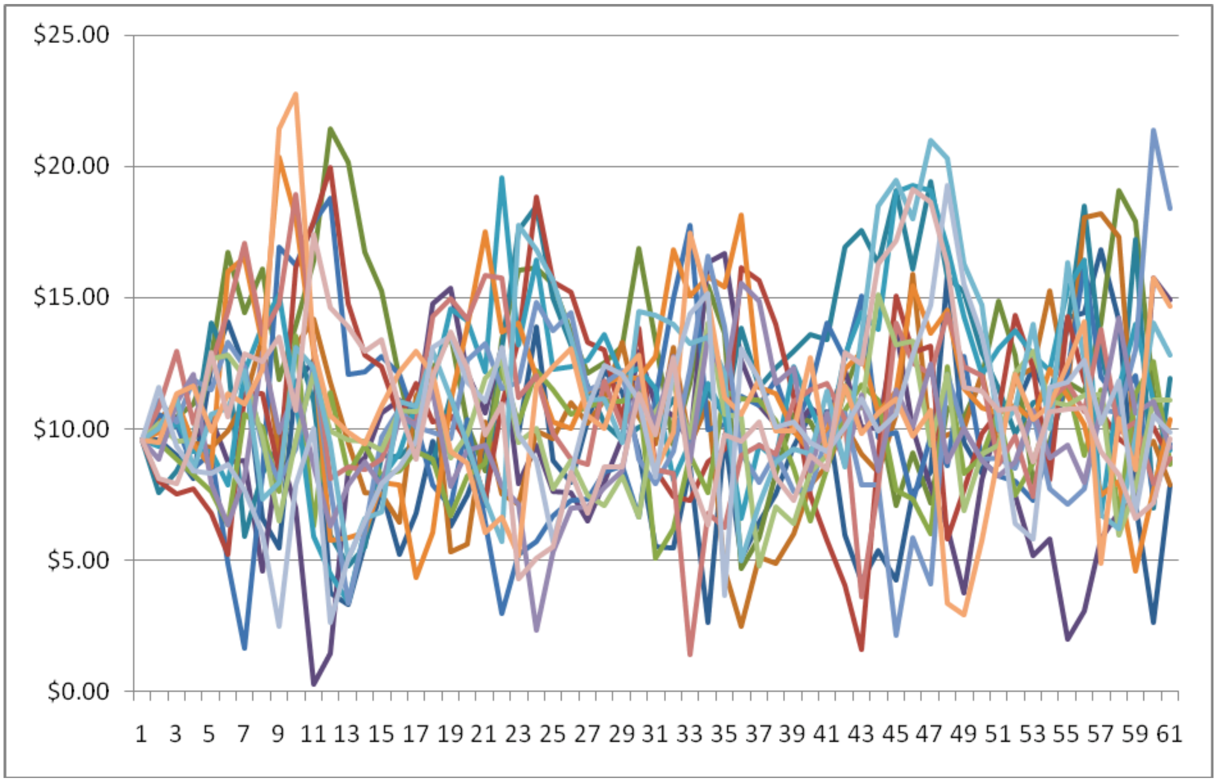
[7] For this version of the paper our electricity spot data are actually from the Electricity Reliability Council of the Mid-Atlantic (ERCMA) because our CALPX data only goes through 2001. We hope to obtain CALPX data to refit the OU for electricity to California derivatives markets.

Figure 4.2: Representative paths for Monthly Electricity Spot Prices (2008-2016)



(Dollars/MWhs/Month) Authors' Simulations

Figure 4.3: Representative paths for Monthly Henry Hub Natural Gas Spot Prices (2008-2016)



(Dollars/mmBTUs/Month) Authors' Simulations

4.2 Simulating the Impact of Stochastic Energy Prices on a Property's NOI

The goal of our simulation exercise is to consider the importance of energy dynamics on the valuation of commercial real estate and the derivative contracts, such as mortgages or bonds, that are collateralized by building cash flows (i.e. the lease portfolio rents). Toward this end, we exploit a variety of information sources to characterize a "representative" central business district commercial real estate office building in California. The information we require includes: transaction prices, capitalization rates, square footage, location, net operating income, market rents, primary tenants, and information concerning the energy usage and cost of energy for similar buildings in California.

Our real estate market data comes from two sources. The transaction data, including tenant and building characteristics, come from Real Analytics. We select a building type and size that corresponds to available information on energy usage and cost using ENERGYIQ, based upon the Commercial Energy Use Survey (CEUS), developed by the Lawrence Berkeley National Laboratory. Our representative building is located in San Diego, it recently transacted, and it has 225,000 rentable square feet and tenants that work in financial services, insurance, administration, and real estate industries (FIRE). The building was built in 1999 again giving it appropriate correspondence with the CEUS performance summaries.

Table 4.1: Representative Building Example

Location	San Diego, CA
Square Footage	225,000
Cap rate at sale	6.97%
Office-tenant	FIRE
Sale price	$127,100,000.00
NOI at sale	$8,858,870.00

We obtained information on class A asking rents for San Diego from Grubb & Ellis, Office Market Trends for quarter 1, 2006 through Quarter 1, 2009. This market information is presented in Table 4.4.

Table 4.2: Class A Asking Rents

Annual	$/Square Feet (full Servicegross)
2006	$35.4
2007	$37.10
2008	$39.3
2009	$35.70

Grubb & Ellis, Office Market Trends

We calculated the energy performance comparables for California commercial office buildings of 150,000 square feet or larger with FIRE tenants, using ENERYIQ. These data summarize the energy performance using information from utility bills for a sample drawn in 2002. The energy consumption breakdown for such buildings is presented in Table 4.3. As shown, the average electricity consumptions per Kilo Watt Hours (KWh) per square foot per year for a building of this size and type is 16.24 for electricity and 16.63 thousand British Thermal Units (KBTU) per square foot per year. Most of the electricity cost is heating and ventilation, lighting, and the operation of office equipment. Most of the natural gas cost is heating.

Table 4.3: 2002 Energy Consumption - EnergyIQ- Commercial Energy Use Survey (CEUS)

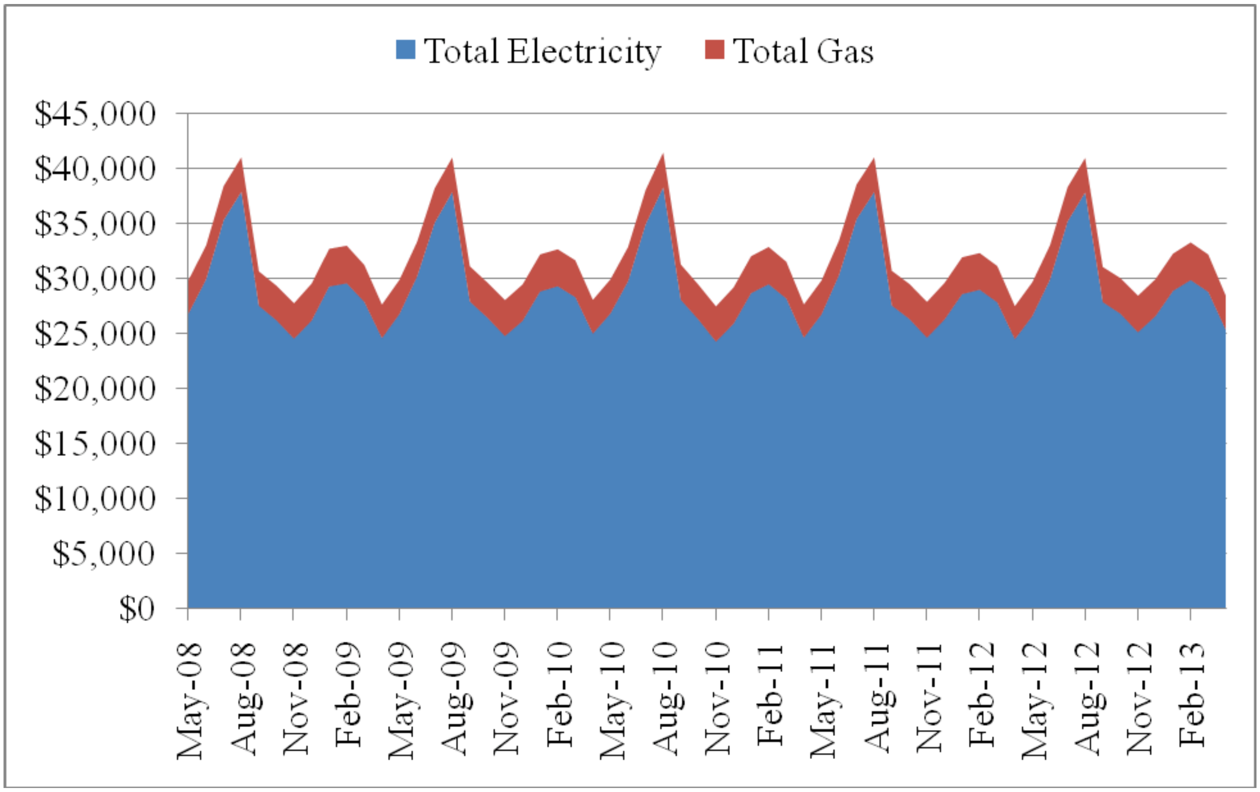
	Electricity Consumption (kWh/sf/yr)	$/ Natural Gas (kBTU/sf-yr)
Year Built Vintage	1991-present	1991-present
Heating	0.36	13.49
Cooling	4.06	
Vent	2.3	
Lighting	4.86	
Drinking & Hot Water	0.13	2.93
Office Equip.	3.40	
Refrigeration	0.19	
Cooking	0.03	0.20
Motors	0.67	
Air Compressors	0.07	
Misc.	0.16	0.01
Total	16.24	16.63

All Buildings with tenancy as Financial, Insurance, and Real Estate activities, as aggregated by EnergyIQ for commercial real estate buildings with 150,000 square feet or more of rentable space. Consumption measured from 2002 energy bills.

We report the results of our Monte Carlo simulations of monthly energy costs for electricity and natural gas for our representative building, using our calibrated OU processes and our assumptions concerning the characteristics of this building in Figures 4.4, 4.5, and 4.6. We make one added assumption that the property was underwritten at the CEUS estimates for the average cost per square foot of electricity use ($1.62) and the average cost per square foot of natural gas use ($.166) for buildings with rentable square footage of greater than 155,000 that were built post 1991. This assumption implies that the observed Net Operating Income is computed using the CEUS estimates of the energy component of operating costs. Interestingly, the annual average cost of energy for the San Diego building is $402,851 using the CEUS/EnergyIQ values for such office buildings and our simulated long run annual average is $384,341 using our market calibrated, correlated OU processes. Thus, our assumption is a conservative representation of the unobserved actual underwriting on the building.

As shown in Figures 4.4, 4.5 and 4.6, there is considerable seasonal variability in both the electricity and the natural gas components of energy consumption in our building. Figure 4.5 presents the overall simulated total energy consumption of the San Diego building from April of 2008 through April of 2013. Given current forward contract pricing (See Appendix I), there is an important summer and winter seasonal to these costs, the summer seasonal exhibits very significant volatility, and the electricity costs dominate.

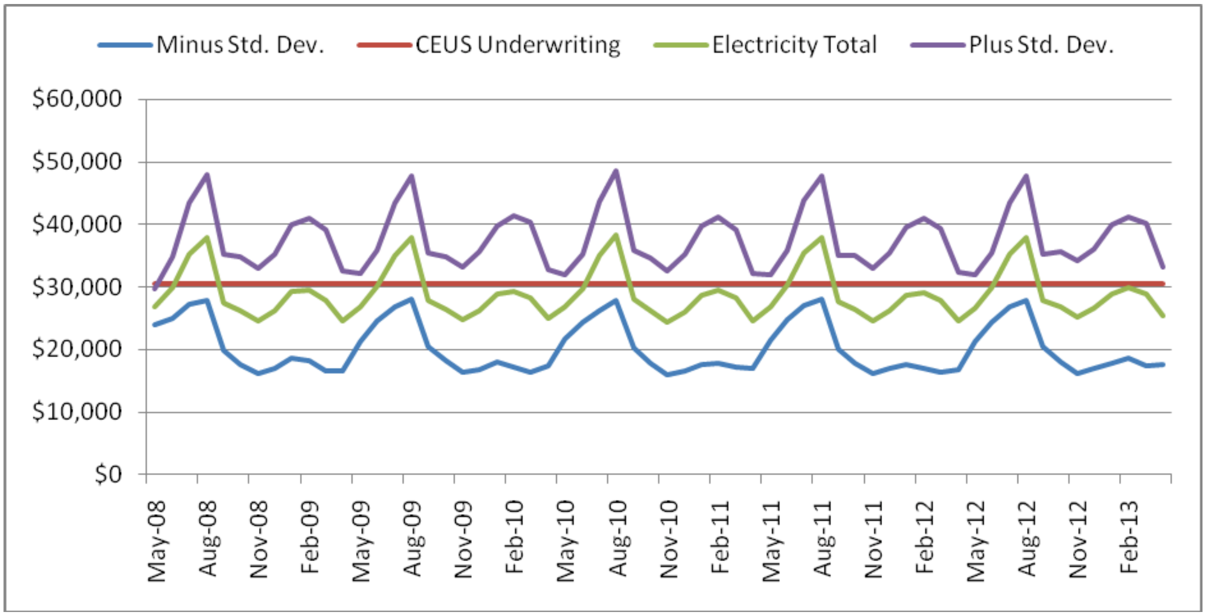
Figure 4.4: Simulated Monthly Total Energy Cost (Sum electricity and natural gas) San Diego FIRE Office.



Aggregate monthly costs in dollars for the 225,000 Square Foot Representative San Diego Building.

In Figures 4.5 and 4.6, we report the results of simulating the electricity and natural gas components of the energy costs and compare these with the CEUS benchmark. In Figure 4.5, we present the mean and the plus and minus one standard deviation simulation results for total costs of electricity per month for the representative San Diego building. As shown, about 17% of the months exhibit energy costs that significantly exceed the assumed CEUS underwriting cost level and all of the one standard deviation values exceed the CEUS electricity cost levels. Clearly, the volatility of the summer electricity cost represents an important source of risk both to building owners and to lenders who ignore energy consumption volatility in their underwriting. It also represents a potentially important opportunity to consider offsetting positions that would hedge this risk such as installing photovoltaic technology that would enable the building owner to sell energy to the grid at high energy demand periods and thus offset their own higher electricity cost periods or buying various types of energy options.

Figure 4.5: Simulated monthly electric power costs ($ electricity price × MWhs used × total square footage per Month), the monthly cost for the 225,000 square foot representative San Diego building.



The CEUS underwriting value is the total monthly cost of electricity assuming that the realized cost is $1.62 per square foot per year for a 225,000 square foot building.

Figure 4.6 presents the simulation results for the natural gas component of the energy consumption for the representative San Diego building. Again, there is an evident seasonal, although the peak to trough dynamics of natural gas is significantly less than that of the of the electricity total cost dynamics for the building. Again, the natural gas cost component exceeds the assumed CEUS natural gas energy cost in nearly all periods, so this assumption appears less conservative for natural gas. A one standard deviation shock to natural gas cost significantly exceeds the CEUS natural gas cost levels.

To better understand, the underwriting implications of the obvious volatility that characterizes these costs, we carry out a simulation where we assume that the San Diego building was underwritten to a Debt Service Coverage ratio (DSCR) of 1.25, based on the CEUS energy cost projections, and the observed net operating income (NOI) of the building at the beginning of 2008. We assume that the lender underwrites the debt service payments based on the 1.25 DSCR and that the building owner pays the energy costs over and above energy costs of the CEUS underwritten values and experiences an augmentation to NOI if energy costs fall below the CEUS underwritten cost of energy.[8]. We then consider the effects

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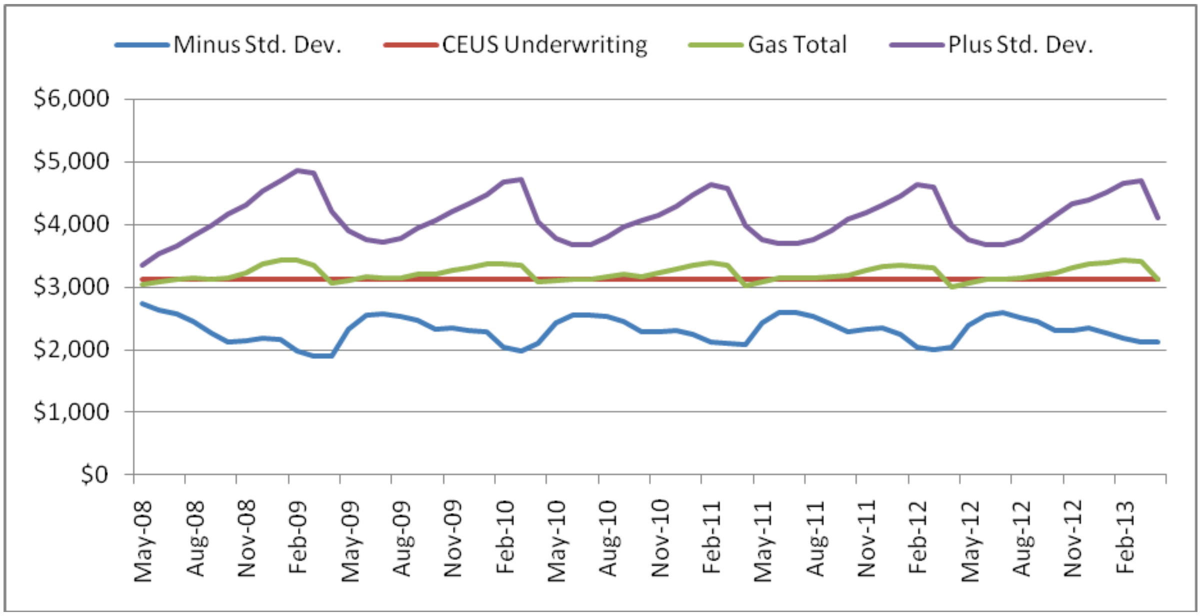
[8] We are thus assuming a gross rent structure in which the leases are structure such that rents to the lessee are set accounting for average energy cost based on CEUS and the lessor/owner pays the realized energy cost

Figure 4.6: Simulated monthly natural gas costs ($ gas price× MBTUs used × total square footage per Month), the monthly cost for the 225,000 square foot representative San Diego building.



The CEUS Underwriting value is the total monthly cost of gas assuming that the realized cost is $.166 per square foot per year for a 225,000 square foot building.

on the mean and standard deviation of the computed DSCR for a one standard deviation shock and a two standard deviation shock to total energy costs. We consider these effects for the monthly underwriting NOI, of $738,239. We then reconsider the same experiment, for the following year, 2009, when rents have fallen to $35.70 per year, or a monthly NOI of $669,375.

As shown, the 2008 DSCR just rounds to 1.25, but with a one standard deviation positive shock the DSCR falls to 1.24 and falls to 1.21 with a two standard deviation shock in energy prices. Thus, possible shocks lead to significantly lower DSCR for the lender that, when combined with lower property values due to the increased costs of energy, increase the likelihood of default on the part of the borrower. The effects of this volatility are exacerbated in 2009 when market rents fall and the NOI falls. The new average DSCR is 1.14 rounded but the one and two standard deviation shocks cause these values to fall to 1.12 and 1.11 respectively (accounting for the standard deviation around the effects of these shocks, the DSCR falls to 1.00.) These negative outcomes are again associated with decreases in the capitalized value of the NOI, which implies a lower market price (particularly because capitalization rates rose to 8.35% in San Diego implying a new lower market price). Both of these outcomes would increase the possibility of default and the need for the lender to account for this risk in higher initial underwriting standards. Again, the obvious benefits of undertaking energy retrofits that could mitigate the high volatility of the seasonal in these costs would clearly be advantageous if fairly priced financing instruments could be designed to finance such investments.

Table 4.4: Simulation results for the Average Debt Service Coverage Ratio for the Mean total energy cost, for a one standard deviation positive shock to total energy cost, and a two standard deviation shock to total energy costs at Q1 2008 and Q1 2009 Class A rents in San Diego

	Mean	One Standard Deviation	Two Standard Deviation
Q1 2008 Rents	1.25	1.24	1.21
Std. Dev.	(.007)	(.008)	(.011)
Q1 2009 Rents	1.14	1.12	1.11
Std. Dev.	(.007)	(.008)	(.011)

Grubb & Ellis, Office Market Trends

We also simulate the price of our representative 225,000 square foot San Diego office building over a five year investment horizon. This simulation is meant to be illustrative of the importance of adding the stochastic dimension of energy costs into a valuation analysis. For our analysis we again assume a gross leasing structure in which the level of gross rent sufficient to achieve the underwritten net operating income of \$8,858,870.00 at the CEUS average energy cost for this type of building given its square footage and use by tenants in financial, insurance, and real estate economic activities. We then simulate the distribution of the realized net operating income of the representative San Diego property assuming that NOI varies by the net realized energy cost relative to the CEUS underwritten energy level.[9] We discount using the term structure reported in Appendix I and we capitalize the month sixty NOI using the observed end of year 2008 cap rate in San Diego of 6.7%. As shown in 4.7, we find under our assumptions that the price of the San Diego building fall below its underwritten price of \$127,100,000.00 more than 10% of the simulated draws. This suggests that there is a more than 10% chance of default on the mortgage loan on the building assuming that the borrower would default on the loan when the loan-to-value ratio exceeds one from below. Obviously, more realism could be added to this simulation, however, given the relative accuracy of our match to the CEUS initial operating cost of the San Diego building, we believe that, as structured, our simulation is indicative of the potential risk to lender's mortgage holdings that may arise from energy cost risk that is not underwritten into the mortgage contract structure.

5 Summary and Conclusion

U.S. buildings consume almost 39% of the total U.S. energy usage, and appear inefficient compared to the available technology and the efficiency of European structures. Government building codes, disclosure requirements, and fiscal subsidies have been the primary

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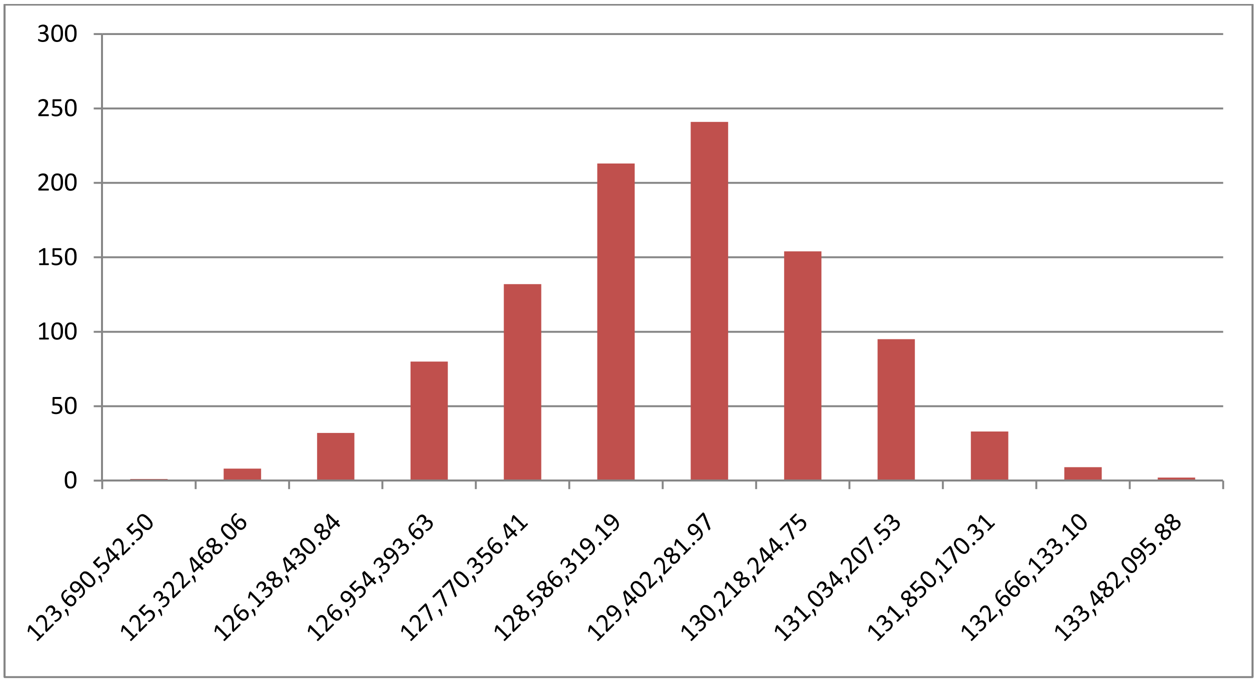
[9] More realism could be added here using stochastic rents that are perhaps correlated with the energy costs

Figure 4.7: Simulated Value of the Representative San Diego Office Building on April 2008 Assuming a Five Year Investment Horizon, CEUS Average Energy Cost for this building to realized Stochastic Electricity and Natural Gas Costs to Compute the Realized Net Operating Income Over the Holding Period.



instruments used to stimulate the adoption of energy-efficient technology in both the U.S. and Europe. While these instruments have achieved important successes, they also have significant limitations.

In this paper, we instead look at market mechanisms to stimulate voluntary private sector energy-efficient investments. We focus on a particular market failure, namely the absence of energy efficiency as an input to the underwriting decision for mortgage loans on commercial properties. In principal, rising and volatile energy prices can be as important a source of mortgage defaults as the standard inputs used in commercial mortgage underwriting.

We argue that the failure of commercial mortgage lenders to take energy-efficiency into account is primarily the result of insufficient information to connect high and volatile energy prices to mortgage default. Current commercial mortgage underwriting uses the loan to value ratio (LTVR) and debt service coverage ratio (DSCR) to account for the macroeconomic and housing market sources of market default. We propose a new energy efficient score (EES) and an energy volatility score (EVS) to account for the impact of energy prices on mortgage default.

We carry out the first step in the development of EES and EVS measures by creating a dynamic model to compute the impact of stochastic energy prices on the net operating income (NOI) of a representative building. We use a Monte Carlo methodology to provide quantitative measures –both expected values and the range of variability–of the resulting changes in NOI. Our preliminary results indicate that energy price volatility is a previously unrecognized and significant source of potential commercial mortgage default.

Appendix I: Assumed Market Conditions April 2008

Monthly Power & Natural Gas Futures and European calls on futures prices

The zero-period futures prices are monthly block prices for delivery in the current month. The underlying for the futures are monthly flows of power and of gas over the delivery month. The underlying for power and gas call options is the futures price where option expiry–future delivery. All of the calls are struck at-the-money-forward. (Source: 2008 Financial Engineering Case Competition. Fillmore Investors LLP, authored by Duane Seppi, Carnegie Mellon University. Data sources are the Electricity Reliability Council of the Mid-Atlantic (ERMCMA) and Bloomberg, Henry Hub spot and futures gas prices.

	Apr. 2008	May 2008	June 2008	July 2008	Aug. 2008	Sept. 2008	Oct. 2008	Nov. 2008	Dec. 2008	Jan. 2009	Feb. 2009	Mar. 2009	April 2009
U.S. Treasury Term Structure													
zero yields		0.0300	0.0320	0.0320	0.0315	0.0320	0.0320	0.0320	0.0330	0.0330	0.0330	0.0330	0.0330
zero prices		$0.9975	$0.9947	$0.9920	$0.9896	$0.9868	$0.9841	$0.9815	$0.9782	$0.9756	$0.9729	$0.9702	$0.9675
Electricity Prices (per MWh)													
futures prices	$82.00	$88.15	$98.35	$116.00	$124.40	$90.50	$86.25	$80.65	$86.05	$96.00	$97.20	$91.75	$80.80
dollar price of European calls		$3.54	$5.89	$9.62	$11.88	$8.95	$10.02	$9.85	$10.65	$12.56	$13.36	$13.18	$9.32
Natural Gas Prices (per mmBTU)													
futures prices	$9.60	$9.79	$9.88	$9.97	$10.03	$10.05	$10.12	$10.40	$10.75	$10.97	$10.95	$10.71	$9.75
dollar price of European calls		$0.39	$0.58	$0.73	$0.89	$1.07	$1.26	$1.33	$1.43	$1.58	$1.73	$1.77	$1.42

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