Monte Carlo Cash Flows and Sustainability: How to Decide on Going Green

Authors Michael Stein, Wolfgang Braun, Marta Salvador Villà, and Volker Binding

Abstract Green, sustainable or energy-efficient buildings apparently outperform other buildings with respect to rental level, value, and/or occupancy rates according to empirical findings. Most studies focus on commonly accepted databases to analyze the value or rent differences from a top-down perspective, that is, investigating value or rent differences between subject and control groups. But the decision-making problem at hand is mainly omitted from detailed discussions. We propose a framework using cash flow simulations in order to mirror the decision-making problem that owners face. By enabling both costs and benefits in different ways as inputs to a simulation model, we set up a large variety of realistic scenarios. We also consider findings and indications from previous decision modeling research. Our approach may be employed at all levels of detail that is needed and assists in economic-based decisions for sustainable investing.

Recent years saw a tremendous increase in market activity and discussions in the area of sustainable real estate, although, for example, DeLisle, Grissom, and Högb erg (2013) note that there still is no consensus on what it actually means. This is in contrast to the needs of an information-based world with fast-moving economies. Transparent and quickly adoptable definitions and standards that were developed in the years before were apparently not removing much of the definitional confusion. Irrespective of definitions, we now have several certification systems detailing green features, designs or systems that might be utilized in a commercial property. But how does one decide how green to be and whether there is a payoff?

In the United States, the ENERGY STAR program of the U.S. Environmental Protection Agency (EPA) and the Leadership in Energy and Environmental Design (LEED) Green Building Rating System of the U.S. Green Building Council (USGBC) have become the accepted standards. The Building Research Establishment Environmental Assessment Method (BREEAM) of BRE Global is widely accepted in the United Kingdom, although other European green building councils operate the method as well. Further examples are Haute Qualité Environnementale (HQE; High Quality Environmental standard) of Association HQE in France, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, the Green Building Assessment System of the
China Green Building Network (CGBN) or the certification system of the German Society for Sustainable Building (DGNB; Deutsche Gesellschaft für Nachhaltiges Bauen). All systems aim at providing a framework that enables the classification of property with respect to “sustainability,” “greenness,” “environmental impact” or similarly termed attributes.

Clearly, the variety of systems and programs brings with itself considerable variation among the approaches, level of investment, and differences about how narrow or wide sustainability is defined. Not only are green or ecological characteristics included in the different systems and programs, accessibility, process quality or even the location enter some certification schemes. Depending on the respective system at hand, decision makers may face very different settings that form what ultimately is labelled sustainable or not.

Despite these issues that have yet to be resolved, considerable effort was spent on estimating whether and how sustainable or green buildings perform better in economic terms, given availability of classified data. Studies for the U.S. are provided by Miller, Spivey, and Florance (2008), Fuerst and McAllister (2009, 2011a, 2011b), Eichholtz, Kok, and Quigley (2010), Pivo and Fischer (2010), Wiley, Benefield, and Johnson (2010), Dastrup, Graff, Costa, and Kahn (2012), Eichholtz, Kok, and Yonder (2012), and Reichardt, Fuerst, Rottke, and Zietz (2012) among others. Brounen and Kok (2010), Fuerst and McAllister (2011c), Kok and Jennen (2012), and Cajias and Piazolo (2013) provide insight on the value and return effects in the European area, while Yoshida and Sugiura (2010) and Deng, Li, and Quigley (2012) study sustainable properties’ performance differences in an Asian context. With minor exceptions, the studies provide initial evidence on economic gains from certification, as can be seen in Exhibit 1 where we list several exemplary studies. Naturally, the studies differ not only with respect to country or sector focus but also in terms of methodology. The results summarized in Exhibit 1 thus provide merely a rough overview in order to have an orientation about the scale of differences in values and/or returns between certified and non-certified groups. An example where effects are indeed disentangled is provided by Chegut, Eichholtz, and Kok (2014), who find that while areas that are rich with green buildings are experiencing a positive impact, the additional supply limits the positive effect for green buildings. Their finding provides deeper insight into the supply-side effects studied in Eichholtz, Kok, and Quigley (2013), who report robust premia for green buildings.

Naturally, the identification of benefits in terms of higher values/rents/returns or reduced vacancy risk and vacancy times for sustainable real estate is of major interest not only to decision makers that aim at profitable business, but to certification providers, councils, governments, and other policymakers as well. Only if the (economic) value added by (certified) sustainability is significant and highly probable, certification methods and schemes will in the long-run be successful and thus may serve as accepted tools that finally help inducing a “sustainable” or at least “green” industry. Moreover, the conceptual differences mentioned above and the differences in what is expected by market participants is crucial, which is discussed by Bügl, Leimgruber, Hüni, and Scholz (2009) and DeLisle, Grissom, and Högb erg (2013), among others. Even if one abstains from
### Exhibit 1 | Findings of Studies on Certification

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimated Variable</th>
<th>Finding</th>
<th>Certification / Characteristic</th>
<th>Location</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miller et al. (2008)</td>
<td>Value</td>
<td>+5.3%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>+9.9%</td>
<td>LEED</td>
<td>U.S.</td>
<td>Office</td>
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<tr>
<td></td>
<td>Occupancy</td>
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<td>Office</td>
</tr>
<tr>
<td></td>
<td>Occupancy</td>
<td>+4.2%</td>
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<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
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<td>Rental Level</td>
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<td>Office</td>
</tr>
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<td>Office</td>
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<tr>
<td>Wiley et al. (2008)</td>
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<td>Office</td>
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<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2009)</td>
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<td>+3%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Occupancy</td>
<td>+8%</td>
<td>LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Brounen and Kak (2010)</td>
<td>Value</td>
<td>+2.8%</td>
<td>Energy Certificates</td>
<td>Netherlands</td>
<td>Residential</td>
</tr>
<tr>
<td>Eichholtz et al. (2010)</td>
<td>Rental Level</td>
<td>+3%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Rental Level</td>
<td>+7%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Pivo and Fischer (2010)</td>
<td>Rental Level</td>
<td>+5.2%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Rental Level</td>
<td>+4.8%</td>
<td>CBD regeneration properties</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Occupancy</td>
<td>+1.3%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Occupancy</td>
<td>+0.2%</td>
<td>LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>+8.5%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>+6.7%</td>
<td>CBD regeneration properties</td>
<td>U.S.</td>
<td>Office</td>
</tr>
</tbody>
</table>
**Exhibit 1** (continued)
Findings of Studies on Certification

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimated Variable</th>
<th>Finding</th>
<th>Certification / Characteristic</th>
<th>Location</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yoshida and Sugiura (2010)</td>
<td>Value</td>
<td>−6% to −11%</td>
<td>Green labeled</td>
<td>Japan</td>
<td>Condos</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Rental Level</td>
<td>+3% to +5%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Value</td>
<td>+9%</td>
<td>ENERGY STAR and LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Value</td>
<td>+18%</td>
<td>ENERGY STAR</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Value</td>
<td>+25%</td>
<td>LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Value</td>
<td>+28% to +29%</td>
<td>ENERGY STAR and LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst and McAllister (2011a)</td>
<td>Occupancy</td>
<td>none</td>
<td>LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Fuerst et al. (2011b)</td>
<td>Rental Level</td>
<td>+4% to +5%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Commercial</td>
</tr>
<tr>
<td>Fuerst et al. (2011b)</td>
<td>Value</td>
<td>+25% to +26%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Commercial</td>
</tr>
<tr>
<td>Dastrup et al. (2012)</td>
<td>Value</td>
<td>+16%</td>
<td>ENERGY STAR or LEED</td>
<td>U.S.</td>
<td>Office</td>
</tr>
<tr>
<td>Dastrup et al. (2012)</td>
<td>Value</td>
<td>+3.5%</td>
<td>Solar Panels</td>
<td>California</td>
<td>Housing</td>
</tr>
<tr>
<td>Deng et al. (2012)</td>
<td>Value</td>
<td>+6% Green Mark</td>
<td>Green Mark</td>
<td>Singapore</td>
<td>Housing</td>
</tr>
<tr>
<td>Deng et al. (2012)</td>
<td>Value</td>
<td>+14% Platinum</td>
<td>Green Mark</td>
<td>Singapore</td>
<td>Housing</td>
</tr>
<tr>
<td>Deng et al. (2012)</td>
<td>Value</td>
<td>+2.3% Gold Plus</td>
<td>Green Mark</td>
<td>Singapore</td>
<td>Housing</td>
</tr>
<tr>
<td>Deng et al. (2012)</td>
<td>Value</td>
<td>+14% Platinum</td>
<td>Green Mark</td>
<td>Singapore</td>
<td>Housing</td>
</tr>
<tr>
<td>Cajias and Piazolo (2013)</td>
<td>Rental Level</td>
<td>+0.76% Euro / sqm</td>
<td>Energy-efficient vs other</td>
<td>Germany</td>
<td>Residential</td>
</tr>
<tr>
<td>Cajias and Piazolo (2013)</td>
<td>Value</td>
<td>+3.15%</td>
<td>Energy-efficient vs other</td>
<td>Germany</td>
<td>Residential</td>
</tr>
</tbody>
</table>

Note: This table provides an overview on some of the most indicative previous regarding the benefits of certification.
narrowing the focus to economic or non-economic considerations, the focus may be differing: Kimmet (2009) discusses the differences between social responsibility and sustainability, finding that the criteria do not always lead to results where both are achieved.

However, apart from those that focus on market participants’ views on sustainability, the studies discussed above aim at resolving the question about the beneficially of “going green” with a top-down or aggregate view on what one on average may expect given the respective certification scheme or classification. While these studies provide answers with respect to the average benefits of certification based on different systems, the inside view, or bottom-up perspective of valuation under consideration of sustainability is a different one. This special area of sustainability and valuation is examined by Lützkendorf and Lorenz (2007, 2011), Lorenz and Lützkendorf (2011), and Warren-Myers (2013), among others. While our approach is merely embedded in the valuation area, we do not approach the topic of valuation standards, but rather focus on the inside view of decision making as it is of paramount importance for investors to make decisions on their own economic surrounding and the structures they face. Thus, we focus on the purely economic considerations for now, with the underlying decision-making problem on whether or not to aim for certification being considered a complex trade-off system: As investors or owners face the problem of choice whether to construct property that can be certified or not, or to retrofit in order to get certification, they need to handle the trade-off between increased construction costs and possibly higher future income. If corporate social responsibility or other non-economic factors for now are excluded, decisions are based on this trade-off. So decision makers would either calculate the needed minimum additional profit from certification and property characteristics (and their aggregated effects) or calculate what the maximum additional cost may be, based on the (expected) value added from characteristics.

Accordingly, depending on the structure each decision maker faces and the information she has about possible benefits, she will have to make her optimal decision. We explain our systematic approach on how this may be accomplished on a detailed basis in the next section. We do so by laying out a concept that serves as a blueprint for calculations needed in the decision-making process. Adding to the literature in the growing field of studies related to sustainable real estate, to the authors’ knowledge this is the first bottom-up and simulation approach that highlights the “green/sustainable decision-making problem,” while a study by Jackson (2009) employs Monte Carlo simulations in a risk and return context based on findings of several studies mentioned above. In the third section, we describe the parameters and indications we use, followed by the result section. We provide an extension in the fifth section, followed by conclusions and a future outlook in the last section.

Real Estate Cash Flow Model for Decision Making

General Model Setup

In general, we use a cash flow model that is based on several inputs for which stochastic processes are defined, and where the random outcomes define the
resulting cash flows. With our simulation approach, we are in line with many studies that apply Monte Carlo methods for cash flows in the real estate area (e.g., Pyhrr, 1973; Atherton, French, and Gabrielli, 2008; and Loizou and French, 2012), which mainly focus on risks. The application of Monte Carlo methods both in static and dynamic approaches is discussed by Pfnür and Armonat (2013). They employ stochastic processes, where the focus is on operational flows in a risk environment. They argue that the findings of Pfnür and Armonat (2004) and Farragher and Savage (2008) identify that the majority of Monte Carlo approaches in real estate valuation are static and reflect linear trends. Pfnür and Armonat (2013) provide a detailed overview on previous applications of simulations in the real estate domain and find that most of the applications center on modeling income, credit default probabilities, and capital costs. In our approach, we aim at a full-scale model where all elements that are causal to cash flows are modeled on simulated basis.

We employ an example building consisting of \( N \) identical rental units for which the most relevant drivers of cash flows are modeled. In our model, we enable a discounted cash flow model for valuation and define the property value \( V_t \) at each point over time \( t \) as follows: \( V_t = \sum CF_{t+\tau} / (1 + r_{t+\tau})^{t+\tau} \) with \( CF_{t+\tau} \) being the cash flow in future period \( t + \tau \). Summing up all discounted cash flows for future periods \( \tau = 1, ... \) therefore results in the current value of the property.

The cash flow of the building in each period \( t \) is the result of both the amount of rental units with an existing lease contract \( 0 \leq n_t \leq N \) and the level of the rent \( R_t \). The rental level is determined by an exemplary rental index that is inflation-adjusted. Notably, this is a simplification where the assumption is that on average the rental level increases along with general inflation, which could be replaced with rental level projections, cyclical methods or applicants’ views. Evolving inflation over time is modeled as a geometric Brownian motion:

\[
I_t = I_0 \cdot e^{X_t}, \quad \text{with} \quad dX_t = \left( a - \frac{1}{2} b^2 \right) dt + b \cdot dW_t.
\]

\( W_t \) is a Wiener process with \( a = 0.0194 \) and \( b = 0.01 \). This specification is a special case of the model by Jarrow and Yildirim (2003), with the parameters set according to typical long-term German inflation rate behavior.

As the focus of our study is on the certification in a decision-making process, we model the interest rate curve with a reasonable example value and apply a constant rate of 4%. Having a very general example necessitates that we model the building in the pre-letting phase, and therefore assume that there are no contracts existing at the valuation start, i.e., \( n_t = 0 \) for \( t = 1 \).

With no loss of generality, the simple modeling of the interest rate curve or the rental level may be replaced with more complex systems. This however is not
needed for our task at the moment as we want to isolate the certification decision problem most clearly.

In our simple case, we assume that there are 10 identical rental units of 1,000 square meters each. In line with the assumptions for the rental increase, we assume that the total costs $TC_t$ (where we do not focus on allocable or non-allocable costs) rise in parallel with the inflation rate. From the income and cost side explained above, we arrive at the final definition for the cash flow in each period $t$:

$$CF_t(R_t, AC_t, NAC_t, N, n_t) = R_t \cdot n_t - TC_t.$$

While this definition is more or less clear-cut given the modeling with inflation indexing, we also need a proper setup for the vacancy or occupancy status, as in each period the number $n_t$ of occupied rental units must be known. In accordance with many other applications that employ stochastic waiting times in economic settings, we use an exponential distribution to model the vacancy duration. The parameter $\lambda$ parameterizes the exponential distribution for a random variable $x$ that is defined as the time that has to pass until the first realization of a certain outcome is observed. The following density function is denoting the exponential distribution:

$$f_\lambda(x) = \begin{cases} 
    \lambda e^{-\lambda x} & x \geq 0 \\
    0 & x < 0 
\end{cases}$$

Accordingly, the random variable $x$ has a mean of $1/\lambda$ and a variance of $1/\lambda^2$.

Following the definition of the vacancy duration, we have defined all necessary equations to model the cash flow process in a simple stochastic way. This means that we can now set the remaining parameters and make assumptions for simulations in the basis scenario: (1) time intervals are defined on monthly frequency; (2) initial contracts and all possible rental extensions are based on five year contracts; (3) a probability of 50% for a rental start or extension after contract expiry is assigned; and (4) when extensions are not immediately reached, the average vacancy duration is six months ($\lambda = 1/6$).

Notably, one may define all sorts of different parameters and assumptions, depending on the respective economic surrounding of the property under consideration. For example, one might set the vacancy rate or the inflation rate as constant over time, define sinusoids, or even model future rental growth with specific models. In addition, the amount and sizes of differing rental units, contracts, special characteristic cost, and other parameters may enter the calculation whenever needed. Complexity in this setup accordingly is only the result of the model assumptions and the respective property and market structures, so the needed flexibility regarding a realistic decision-making process may be transparently accomplished.
Given the parameterization, the calculation of cash flows and therefore values is done by using Monte Carlo simulations for all stochastic elements. A large set of simulations needs to be done in order to capture a reasonable number of different paths over time, where we use monthly calculations. In our setup, we simulate with 50,000 random paths. Exhibit 2 depicts how economic influences like the inflation rate factor into the calculations and how the distribution of cash flows emerges. Of course the distribution type in the graphic is just exemplary, and in the simulations depends on the specific stochastic processes that were defined.

**Examples and Parameter Variations**

Using the specification of the model from above, we report the example calculations in this section. We report both the statistics of simulated outcomes of the baseline specification and variations to the parameters.

We consider it straightforward to adjust the model parameters in order to see whether the model is responsive to changes and how sensitive it behaves. This necessitates a grid for combinations of parameter variations. Simulations with 50,000 Monte Carlo paths for each combination scenario to obtain the respective cash flows over time were done using the following parameter ranges: (1) contract lengths between three and fifteen years in three-year steps are used: 3-6-9-12-15; (2) probabilities for a rental start or extension after contract expiry are used in 20%-steps between 0% and 100%: 0-20-40-60-80-100; (3) average vacancy is varied between one and twelve months in steps of about three months: 1-3-6-9-12; and (4) rental level of 24.5 ¤/sqm (a reasonable example value for a Frankfurt/Germany office building) is increased up to approximately 15% (3.67 ¤/sqm) above that level in the following steps: 0-0.75-1.5-2.25-3-3.75.

For the cost level at the beginning, a market-conform value of 8.5 ¤/sqm is used. Above combinations lead to 900 scenarios for the grid. By defining the grid, one can see various combinations of outcomes that can be put in relation to empirical findings regarding the effect of certification. We need to take into account here that due to the general model setup, we do not set vacancy or occupancy rates directly; they are a result of the parameters of the rental structure. Thus, one calculates the vacancy rate as an average over time and over simulations. Exhibit 3 presents 10 examples from the 900 scenario grid and Exhibit 4 depicts the change in the average vacancy rate compared to the base scenario and the change in the rental level compared to the base scenario, along with their influence on the property value.

Of course, the approach to use all combinations of parameters yields scenarios that one would consider more likely, as well as others that one would consider less likely. It is still straightforward to consider all scenarios however, in order to capture the full range of possible outcomes.

From Exhibits 3 and 4, one can see, for example, that a reduction in the average vacancy rate of 2% and an accompanying increase in the rental level of 2% would lead to an increase in property values of about 5%. This is one of the points where the interpolated result surface indicates a 5% value increase against the shaded
Exhibit 2 | The Monte Carlo Setup for Cash Flow Generation

- Large number of possible future evolutions
- Consistent scenarios

Simulation of driving economic variables

Cash-Flow-Model

discounting + risk adjustment


### Exhibit 3 | Examples from 900 Scenarios of the Grid

<table>
<thead>
<tr>
<th>Rental Level (€)</th>
<th>Extension Probability</th>
<th>Average Vacancy Rate</th>
<th>Contract Length</th>
<th>Resulting Value</th>
<th>Std. Dev. of Resulting Value</th>
<th>Average Vacancy Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.5</td>
<td>0.5</td>
<td>0.1667</td>
<td>5</td>
<td>67.2925</td>
<td>2.8839</td>
<td>0.0538</td>
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<tr>
<td>26</td>
<td>0</td>
<td>0.0833</td>
<td>3</td>
<td>72.8199</td>
<td>2.8172</td>
<td>0.0425</td>
</tr>
<tr>
<td>28.25</td>
<td>0.4</td>
<td>0.0833</td>
<td>9</td>
<td>83.6918</td>
<td>3.0112</td>
<td>0.0103</td>
</tr>
<tr>
<td>24.5</td>
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<td>73.3101</td>
<td>2.9802</td>
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<tr>
<td>27.5</td>
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<td>1.0</td>
<td>9</td>
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<td>3.1196</td>
<td>0.0517</td>
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<tr>
<td>26</td>
<td>0.8</td>
<td>1.0</td>
<td>15</td>
<td>76.2883</td>
<td>3.0894</td>
<td>0.0139</td>
</tr>
<tr>
<td>26.75</td>
<td>0.2</td>
<td>0.75</td>
<td>3</td>
<td>58.8596</td>
<td>2.7397</td>
<td>0.1806</td>
</tr>
<tr>
<td>27.5</td>
<td>0.4</td>
<td>0.5</td>
<td>12</td>
<td>79.1485</td>
<td>3.0408</td>
<td>0.0325</td>
</tr>
</tbody>
</table>

*Note: This table shows the base scenario and some examples from the 900 scenarios that were used.*

surface indicating the baseline scenario. All results appear to be reasonable on economic grounds, given the respective input’s difference to the baseline. Furthermore, while exact judgment on the correctness of magnitudes of the changes is difficult, the changes are sub-additive. This is good news regarding the plausibility of the chosen approach of Monte Carlo simulations for each component of the model.

How the prevailing structure for each building factor into the resulting surface of changes in values depends on the parameterization itself of course, and accordingly enables full flexibility. In the next step, decision making is simulated in light of the benefits and costs of “going green,” with indications as to what can be expected.

### Investing in Sustainability? Available Benefit and Cost Indications

#### Indications for Certification Benefits

As mentioned in the introductory section, there has been increased activity regarding the estimation of economic benefits of certification. To have an orientation of possible ranges of outcomes, we reviewed the findings in the related studies. An overview on some of the most important results of the recent past is reported in Exhibit 1. Most studies focus on property in databases where they are classified on being certified by ENERGY STAR or LEED. Office is the most actively researched sector followed by housing, which is understandable based on data availability and market size.
The graphs show the interplay of the percentage vacancy rate change (as a result of the three parameters contract length, continuation probability, and average vacancy duration), the rental level change, and the change in property value against the base scenario. The surface is interpolated with the dots representing the 900 scenario outcomes. The two-dimensional plots show the same result surface, but from the respective side view.
Naturally, results differ in magnitude, but apart from the exception of the Yoshida and Sugiura (2010) analysis, all studies find (mostly significant) positive effects from certification. Researchers analyzed rental levels and values, as well as occupancy rates. Incorporating these effects in a general granular setup is easy, as the rental level may be used directly and the occupancy rate as the opposite of the vacancy rate is indirectly obtained (the vacancy rate in our model is determined by the interplay of extension probability, contract length, and vacancy duration as described above).

In the description of the Monte Carlo model we already mentioned that the complexity of the general model depends only on the details the decision makers may want to focus on. This holds true not only for the very structure, but for the inclusion of certification effects as well.

As reduced pollution and energy-efficiency are crucial for receiving certification, one may want to consider the savings from reduced energy consumption. Thus, there are benefits from reduced costs that add to the positive side of certification effects. According to Miller, Spivey, and Florance (2008), operating expenses from energy costs are lowered by about 30% ($1.27/sf per year vs. $1.81) for ENERGY STAR-rated buildings compared to others. For the general model this means that we might include these effects in the total effects from certification or by adjusting the cost equation. We expect that gains from lower costs on energy translate into higher demandable rents, so it reasonable to do the former and continue with our general model specification.

**Indications for Certification Costs**

Having a considerably good basis for possible economic benefits, we now focus on costs. Evidence on costs arising for certification is scarce and is due to several problems arising when aiming at defining viable ranges for costs. One crucial problem is that certificates are handed out by the respective authorities based on considerably differing criteria or frameworks. In addition, within the different programs, there are always degrees of certification. For example, different degrees of fulfillment in one area may be binding, while other criteria are less crucial. Thus, judging on what characteristics or structures candidate buildings need to have is by no means easy and depends both on the respective certificate’s requirements and the structure of a (planned) building.

In addition, not only do requirements and the different levels and thresholds that may be applicable harden the task of defining cost ranges, the costs themselves are highly heterogeneous among buildings, countries, markets, and construction companies. Deciding to have everything set up in order to get the desired (level of) certification may result in numerous different cost projections or offers. Miller, Spivey, and Florance (2008) note that most available surveys on the costs for going green are from the USGBC and caution against potential downward bias. In addition, they state: “Developers point out the direct cost of certification and the high indirect costs of dealing with inflexible, uninformed, and uncooperative local building code regulators or the lack of local experts and resources. Clearly the costs of going green vary by local market, the number of vendors and
experience in the local market, developer/owner experience, and project or portfolio scale.”

The above citation points in the same direction as our perception of a highly unclear cost side when it comes to certificates in the green or sustainable area. Despite the problems regarding cost indications however, we aim at finding a range that might be used in the simulations or to use as a comparative counterpart for calculated benefits.

Additional building/construction costs are different from certificate to certificate and between levels as the programs naturally demand different characteristics. Miller, Spivey, and Florance (2008) discuss the results of a 2007 study by Greg Kats of Capital E Analytics [Kats (2003) in the following], where direct LEED certification costs are reported as follows: 0.6% (Certified), 1.9% (Silver), 2.2% (Gold), and 6.8% (Platinum). They argue that this is roughly in line with numbers from the USGBC and show that there is variation across regions as well. Apparently, the estimated ranges for costs for Silver are 1.0%–3.7%, for Gold they are 2.7%–6.3%, and a platinum certificate would increase construction costs by 7.8%–10.3%. Interestingly, they report that developer surveys indicate a 3% base cost for minimum certification, which increases the USGBC numbers somewhat.

Fuerst and McAllister (2011b) by citing Kats (2003), Hershfield (2005), and Berry (2007) conclude that green construction cost premia are around 2% on average only, which would be in line with the 3% reported by developers according to Miller, Spivey, and Florance (2008). Like the latter, Fuerst and McAllister (2011b) report results of market participants’ studies too, with reference to Davis Langdon, a global construction consultancy. Langdon (2009) finds interesting evidence of no significant difference in the construction costs of green and non-green commercial buildings in New York City. One noteworthy point is that if the construction costs depend strongly on relatively new technology, then the costs may be expected to decrease over time. This would imply that there is an added value from the option to wait. We do not consider this case of expectation building in the following, but it would be easily added to the setup by setting the calculation point to a future period, then with the lower construction costs being relevant.

With regards to maintenance costs, the picture is even less clear cut: While Yoshida and Sugiura (2010) attribute part of the found discount at which energy-efficient condos are valued to the risk of increased maintenance costs of cost-saving technology, Kats (2003) takes the notion that green buildings in general should have lower maintenance costs.

**Decision Making Implications**

Having defined reasonable spans of parameter variations and having discussed additional benefits and costs from certification based on the literature, we can get a grasp on the decision-making problem. For example, when expecting higher construction costs of 7.8%–10.3%, we may use the surface obtained from the grid
simulations to identify what is needed to at least offset the additional costs. Put another way, one can identify combinations of changes on rental level and vacancy rate that lead to expected cash flows of the property whose present values are at least as high as the additional costs.

With respect to the spans used for simulations, we can back-out those scenarios for which the expected gains are at least offsetting the additional costs from investing in sustainability. Exhibit 5 presents the overview for the four inputs used (i.e., contract length, probability of continuation, average vacancy duration, and initial rental level). It is possible to see the variations that were included in the various scenarios and whether that scenario was one that resulted in a higher present value of at least 7.8%. From this it is possible to see what fraction of scenarios with a single fixed parameter value led to an increase in property value of the needed magnitude.

So the decision-making process can be done by facilitating either a change analysis, as in Exhibit 4 where the most crucial effects of rent, vacancy, and value are related to each other, or a parameter analysis like in Exhibit 5. The respective probabilities for likely scenarios and parameters thereby are at the discretion of the decision maker applying the approach.

**Extending the Model: Developments and Partial Rental Losses**

While the focus so far has been on the decision of whether to develop a sustainable building in the first step and to calculate possible paths that follow, we need to focus on an aspect that has strong relevance for decision makers in practice, namely the decision on developments of standing assets. If buildings are candidates for refurbishments and retrofitting, decision makers need to explicitly model the loss of rental income if parts of the buildings are uninhabitable during the process. In the framework proposed above, we can easily introduce modifications that take into account a reasonable span of development times during which rental income is reduced in full or partially.

Exhibit 6 depicts the effect of development times (measured in months) on the present value for the base scenario and for possible more beneficial scenarios after going green (i.e., higher rental level, higher probability of continuation or a lower vacancy duration). Naturally, for the base scenario with development time, the line is always below the base scenario without development time. As for the analysis before, it depends on the economic benefits of sustainability as to whether this outweighs the costs that have to be incurred. For the sake of brevity, we do not plot the combinations of benefits and we do not calculate the construction costs in this example. As the construction costs are due more or less at the beginning of the decision making problem, one can simply add those to the needed benefit of the project, and one might use the reported 7.8% from above. In the simulation results shown here, we assumed that all rental income is lost for the respective development time spans. Separate calculations revealed that when only partial rental losses are incurred due to only partially uninhabitable buildings, those
Exhibit 5 | Four Model Parameters and Their Effects in Simulation Outcomes

The graphs show the interplay of the respective parameters and the change in value of the exemplary building compared to the base scenario. Outcomes that are at or above 7.8% value change are indicated by > arrows and outcomes that fail to produce an increase of at least 7.8% are indicated by < arrows.
Exhibit 6 | Development Times and Their Effects

The graphs show the interplay of the development time where all rental income is lost and the present value against the base scenario without development time.
results are fairly linear to the full loss model. Notably, when assuming construction costs of 7.8%, not much of the benefit-adjusted curves would be resulting in an economic gain, so only strong rental income increases or combinations of benefits would lift the projection over the break-even line. For example, an increase of about 6% in the demandable rent only leads to the demanded increase in the current value when coupled with a reduced average vacancy (3 to 6 months) or increase in continuation probability (50%–80%). Then, the current value increases by 7.62% and 8.69% respectively, when for example six months of rental loss is assumed.

### Conclusion

We approach the decision making problem in the area of sustainability or going green by using a cash flow model that may be employed based on each decision maker’s property and its structure. Defining a reasonably large parameter span served us well when it comes to defining scenarios for Monte Carlo cash flow modeling and evaluation of how probable certain outcomes are. Naturally, the parameter span should reflect both property-specific parameter possibilities and empirically found indications.

It is of utmost importance to specify the components of cash flows directly, and compose the resulting projections using the simulations from the processes. Only a detailed modeling in this way enables decision making based on the respective characteristics of property and the related economic surrounding. While we have abstained from coupling processes and thus have assumed all outcomes from the grid to be equally probable, scenario analysis and stress testing may be easily facilitated when imposing dependence structures on the stochastic processes.

The outcomes of the modeling can be put in direct relation to empirical findings and market information to assess the probability of a possibly benefiting effort to go green/sustainable. With the detail degree of the approach being in the hands of the decision maker, we consider the proposed model useful in bottom-up decision making what is analyzed in detail by academics and practitioners. Therefore, the cash flow based analysis is adding to the field of sustainability research by being the natural counterpart to top-down analyses that are needed to derive indications on possible average costs and benefits when deciding on whether or not to go green.

### References


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