

**A FRAMEWORK FOR INTEGRATING VALUE AND  
UNCERTAINTY IN THE SUSTAINABLE OPTIONS ANALYSIS  
IN REAL ESTATE INVESTMENT**

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## **ABSTRACT**

Real estate professionals, such as investors, owner-occupants, and lenders who are involved in the investment decision-making process are increasingly interested in sustainability and energy efficiency investment. However, current tools and techniques, both technical and financial, typically used for assessing sustainability on their own are unable to provide comprehensive and reliable financial information required for making high-quality investment decisions. Sustainability investment often includes non-cost benefits, value implications, as well as substantial risk and uncertainty that current methods do not simultaneously incorporate in their assessment process.

Through a combined quantitative and qualitative approach, this research creates a new systematic assessment process to consider both cost and non-cost savings and therefore the true financial performance of a set of sustainable options in the context of value and risk, while explicitly deriving and including various uncertainties inherent in the process. The framework integrates assessment tools of technical decision-makers with those of investment decision-makers into a single platform to improve the quality of financial performance projections, and therefore, investment decisions concerning sustainable options in real estate.

A case study is then conducted to test and demonstrate the numeric application of the proposed framework in the context of a non-green office building. The case study presents how to connect the technical outcomes to financial inputs, present the information, and estimate the true financial performance of a green retrofit option, where incremental value and uncertainty have been modeled and included. Three levels of financial analysis are performed to estimate the distribution of financial outcomes including: 1) Cost-based level-1: only energy related costs savings were considered; 2) Cost-based level-2: the non-energy cost savings, including health and productivity, were also considered; and 3) Value-based level: the value implications of the green retrofit option were considered in addition to items in level 2. As a result of applying the proposed framework when evaluating sustainability investment options, many investment opportunities that were otherwise ignored may be realized, and therefore, the breadth and depth of sustainability investment in real estate will increase.

## DEDICATIONS

*I dedicate this dissertation to my wonderful family; particularly to my special wife, Pardis, for her understanding, patience, and full support. Her true love, encouragement, and confidence in my ability to success have taken the load off my shoulder during challenging times and I feel extremely fortunate to have her by my side. A special feel of gratitude to my parents: to my father who has always been my role-model for personal sacrifices, persistence, and hard work, and who instilled in me the inspiration to set high goals and the confidence to achieve them; to my loving mother for her true faith, continuous emotional support, prayers, and encouragement not only during my doctoral studies but my entire life; to my brother who has always generously dedicated his time for helping me to meet my objectives, and to my sister for her kindness and support. Without all of you, I would not have been able to get where I am now.*

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All photos in this dissertation are taken the author.



## **TABLE OF CONTENTS**

TABLE OF CONTENTS .....	v
LIST of FIGURES .....	xii
LIST OF TABLES.....	xv
LIST OF EQUATIONS.....	xvii
<b>CHAPTER 1 INTRODUCTION.....</b>	<b>1</b>
<b>1.1 Background .....</b>	<b>1</b>
1.1.1 Sustainable Property Investment.....	1
1.1.2 New Responsibilities of Design Professionals Regarding Sustainable Properties.....	4
1.1.3 Sustainable Development and Buildings .....	6
1.1.3.1 Costs, Benefits, Risks, and Uncertainties of Sustainable Property Investment .....	7
<b>1.2 Problem Statement.....</b>	<b>9</b>
1.2.1 Existing Sustainability Assessment Methods.....	9
1.2.1.1 Green Building Certifications .....	9
1.2.1.2 Building Simulation Programs (BSPs).....	10
1.2.1.3 Simple Financial Methods .....	10
1.2.1.4 Building Performance-Based Methods .....	11
1.2.2 Gap Analysis.....	12
<b>1.3 Scope of Research .....</b>	<b>13</b>
1.3.1 Goal of Research.....	13
1.3.2 Research Approach .....	13
1.3.3 Methodology .....	14
<b>1.4 Contribution and Expected Benefits of the Framework .....</b>	<b>15</b>
<b>1.5 Limitation of Research .....</b>	<b>16</b>
<b>CHAPTER 2 LITERATURE REVIEW.....</b>	<b>18</b>
<b>2.1 Sustainable Property Investment .....</b>	<b>18</b>
2.1.1 Definitions.....	18
2.1.1.1 Sustainable Development and Property .....	18
2.1.1.2 Socially Responsible Property Investment Approach.....	21

2.1.2	Sustainable Property Investment Trend .....	23
2.1.2.1	Existing Property Improvement Investment and Green Retrofits .....	24
2.1.3	Cost, Benefits and Risks of Sustainable Property Investment .....	24
2.1.3.1	Sustainable Property Investment Risks .....	29
<b>2.2</b>	<b>Sustainable Property Performance and Systems .....</b>	<b>30</b>
2.2.1	Building Performance .....	30
2.2.1.1	Building Performance from the Perspective of Design Professionals: The American Institute of Architects (AIA) .....	30
2.2.1.2	Building Performance from the Perspective of Property Professionals: Green Building Finance Consortium (GBFC) .....	32
2.2.2	Existing Tools Used for Sustainable Property Evaluation .....	34
2.2.2.1	Building Simulation Program .....	34
2.2.2.2	Sustainable Certifications and Green Building/Energy Rating Systems .....	35
2.2.2.3	Building Performance-Based Techniques .....	36
2.2.2.3.1	Life Cycle Cost Analysis (LCCA) .....	37
2.2.2.3.2	Life Cycle Assessment (LCA) .....	38
2.2.2.3.3	Value Engineering (VE) .....	39
2.2.3	Comments on Financial Analysis of Sustainable Property Performance .....	41
2.2.3.1	Notes on Evaluating Health and Productivity .....	42
2.2.4	Energy Efficiency Investment .....	44
2.2.4.1	Financial Performance of Energy Efficiency Investment .....	45
2.2.4.2	Energy Performance Forecast .....	47
2.2.4.2.1	Evidence on Inaccuracy/Error of Energy Models Forecasts .....	47
2.2.4.3	Energy Simulation for Retrofit Investments Analysis .....	48
2.2.4.3.1	Energy Model Calibration Process .....	49
2.2.4.3.1.1	Calibration Methodologies .....	51
2.2.4.3.2	eQUEST .....	52
<b>2.3</b>	<b>Risk and Uncertainty in Property Valuation .....</b>	<b>53</b>
2.3.1	Property Valuation .....	53
2.3.1.1	Cost Approach .....	54
2.3.1.2	Sales Comparison Approach .....	54
2.3.1.3	Income Capitalization Approach .....	54
2.3.1.3.1	Discounted Cash flow (DCF) Model .....	55
2.3.1.3.1.1	Capitalization Rate and Discount Rate – Accounting for Risk in Valuation .....	56

2.3.2	Risk and Uncertainty.....	57
2.3.2.1	Risk Analysis Methods – Statistical Approaches.....	59
2.3.2.1.1	Sensitivity Analysis.....	60
2.3.2.1.2	Scenario Building.....	60
2.3.2.1.3	Program Evaluation and Review Technique (PERT) .....	61
2.3.3	Value at Risk (VaR) and Probability Distribution .....	61
2.3.4	Risk and Uncertainty in Valuation Process.....	63
2.3.4.1	Reporting Uncertainty in Property Valuation .....	64
2.3.4.2	Monte Carlo Simulation in Property Valuation .....	66
<b>2.4</b>	<b>Sustainable Property Valuation/Financial Analysis .....</b>	<b>68</b>
2.4.1	Sustainable Property Valuation approaches.....	68
2.4.2	Existing Financial Tools for Evaluating Sustainable Property .....	70
2.4.3	Existing Research on Financial Performance of Sustainable Property .....	71
2.4.3.1	“Case-Based” Studies .....	71
2.4.3.2	“Causal-Comparative” Studies .....	73
2.4.3.3	“Fundamentals of Sustainable Property Valuation” Studies.....	75
2.4.3.3.1	The Green Building Finance Consortium (GBFC).....	78
2.4.3.3.2	GBFC Principles for the Application of Existing Research.....	79
2.4.4	Deriving the Financial Performance of Sustainable Property .....	81
2.4.4.1	Sustainable Options-Based Valuation.....	81
2.4.4.2	Determining the Financial Performance of a Property in the Real Estate Industry .....	81
2.4.4.3	GBFC Sustainable Property Performance Framework .....	82
<b>2.5</b>	<b>Summary.....</b>	<b>83</b>
<b>CHAPTER 3</b>	<b>RESEARCH METHODOLOGY .....</b>	<b>86</b>
<b>3.1</b>	<b>Overview of Problem and Objectives.....</b>	<b>87</b>
3.1.1	Research Target Audience .....	89
3.1.2	Specific investment context.....	90
<b>3.2</b>	<b>Mapping the Assessment Process .....</b>	<b>91</b>
3.2.1	Approach.....	91
3.2.2	The Process and Components .....	93
3.2.3	The Process Steps, Methods and Considerations.....	94
3.2.3.1	Step 1: Simulation Modeling .....	95

3.2.3.2	Step 2: Whole-Building Performance Forecast.....	96
3.2.3.3	Step 3: Financial Modeling.....	97
3.2.3.3.1	Market Analysis.....	100
3.2.3.4	Step 4: Uncertainties Associated with the Process.....	101
3.2.4	Final Statement for the Decision-makers.....	104
<b>3.3</b>	<b>Case study.....</b>	<b>106</b>
3.3.1	Overview of Case Studies Method.....	106
3.3.1.1	Selecting a Single Instrumental/Evaluative/Exploratory Case Study.....	107
3.3.2	Methods and Procedure in the Case Study.....	110
3.3.2.1	Contingent Valuation Method.....	113
<b>3.4</b>	<b>Summary.....</b>	<b>115</b>
<b>CHAPTER 4</b>	<b>CASE STUDY- ENERGY MODELING AND COST-BASED ANALYSIS</b>	<b>117</b>
<b>4.1</b>	<b>Retrofit Option: Lighting Control Systems.....</b>	<b>117</b>
<b>4.2</b>	<b>Step 1: Estimation of Energy Performance Indicators Distribution.....</b>	<b>119</b>
4.2.1	Energy Simulation and Calibration Process.....	120
4.2.2	Final Distribution of Energy Savings and Interaction of Base Models.....	126
4.2.3	Creating Multiple Base Cases for Evaluating a New Retrofit Option.....	128
4.2.4	Accounting for Risks.....	130
4.2.5	Five Cases for Lighting Control Systems Option – Determining Variance.....	131
4.2.6	Energy Performance Indicators Distribution: Energy Consumption (KWh) and Demand Peak (KW) Savings.....	133
<b>4.3</b>	<b>Step 2: Estimation of Whole-Building Performance and Cost-Based Economic Analyses.....</b>	<b>135</b>
4.3.1	Energy Cost Savings Analysis.....	137
4.3.1.1	Capital Costs.....	137
4.3.1.2	Utility Incentives.....	137
4.3.1.3	Operation Costs and Maintenance Cost Savings.....	139
4.3.1.4	Total Cost Savings.....	140
4.3.2	Cost-Based Financial Analysis Level 1 - Energy Savings.....	141
4.3.2.1	Simple Payback and Simple ROI Distributions.....	142
4.3.2.2	Life Cycle Cost Analysis (LCCA) – NPV and IRR Distribution.....	143

4.3.2.3	Non-Energy/Social Benefits .....	148
4.3.2.4	Calculating Health and Productivity Cost Savings .....	148
4.3.3	Cost-Based Financial Analyses Level 2 – Energy and Non-Energy Savings .....	151
4.3.3.1	Simple Payback and Simple ROI Distribution.....	151
4.3.3.2	Life Cycle Cost Analysis (LCCA) - NPV Distribution .....	153
4.3.4	Non-Cost Savings Benefits .....	155
4.3.4.1	The Contribution in Achieving LEED Certifications .....	156
4.3.4.2	Improved Building Energy Performance Rating and Greenhouse Gas (GHG) Emissions.....	157
4.3.4.3	Improved Occupants’ Comfort/Satisfaction and Safety/Security .....	159
4.3.5	Discussion on Using Multiple Base Models for Simulating Retrofit Options.....	159
<b>4.4</b>	<b>Summary.....</b>	<b>161</b>

**CHAPTER 5 CASE STUDY– MARKET RESEARCH AND VALUE-BASED ANALYSIS .....164**

**5.1 Value-Based Financial Analysis.....164**

**5.2 Step 3: Estimation of Distributions of the DCF Inputs .....165**

5.2.1	Market Analysis .....	167
5.2.1.1	Interviews with the Key Stakeholders—Qualitative Information .....	167
5.2.1.1.1	Survey Introduction and Questions.....	167
5.2.1.1.2	Key Findings of the Surveys.....	168
5.2.1.2	Rockville Market Statistics .....	171
5.2.1.3	Current Evidence on Impact of Green on Property Value: .....	172
5.2.1.4	Comparable buildings in Rockville, MD .....	173
5.2.2	Determining the Triangular Distributions of the Key DCF Inputs .....	174
5.2.2.1	Data Analysis .....	175

**5.3 Step 4: Estimation of Distributions for the Financial Indicators .....177**

5.3.1	Financial Outcomes Distributions—TMC is an Owner-Occupied Building .....	178
5.3.1.1	Impact of the Value-Based Analysis Approach on Financial Outcomes .....	182
5.3.2	Financial Outcomes Distributions—TMC is an Owner-Investor Building .....	183
5.3.2.1	Interpretation of Distributions of Final Outputs.....	190
5.3.2.2	Impact of the Value-Based Analysis Approach on Financial Outcomes .....	191
5.3.3	Sensitivity Analysis - Impacts of Various DCF Inputs on Financial Outcomes .....	192
5.3.3.1	Rental Rate and Annual Rental Growth do not change .....	193

5.3.3.2	Occupancy rate and renewal probability do not change .....	195
<b>5.4</b>	<b>Summary.....</b>	<b>196</b>
<b>CHAPTER 6 CONCLUSION AND DISCUSSION .....</b>		<b>199</b>
<b>6.1</b>	<b>Research Summary.....</b>	<b>199</b>
<b>6.2</b>	<b>The Application of the Value-Based Assessment Framework.....</b>	<b>204</b>
6.2.1	Integrating Uncertainties into the Framework .....	208
6.2.2	Importance of Integrating Value in the Financial Assessment Process .....	209
<b>6.3</b>	<b>Limitation of Research and Areas of Improvement.....</b>	<b>213</b>
6.3.1	Future Research .....	217
<b>6.4</b>	<b>Author’s Biography and Research Dissemination.....</b>	<b>218</b>
<b>APPENDICES .....</b>		<b>223</b>
<b>APPENDIX A: Lighting Control Systems Analytics (LCSA) Model.....</b>		<b>223</b>
<b>APPENDIX B: Impact of Electricity Escalation on LCC Outcomes.....</b>		<b>229</b>
<b>APPENDIX C: Statements of Energy Performance.....</b>		<b>234</b>
<b>APPENDIX D: Survey Introductions .....</b>		<b>244</b>
Introduction for the Property Owner & the President of Davis Construction.....		244
Introduction for the Appraisers and Brokers.....		249
<b>APPENDIX E: List of Market Questions .....</b>		<b>254</b>
<b>APPENDIX F: Summary of Interviews.....</b>		<b>255</b>
President of Davis Construction Company and the Owner of the TMC.....		255
The Property Manager of TMC, Cushman & Wakefield:.....		257
The Senior Vice President at TRANSWESTERN, Office Brokerage in MD.....		257
The Senior Appraiser at Cushman & Wakefield.....		258
The President of PGH Consulting, LLC .....		260
Directors of Research & the Brokerage Group at Cushman & Wakefield .....		261
Senior Managing Director and Principal at Cassidy Turley .....		261
<b>APPENDIX G: Published Papers.....</b>		<b>262</b>
6 <sup>th</sup> International Conference on IEECB’10: Frankfurt, Germany - Full Paper .....		262

2010 ACEEE Building Summer Study: Pacific Grove, CA – Full Paper.....	275
2011 ARCC Annual Meeting, Detroit, MI – Full Paper .....	289
7 <sup>th</sup> International Conference on IECEB’12: Frankfurt, Germany - Full Paper .....	298
26 <sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech – Poster.....	312
27 <sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech – Poster .....	314
Property Management Published by Emerald Publishing Group–Abstract .....	316
A Three-Level Analysis Approach for Deriving the True Financial Performance of Energy Retrofit Options.....	317
<b>APPENDIX H: IRB Approval Letter .....</b>	<b>318</b>
<b>REFERENCES.....</b>	<b>321</b>

## **LIST of FIGURES**

Figure 1-1: Communication between Design and Property Professionals.....	4
Figure 1-2: Research Objective .....	14
Figure 2-1: Equal Dimensions .....	19
Figure 2-2: Discounted Cash Flow Model.....	55
Figure 2-3: General Interpretation of Shapes of Normal Distribution .....	59
Figure 2-4: A hypothetical continuous probability distribution—normal distribution .....	62
Figure 3-1: Summary of Tasks .....	87
Figure 3-2: A Process for Deriving the Financial Performance of Sustainable Options.....	92
Figure 3-3: Components of the Valuation Process .....	93
Figure 3-4: Process Steps and Methods.....	95
Figure 3-5: A Schematic Diagram for Demonstrating the Function of the Proposed Assessment Process .....	103
Figure 3-6: Qualitative Filtering in Sustainable Property Valuation Process .....	105
Figure 3-7: Twinbrook Metro Center 1 (TMC) Building .....	108
Figure 3-8: Interior of TMC .....	109
Figure 3-9: Case Study Methods and Data Collection Procedure.....	112
Figure 4-1: eQuest Model.....	121
Figure 4-2: Actual KWh from Electricity Bills Vs. Actual Weighted Average.....	123
Figure 4-3: The eQuest Model prediction vs. actual consumption .....	125
Figure 4-4: Interaction of base model inaccuracy in generating the final simulation outcomes.....	127
Figure 4-5: The Distribution of Predicted Energy Use (MWh) of 22 Base Models .....	129
Figure 4-6: The Distribution of Annual Energy Consumption Savings (MWh).....	134
Figure 4-7: The Distribution of Annual Peak Demand Savings (KW).....	134
Figure 4-8: The Distribution of Total Annual Energy Cost Savings .....	140
Figure 4-9: The Distribution of Annual Energy Cost Savings per Sq.Ft.....	141
Figure 4-10: The Distribution of Annual Energy Cost Savings per Employee of Davis Construction Company .....	141
Figure 4-11: The Distribution of Simple Payback (Year) – Energy Savings.....	142
Figure 4-12: The Distribution of Simple ROI – Energy Savings.....	142
Figure 4-13: The Distribution of 5-Year NPV.....	144
Figure 4-14: The Distribution of 10-Year NPV.....	144
Figure 4-15: The Distribution of 15-Year NPV.....	145
Figure 4-16: The Distribution of 20-Year NPV.....	145
Figure 4-17: The Distribution of 5-Year IRR.....	146
Figure 4-18: The Distribution of 10-Year IRR.....	146
Figure 4-19: The Distribution of 15-Year IRR.....	147
Figure 4-20: The Distribution of 20-Year IRR.....	147
Figure 4-21: The Distribution of Total Cost Savings (Health & Productivity Savings Are Included).....	150



Figure 4-22: The Distribution of Cost Savings per Sq.Ft (Health & Productivity Savings Are Included).....	150
Figure 4-23: The Distribution of Total Cost Savings per Employee of Davis Construction Company (Health & Productivity Savings Are Included).....	151
Figure 4-24: The Distribution of Simple Payback (Health and Productivity Savings Are Included).....	152
Figure 4-25: The Distribution of Simple ROI (Health and Productivity Savings Are Included).....	152
Figure 4-26: The Distribution of 5-Year NPV (Health and Productivity Savings Are Included).....	153
Figure 4-27: The Distribution of 10-Year NPV (Health and Productivity Savings Are Included).....	154
Figure 4-28: The Distribution of 15-Year NPV (Health and Productivity Savings Are Included).....	154
Figure 4-29: The Distribution of 20-Year NPV (Health and Productivity Savings Are Included).....	155
Figure 5-1: The Distribution of 5-Year NPV- the Owner-Occupied Scenario .....	179
Figure 5-2: The Distribution of 10-Year NPV- the Owner-Occupied Scenario .....	180
Figure 5-3: The Distribution of 15-Year NPV- the Owner-Occupied Scenario .....	180
Figure 5-4: The Distribution of 20-Year NPV- the Owner-Occupied Scenario .....	181
Figure 5-5: The Distribution of 5-Year IRR- the Owner-Occupied Scenario.....	181
Figure 5-6: The Distribution of 10 & 15 &20-Year IRR- the Owner-Occupied Scenario.....	182
Figure 5-7: Impacts of Revenue on Final NPVs - the Owner-Occupied Scenario.....	183
Figure 5-8: Impacts of Revenue on Final IRRs - the Owner-Occupied Scenario.....	183
Figure 5-9: The Distribution of 5-Year NPV- the Owner-Investor Scenario .....	184
Figure 5-10: The Distribution of 10-Year NPV- the Owner-Investor Scenario .....	185
Figure 5-11: The Distribution of 15-Year NPV- the Owner-Investor Scenario .....	185
Figure 5-12: The Distribution of 20-Year NPV- the Owner-Investor Scenario .....	186
Figure 5-13: The Distribution of 5-Year IRR- the Owner-Investor Scenario.....	186
Figure 5-14: The Distribution of 10 & 15 & 20-Year IRR- the Owner-Investor Scenario.....	187
Figure 5-15: The Distribution of Average 5-Year NPV- the Owner-Investor Scenario .....	188
Figure 5-16: The Distribution of Average 10-Year NPV- the Owner-Investor Scenario .....	188
Figure 5-17: The Distribution of Average 15-Year NPV- the Owner-Investor Scenario .....	189
Figure 5-18: The Distribution of Average 20-Year NPV- the Owner-Investor Scenario .....	189
Figure 5-19: Probabilities in a Normal Distribution .....	190
Figure 5-20: Comparison of Process Outputs – Single-Point Estimates VS. Distributions.....	191
Figure 5-21: Impacts of Revenue on Final NPVs– the Owner-Investor Scenario .....	192
Figure 5-22: Impacts of Revenue on Final IRRs– the Owner-Investor Scenario .....	192
Figure 5-23: Impact of Including Revenue on NPVs When the Rent-Related Inputs Do Not Change– the Owner-Investor Scenario .....	193
Figure 5-24: Impact of Including Revenue on IRRs When the Rent-Related Inputs Do Not Change– the Owner-Investor Scenario .....	194
Figure 5-25: Impact of Including Revenue on NPVs When the Occupancy and Renewal Probability Do Not Change– the Owner-Investor Scenario .....	195

Figure 5-26: Impact of Including Revenue on IRRs When the Occupancy and Renewal Probability Do Not Change–the Owner-Investor Scenario .....	195
Figure 6-1: A Schematic Diagram of the Proposed Assessment Framework .....	206
Figure 6-2: Application of the proposed framework in the case study .....	207
Figure 6-3: Impact of Including Health & Productivity Savings and Revenue on the NPVs – the Owner-Occupied Scenario .....	209
Figure 6-4: Impact of Including Health & Productivity Savings and Revenue on the IRRs - the Owner-Occupied Scenario .....	210
Figure 6-5: Impact of Including Revenue on the NPVs – the Owner-Investor Scenario .....	211
Figure 6-6: Impact of Including Revenue on the IRRs – the Owner-Investor Scenario .....	212

**APPENDICES**

Figure 1: Electricity Escalation Rate .....	229
Figure 2: Average 5-Year NPV .....	230
Figure 3: Average 10-Year NPV .....	230
Figure 4: Average 15-Year NPV .....	231
Figure 5: Average 20-Year NPV .....	231
Figure 6: Average 5-Year IRR .....	232
Figure 7: Average 10-Year IRR .....	232
Figure 8: Average 15-Year IRR .....	233
Figure 9: Average 20-Year IRR .....	233

## **LIST OF TABLES**

Table 2-1: Six Building Performance Mandates (AIA) (Rush, 1986, p. 233) .....	31
Table 2-2: Building Performance (GBFC) (Muldavin, 2010, p. 211).....	33
Table 2-3: Acceptable tolerance for monthly data calibration (Pan, et al., 2007, p. 652).....	50
Table 2-4: Sustainable Financial Analysis Alternatives (Muldavin, 2010, p. 101) .....	71
Table 3-1: Building Characteristics .....	107
Table 4-1: Actual monthly electricity usages from 2009 bills and monthly weighted average usages .....	122
Table 4-2: Acceptable tolerance for monthly data calibration (Pan, et al., 2007, p. 652).....	124
Table 4-3: Final Calibrated Model Error Indicators in Compare to Actual Electricity Usages .....	125
Table 4-4: Variables and Ranges for Creating Multiple Base Cases .....	128
Table 4-5: Five base models assumptions, savings and error indicators .....	130
Table 4-6 : Variables and Range for Creating Five Lighting Controls Cases.....	132
Table 4-7: Capital Costs .....	137
Table 4-8: Pepco Lighting Controls Incentives (Pepco, 2011a) .....	138
Table 4-9: Total Incentives for each Lighting Retrofit Case .....	138
Table 4-10: Net Investment Costs .....	139
Table 4-11: Weighted Average of Pepco Electricity Charges .....	139
Table 4-12 : Assumptions for LCCA.....	143
Table 4-13: Health and Productivity Assumptions and Savings.....	149
Table 4-14: The Contribution of Lutron Lighting Controls to LEED Certifications (adapted from Jouaneh, 2010, p. 6).....	156
Table 4-15: Probabilities for Achieving Four Levels of LEED Certifications .....	157
Table 4-16: Energy Performance Comparison .....	158
Table 4-17: Impact of Lighting Controls on Energy Performance Rating and GHG Emissions .....	159
Table 4-18: Impacts of simulating by multiple base models on financial outcomes .....	160
Table 5-1: DCF Assumptions .....	176
Table 5-2: Summary of Financial Outcomes Ranges and Averages- the Owner-Occupied Scenario .....	179
Table 5-3: Impacts of Value on Financial Outcomes Average– the Owner-Occupied Scenario .....	182
Table 5-4: Summary of Financial Outcomes Ranges and Averages- the Owner-Investor Scenario .....	184
Table 5-5: Impacts of Value on Financial Outcomes Average– the Owner-Investor Scenario .....	191
Table 5-6: Financial Outcomes When the Rent-Related Inputs Do Not Change - Owner-Investor Scenario .....	194
Table 5-7: Financial Outcomes When the Occupancy and Renewal Probability Do Not Change - the Owner-Investor Scenario .....	196
Table 6-1: Comparison of the Value-Based Financial Analysis with Level 1 Analysis - the Owner-Occupied Scenario .....	210
Table 6-2: Comparison of the Value-Based Financial Analysis with Level 1 Analysis - the Owner-Occupied Scenario .....	212

**APPENDICES**

Table 1: Estimation of Errors Indicators of the Five Selected Base Models .....224

Table 2: Pepco Electricity Rate Assumption and Forecast .....225

Table 3: Energy Savings, Simple Cost, and LCC Analysis for BM (-2) .....226

Table 4: Summary of LCCA.....227

Table 5: Health and Productivity Savings Analysis .....228

## **LIST OF EQUATIONS**

Equation 2-1: Range and mean for EUIs (1) .....	47
Equation 2-2: Range and mean for EUIs (2) .....	48
Equation 2-3: Range and mean for EUIs (3) .....	48
Equation 2-4: Cap Rate and Property Value.....	56
Equation 2-5: DCF Valuation.....	56
Equation 2-6: Relationship between Discount Rate and Cap Rate .....	57
Equation 2-7: The Key Determinants of a Cap Rate .....	57
Equation 2-8: PERT Formula for Mean .....	61
Equation 2-9: PERT Formula for Standard Deviation.....	61
Equation 4-1: ERR and RSME formulas (Pan, et al., 2007, p. 657).....	123

# **CHAPTER 1 INTRODUCTION**

## **1.1 Background**

### **1.1.1 Sustainable Property Investment**

Property investment in sustainable building features is not a new concept; it has been around for more than a decade in the United States and longer in Europe. However, with rising energy costs, climate change and global warming, property professionals, such as investors, owner-occupants, real estate developers, asset managers, lenders and bankers who are involved in the investment decision-making process have become more interested in investing and financing sustainable buildings features.

Sustainability investment has become a mainstream consideration in planning and design of most building development, both new construction and retrofit, and often presents itself as an excellent investment opportunity among real estate investors and owner-occupants. Most investors and owner-occupants of existing buildings have indicated that they would not undertake a retrofit strategy of a building without considering investment in at least some sustainable features. These professionals believe that the benefits of building investment with sustainable features will increase in coming years; and therefore, they are not only concerned about today's market demand, but also future demand.

Many space users have indicated that they are prepared to pay more for rent or for purchasing sustainable buildings with the expectation to reap the benefits, such as operational cost savings, improved corporate reputation, and health and productivity. The result of a survey of commercial property industry stakeholders undertaken by Ernst & Young indicates that about two-thirds of interviewees would pay more for a Green Star building. Some reported that they already pay more if convinced of the value. Most said they also would not undertake refurbishment of a building without considering a Green Star rating. Several of the remaining third indicated that although they would only pay the same price at present, in future they would expect to pay a premium (Bowman & Wills, 2008, p. 17). In terms of financing sustainable property development, Muldavin and Fusscas (2007) have argued that "financing the green development is a lot like traditional financing, but additional detail and attention must be paid to those costs-benefits and risks that most lenders are not yet familiar with to ensure the lowest-cost financing on the best possible terms" (p. 81). Therefore, financing sectors are in need of better understanding of the costs, benefits and risks of green building investments to be able to make a more informed decision.

Real estate investors often rely on the concept of market value<sup>1</sup> as the basis in making major property investment decisions<sup>2</sup>, such as acquisition of an existing asset, but it is still unclear how sustainability impacts the properties' market value and how sustainability can be achieved with economically sound solutions. Scores of studies have been performed on financial performance of sustainable properties and many tools and techniques have been used by decision-makers for assessing the financial performance of properties with sustainable features; however, there is still not a precise answer for the following questions when evaluating a sustainable property: “does green pay off and if so, by how much?,” “what are the true returns on sustainability investment?,” “how does sustainability impact the properties' financial value?,” “how does one consider the full scope of costs and benefits, tangible and intangible, of sustainable features in financial analysis?,” “what are the most profitable sustainable options?,” “are benefits sufficient to take the risk?,” or “how does one quantitatively account for the various uncertainties and risks associated with investment in sustainable features?”

The previous studies about financial implications of sustainable buildings have been categorized in three types, including “case-based studies”, “causal-comparative studies”, and “fundamentals of sustainable property valuation studies” about sustainable property evaluation.

The majority of these studies are “case-based” which focus on the financial performance of a single sustainable building or “causal-comparative studies” which focus on comparison of larger sets of sustainable buildings versus their peer non-sustainable ones utilizing statistical modeling techniques, such as regression analysis. The result of these types of studies generally shows that the financial performance of sustainable buildings outperforms the conventional ones and a building with green features and certifications, such as LEED and Energy-Star may have higher rents, higher occupancy levels, lower operation costs and higher absorption rates and therefore higher market values. These studies attempt to statistically estimate the premium value of sustainable buildings and answer the question of “does green pay off?” to encourage investors and owner-occupants to consider sustainable options investment while making investment decisions. Although the result of these studies would provide decision-makers with

---

<sup>1</sup> “Based on the concept of market value as defined today, value can only be recognized when it is reflected in the form of definite, quantifiable data” (Chappell & Corps, 2009, p. 14).

<sup>2</sup> There are many types of investment decisions such as property acquisition, property development, major or minor retrofits, a commercial interiors decision, or replacing a roof or HVAC system. In most of these decisions, with the exception of acquiring an existing asset, decision-makers may not conduct a formal narrative appraisal analysis. They may consider assessment of net cash flow, incentives, risks, and potential value-added to the property or enterprise in their decision-making, but they may not conduct a full assessment of market value, utilizing three main valuation approaches, which are discussed in Section 2.3.1. Owner-occupants often base their real estate decisions on initial costs, total occupancy costs, and enterprise considerations rather than market value.

useful information and deeper insights into sustainable property investment, *they are not sufficient for valuers to rely on in making specific investment decisions for a particular property*, such as acquisition of a sustainable office building.

Whereas the above studies typically evaluate the green value with a top-bottom approach, the third type of current studies, sustainable property evaluation, attempts to address the fundamental issues related to financial analysis of sustainable property, including suggestions about establishing the relationship between sustainability, building performance, and property worth and market value. These studies aim to assist investors in understanding the true market value of sustainability and ultimately, in making high-quality investment decisions. This research is built upon theoretical findings and fundamentals suggested by this type of study.

The investors and valuers would often rely on factual data, such as market evidence on closed sales and/or leasing of comparable properties, as a basis for their qualitative analysis in property valuation. The sufficient empirical data is not available for sustainable properties to allow the investment community to arrive at the accurate estimation of market value of sustainable features. Therefore, it is necessary for more time to pass and more transaction data to be generated for green buildings to provide professionals with a more reliable basis to conduct their qualitative analyses and enable them to determine a more reliable financial premium for green buildings and establish a reliable link between green features and value. Real estate valuers still do not feel certain in assigning specific incremental market value for the green features and certifications—based on the results of these general studies—when evaluating the financial value of a particular sustainable property.

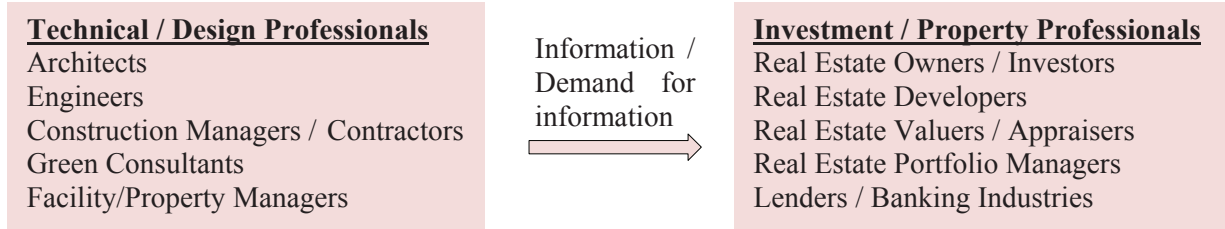
However, investors and owner-occupants still need to make decisions regarding whether or not to invest in sustainable options, especially when they are deciding about retrofitting the existing properties. Furthermore, the process of selecting financial inputs in investment analysis is a qualitative process that requires many subjective adjustments to factual/comparable data to account for the difference with the subject property, including time of sale, zoning, size, age, design and functionality, micro-location, and build-out and floor level of spaces available. Even with sufficient market evidence, valuers need to conduct a qualitative analysis to subjectively adjust the data. Thus, a better presentation of information, i.g. costs, benefits, and risks associated with investing sustainable features, could be significantly helpful in enabling property professionals to integrate the potential value and risk in their decision-making process concerning sustainability investment.



**A Note on Risk:** Real estate investors are interested to mitigate risks as much as possible. Risk enables investors to achieve higher value and provides opportunities for investment. What is important is that investors will be able to identify and understand risks and uncertainties well enough to either mitigate them through mechanism, such as insurance and contracts, or incorporate the risks they cannot mitigate into price. Identifying and including various sources of uncertainties inherent in the sustainability assessment process into decision-making process is one of the gaps that this research is aiming to fill.

**1.1.2 New Responsibilities of Design Professionals Regarding Sustainable Properties**

There are two groups of decision-makers who are involved in the development process of a building: design professionals, who are involved in technical decision making processes, and property professionals, who are involved in financial or investment decision making processes. Design professionals include architects, engineers, etc. Property professionals include real estate investors, developers, valuers, lenders, etc.



**Figure 1-1: Communication between Design and Property Professionals**

As illustrated in Figure 1-1, design professionals would generally propose design alternatives and provide property professionals with information concerning the impacts of their design suggestions (costs and benefits) on building performance. Property professionals process the cost-benefit information with their own decision-making techniques, and make the final decision about whether or not to proceed with investing in those proposed alternatives.

Essentially, property professionals make their investment decisions based on their predictions of value, both revenue and risk. Private investors need to ensure that the projects they are investing in will generate a reasonable and competitive rate of return in the market with the lowest possible risk; they need to know if the risks associated with their investment are adequately compensated by expected returns generated—

risk and revenue trade off. The financial sectors, such as banking industries and lenders also seek to ensure that the project they are financially supporting will generate adequate funds to cover the debt.

It is important to note that the sustainable property investment procedure is not essentially different from that of a typical property investment analysis from risk and return perspectives. In fact, a thorough communication of value, both revenue and risk, is much more critical when analyzing a sustainable building / feature investment opportunity, due to insufficient market data, and limited knowledge and experience with sustainability investment of property professionals. Real estate investors/owners must recognize the financial return they might have received above the amount they would have received when not investing in these features. Thus, a clear, comprehensive, and reliable presentation of financial performance and risk of sustainable properties in the way that property professionals could understand and apply in their decision making process is vital.

Design professionals are well served as part of the integrated design process to communicate the full scope of costs and benefits of sustainable features to property professionals. Designers should be able to explain how their sustainable design alternatives impact building performance and how those impacts could affect the property value and risk. This information, if presented in a reliable and understandable language, will enable real estate investors/owners to make more informed decisions about sustainable building investment. Lützkendorf and Lorenz (2005) have argued that “In the future, clients will ask about the effects of these design and planning solutions on overall building performance. This creates a new client need that the design team can fulfill by providing building related information relevant to valuation and rating purposes” (p. 231).

Muldavin (2008b) has also discussed that

“It is the job of the sustainability industry [design professionals] to develop the data and organize it in a way that can be utilized by investors, lenders, developers, and corporate real estate executives as well as the commercial brokers and appraisers to assist them in their decision making process” (p. 16).

Currently, design professionals do not report the value of sustainable building to their clients, due to their incomplete or unreliable evaluation methods and lack of their knowledge of the investment decision making process. Communicating the financial performance of sustainable buildings reliably requires performing more sophisticated financial and statistical analyses than what designers traditionally do. In order to convince the investors and owner-occupants, the design professionals need to understand how property professionals value their investment choices, what techniques traditionally they use to evaluate

their alternatives, and how they account for risk and uncertainty in their investment decision making process. Through a better understanding of value, risk and uncertainty, design professionals could prepare and organize information/inputs in the way that assists the decision-makers to better identify and understand the potential risks, i.g. risk associated with systems performance. This might enable them to mitigate some of the potential risks, better price the risks that they are not able to mitigate, and achieve higher returns. As a result, the decision-makers might be convinced to invest in the sustainable options that otherwise they do not, and therefore, more investment opportunities may emerge.

Therefore, development of methods and processes that educate the design professionals about the investment decision-making process, and provide them with a defined procedure to follow to understand the impact of their design decisions on those factors that are important for the investment decision-makers, i.e. value and risk, could be significantly helpful steps toward driving the sustainable properties market. *An integrated approach is required to represent a common language for better communication between technical decision-makers and those involved in investment decisions and bridge the gap between two distinct but interrelated communities, in order to enable them to recognize the more accurate and reliable financial return associated with their investment decisions about sustainability.* One of the goals of this research is to address this deficiency for sustainable options in real estate investment.

### **1.1.3 Sustainable Development and Buildings**

It is generally accepted that sustainable development has three dimensions/benefits including environmental, social and economic benefits, and a property that has the potential to contribute to sustainable development—sustainable property—would provide all three benefits simultaneously to a lesser or greater extent. The emerging trend of “Responsible Property Investment (RPI)”<sup>3</sup> in the international property sector and other evidences of real estate investment especially in the last decade show that the property industry has become mature enough to recognize that all three dimensions of sustainability could have impacts on the property value. “There is general agreement that environmental and social features, particularly those improving health and productivity of workers, will impact the functionality of investment property” (Boyd, 2005, p. 1).

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<sup>3</sup> Responsible property investing (RPI) is a new approach in property investment that focuses on the "triple bottom line", which would take into account social, environmental, and financial returns of the investments. It has been referred to as real estate's latest movement (as cited by Pivo, 2008b, p. 21). According to Pivo and McNamara (2005), RPI means “maximizing the positive and minimizing the negative social and environmental effects of property investing, consistent with fiduciary responsibilities” (p. 130).

Until recently, health and productivity have received less attention among the private investors because there are substantial risks and uncertainties involved in the quantification of their benefits and investors are not able to account for them in their costs-benefits analysis. However, these professionals have now realized that social aspects of sustainable development, such as adaptability, functionality, health and productivity, could significantly influence total real estate costs and market demand. The property value is directly related to the demand from investors, space users, and regulators, and therefore, all factors, which could potentially play roles in deriving the market demand, should be taken into account in the costs-benefits analysis of sustainable properties / attributes.

*Thus, simultaneous consideration of all the sustainability benefits as well as market response to those benefits in the context of a more complete financial assessment process are critical to understand the full scope of costs and benefits of sustainable properties.*

The degree of the impact is complicated and will depend on many factors including characteristics of the building, type of sustainable options, and market condition. It is too simplistic to expect that the change will always, or even frequently, have a positive impact on the financial performance of a sustainable property. What is important is that the impact of enhanced environmental and social factors, i.e. non-energy savings benefits, on space users and the reaction of the market to those benefits is examined and reported to the final decision-makers and is not ignored.

### **1.1.3.1 Costs, Benefits, Risks, and Uncertainties of Sustainable Property Investment**

“The benefits [of sustainable buildings] range from being fairly predictable (energy and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy” (Kats, 2003, p. v). Unfortunately, the majority of current sustainable building investment decisions are solely made based on tangible cost savings, while full costs and benefits of sustainability are beyond cost savings.

For example, better daylighting and ventilation may result in improved worker health and productivity in an office building and may ultimately contribute to significant cost savings for employers because of lower absenteeism and recruiting costs. The result of a study conducted by Miller, Pogue, Gough, & Davis (2009) shows that tenants do pay a premium of 5% to 10% for healthier buildings even though most tenants do not admit to this (84% or more say “No”). Healthier space will also increase the ability to meet evolving tenant demand, which would lead to a lower turnover rate and lower risk of cash flow.

Some of the potential benefits associated with sustainable building investments that are often ignored in current analysis procedures include: access to state or federal government incentives; tax and insurance benefits; better financing options; contributing to achieving green certifications; reducing the carbon emission; improving indoor air quality, daylighting and thermal comfort (environmental benefits); increase adaptability, serviceability, and functionality; improving health and productivity (social benefits); increasing property reputation and marketability; and increasing asset value or revenue due to improved appeal to regulators, space users and investors, which would lead to higher rent, higher occupancy, lower turnover, etc.

*Thus, sustainability offers more than cost savings to real estate. The financial performance of a sustainable property is beyond the energy and operating cost savings. Non-energy benefits as well as potential value implications of sustainable options need to be taken into account in order to arrive at more comprehensive financial outcomes.*

Risk is a significantly important component of the sustainability costs-benefits analysis. No assessment of a sustainable property value would be completed without a full assessment of risks, both positive and negative as “reduced risk is perhaps the most significant benefit of sustainable property investment” (Muldavin, 2009, p. 126). The positive risks may increase the potential benefits and negative risks may increase the potential costs.

Potential positive risks inherent in sustainable property investment include: reducing the risk of losing value due to functional, economic or physical obsolescence; reducing the risk of losing users and investors due to availability of sustainable buildings in future markets; and reduced legislative risk.

There are also uncertainties associated with different levels of sustainable properties assessment including uncertainties associated with forecasting energy performance by energy simulation tools, achieving any certification or energy label, improving health and productivity, future cost of oil or energy price, future interest rates, future utility rates, and achieving the expected rents, occupancy, etc.

*A clear and well-supported presentation of risk and uncertainty associated with sustainable property assessment, both at the building performance and financial performance levels, is critical in preventing underestimation or overestimation of the final financial performance. Risk and uncertainty need to be identified, assessed, and reported in a way that can be understood and analyzed by investors or end users. Consequently, without a simultaneous consideration of the full scope of costs, benefits, risk and uncertainty associated with sustainable property investment, the financial assessment of sustainable real estate is not complete.*

## 1.2 **Problem Statement**

Current assessment methods and analytics, which are used for assessing sustainable performance, do not simultaneously incorporate all of benefits, risks and uncertainties of sustainability investment, nor represent them in the way that assists investors to make informed investment decisions, especially at the property-specific decision level. Property professionals are in need of more comprehensive, reliable, and understandable information and insight about risks and returns of sustainability investment which current tools are unable to provide. These tools and techniques are categorized in the following four types. In this section, it is explained why none of these tools on their own are sufficient to rely upon for making major high-quality investment decisions at the property level.

### 1.2.1 **Existing Sustainability Assessment Methods**

#### 1.2.1.1 **Green Building Certifications**

Current Green Building Certifications and Energy Rating Systems, such as LEED, BREEM, and Energy Star are very often used by decision-makers as a basis for comparing the performance of sustainable buildings. However, these certifications cannot be the sole basis for defining sustainability for the purposes of major investment decision-making because of the following issues:

- They have been primarily designed to measure the environmental impact of sustainability, and therefore, due to their environmental outcomes rather than financial outcomes, are not able to communicate all dimensions of sustainable buildings performance.
- They do not provide any detail about the sustainable features employed in the building and many of the sustainable features that have contributed in achieving the certification may not have a significant direct impact on property performance from a financial perspective.
- Many buildings might have employed valuable sustainable attributes that could influence their market value but are not certified; therefore, relying upon certification may ignore the impact of those sustainable features on financial performance and may lead to undervaluation.
- Sustainable buildings with similar certification level might have different building performance. Sustainability can be achieved through a variety of sustainable features. Even two LEED certified buildings with the same level rating might have employed different systems and design strategies in achieving the same level of certification. Therefore, these buildings might have a different environmental, social and economic performance.

However, it is very important to consider these elements in the financial analyses as many studies have shown that they made a positive contribution to the overall market value of a sustainable property because of their impact on reputation and marketability.

### **1.2.1.2 Building Simulation Programs (BSPs)**

There are many Building Simulation Programs (BSPs), including DOE 2, Energy-Plus, Radiance, Computational Fluid Dynamics (CFD), etc. developed to evaluate building performance indicators such as energy consumption, daylighting, and indoor air quality. These technical tools are widely used by design professionals not only in designing and planning a new building but also in evaluating the energy performance of an existing building. Some of these programs also perform simple financial analyses.

Currently, many minor and major building retrofit decisions are made based on the outputs of these tools. The models help decision-makers to explore and compare the building performance indicators resulting from employing different systems and strategies, and select the most effective options. However, there are some issues with directly using the results of these programs for making major investment decisions:

- These tools are primarily designed to forecast impacts of design decisions on environmental performance indicators and do not take into account other aspects of sustainable building performance. They ignore many potential benefits of properties with sustainable features.
- Their outputs are typically presented in technical terms rather than financial. Although financial performance of sustainable buildings are the result of non-financial building performance factors, investors are more concerned with the final financial performance indicators in financial language and not as much with the technical details associated with the building performance indicators. Most of the current tools are well developed to evaluate building performance, but fail to properly link indicators to financial performance and do not translate the technical details to a more understandable language.
- The simple financial analyses that these tools perform are based on simple estimation of cost savings, payback period and simple return on investment.

### **1.2.1.3 Simple Financial Methods**

The financial analysis techniques traditionally used by real estate investors, owner-occupants, and lenders for assessing the financial performance of sustainable buildings include: Simple Payback (PB), Simple Return On Investment (ROI), Energy-Star financial tools, etc. These approaches primarily focus on initial development cost and operational cost savings, and ignore the full scope of costs, benefits, and risks of sustainable properties, as well as uncertainties in the process of achieving those benefits outlined



previously. “These limitations are not new, but dramatic increases in regulator, space user and investor demand for sustainable properties during the last few years have substantially enhanced the negative implications of these limitations” (Muldavin, 2010, p. 98).

Full costs and benefits of including sustainable features are beyond operational cost savings and traditional sustainability analysis. Ignoring these non-cost benefits may undervalue the investments in sustainable features and exclude many profitable investment opportunities from consideration, which ultimately would lead to underinvestment in sustainability. Nevertheless, because of their simplicity, these types of analysis are used very often; they might be good enough to address minor investment decisions, such as minor retrofit or making decisions among competing HVAC systems, lighting or window products, but are not sufficient for major retrofits or acquisition decisions.

#### **1.2.1.4 Building Performance-Based Methods**

Building Performance-Based Methods such as Life Cycle Costing (LCC), Life Cycle Assessment (LCA), General Cost-Benefit Analysis (CBA), or Value Engineering (VE), are widely used by decision-makers, both technical and financial, to evaluate the performance of a building over its life. The primary problem with most of these methods such as LCC or VE is the cost-based nature of their financial analysis, which would lead to the ignorance of other non-cost benefits of sustainability investment. LCA-based techniques are recognized as one of the best approaches for evaluating the environmental and some of the social aspects of sustainability. They are well developed to incorporate environmental performance over the entire product life cycle.

Some studies have aimed at developing new approaches using the LCA concept in order to incorporate the environmental indicators with other dimensions of sustainability. While LCA “takes the issue of occupant health into consideration, there is less focus on occupant satisfaction, functional fit and productivity” (Lützkendorf & Lorenz, 2005, p. 224). Therefore, to date, performance-based approaches are not well suited to account for all aspects of sustainability simultaneously. Furthermore, they are unable to deal with value and risk simultaneously in their evaluation process. Regarding assessing the financial performance of a sustainable property, Muldavin (2008) has suggested:

you must evaluate a property's sustainable features and develop qualitative and quantitative arguments and support for the intermediate sustainable outcome, such as productivity and health benefits and reductions in cash flow risk. The financial impact of intermediate sustainable outcomes is determined by assessing how these outcomes directly tie to key financial variables like rents, occupancies, tenant retention and cash flow risk (p. 520).



## 1.2.2 Gap Analysis

The increased need for comprehensive, reliable, and understandable information concerning the financial performance of sustainability investment and deficiencies of current assessment tools in providing those information on their own, explained previously, suggest the following principles:

- New integrated assessment approaches are needed to consider the financial performance of sustainability investment and its associated uncertainty simultaneously, and present the outcomes in appropriate terms that can be understood and utilized in the investment decision-making process.
- More focus should be placed on the specific sustainable features and strategies employed in a sustainable property when evaluating the financial performance of a sustainable property rather than simply focusing on sustainable certifications or ratings.
- More focus should be placed on a thorough and reliable estimation of the actual building performance indicators and their relationship with financial performance. Current technical tools, which are primarily developed by design professionals, are well suited to deal with complexity and interaction of building performance if used properly. Their results need to be adjusted intelligently and translated to the appropriate terms in order to be included in the financial models.
- More sophisticated financial techniques, rather than simple cost-based analyses, capable of addressing the full costs, benefits and risks of a sustainable property investment, should be utilized for estimating the financial performance indicators.
- Various ‘uncertainty factors’, both at the building performance and financial assessment levels, should be derived and integrated into the assessment process. More systematic and structured processes and tools are required to assess and present the risk and uncertainty to assist decision-makers to better mitigate or price them. More sophisticated statistical techniques could also be utilized for incorporating uncertainty and communicating more reliable estimates of financial performance.

These are the objectives that this research aims to address through development of a new integrated assessment framework.

## 1.3 **Scope of Research**

### 1.3.1 **Goal of Research**

The goal of this research is to create a systematic assessment framework to consider both cost and non-cost savings and assess the financial performance of a set of sustainable options in the context of value and risk, while explicitly deriving and integrating various uncertainties inherent in the process. The new assessment framework takes sustainable options as the inputs, projects their building performance and market response, and translates their impact into the financial language to be included in a financial model. Through integration of value and uncertainty in the assessment process, this framework aims to improve the quality of financial performance projections and therefore, investment decisions concerning sustainable options in real estate.

### 1.3.2 **Research Approach**

In the development of the new assessment process, issues related to the three following areas have been studied and considered:

- Issues related to sustainable options and their building performance projections;
- Issues related to the sustainable property valuation process and incorporating sustainability into the financial model (Discounted Cash Flow (DCF) model); and
- Issues related to incorporating and communicating the uncertainty in the financial model and assessment process by utilizing the probability distribution approach.

This study is intended to look at these three different domains simultaneously and bring them all together into a single model to functionally evaluate the possible sustainable options and determine their distributions of financial performance indicators in a way that can be utilized by users for making high-quality investment decisions about greening their buildings. Figure 1-2 illustrates these three major areas of studies upon which this research is based and presents the objective of this study:

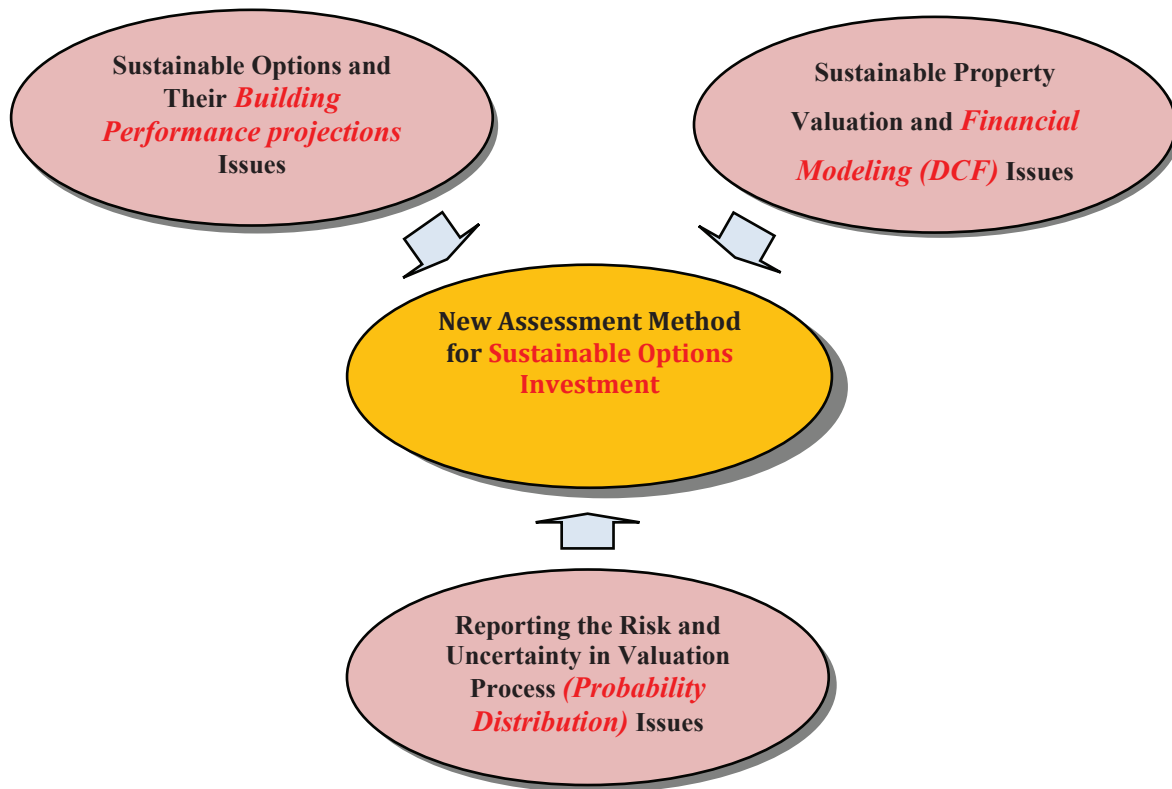


Figure 1-2: Research Objective

### 1.3.3 Methodology

The methodology is a combination of both quantitative and qualitative approaches through integration of a case study and survey tactics. The study begins with mapping of an integrated assessment framework to derive the more reliable financial performance of sustainable options in major green retrofits of existing buildings. Then, an existing non-sustainable office building is selected as an instrumental case study to demonstrate the numeric application of the proposed framework and test its practicality in a real world situation.

An integrated approach was required in this research because the case study includes energy simulation, building performance assessment, real estate market research, and a value-based analysis. The parts related to energy simulation and cost-based analysis required a quantitative assessment approach. However, for the parts related to real estate market research and valuation a qualitative approach was needed for collecting the required information for determining the value parameters.

## 1.4 **Contribution and Expected Benefits of the Framework**

The dissertation explores the critical challenges, weaknesses, as well as principles of implementing sustainability investment decisions and provides guidance and solutions for a more complete assessment and presentation of both building performance and financial performance of sustainability investment in real estate. The primary benefit of this research is to improve the quality of investment decisions concerning sustainable options. By focusing on one of most important market barriers of sustainable real estate investment, valuation of sustainable features, this research contributes to greater market acceptance of sustainable building features. As a result of applying the proposed framework when evaluating sustainability investment options, many investment opportunities that were otherwise ignored may be realized, and therefore, the frequency of sustainability investment in real estate will increase.

The proposed framework goes beyond the current sustainability cost-benefit analysis, captures the more reliable financial performance, and provides the users with more quantitative data and insight about risk and return associated with sustainable options investment. This would encourage decision-makers to rethink about sustainability investment and better respond to the growing demand of space users, regulators and investors for sustainable buildings.

This research bridges the gap between two distinct but interrelated communities that are involved in the sustainability assessment process: technical decision-makers—such as architects, engineers, construction managers, and green building consultants—and investment decision-makers—such as investors, owner-occupants, real estate developers, portfolio managers, real estate appraisers, and lenders. It represents a platform that integrates the interests and tools of technical decision-makers with those of investment decision-makers for addressing the challenges related to financial assessment of sustainable options in real estate investment.

It is hoped that by applying the proposed framework, cost-based financial assessment, such as simple payback and ROI rules, could be replaced in the sustainable property investment decision-making analysis, and therefore, new opportunities for sustainability investments may emerge.

As the demand for sustainability increases and sustainability becomes higher priority in real estate investment decisions, the value implications of sustainability investment would become a more important part of the financial assessment process. In the future, without considering incremental value as well as risk and uncertainty, the financial analysis of a sustainable option investment will not be complete and might result in inappropriate investment decisions.

**Target Audience:** The outcomes of this research will communicate with property professionals in a proper language and benefit them in making high-quality investment decisions and appropriate choices among sustainable options. It will help them to understand the various risk and uncertainty sources in the assessment process of sustainable options which would impact the final financial performance and therefore the investment decisions.

The process could also be very helpful for design professionals to estimate the financial performance of sustainable options in a way that the property professionals can rely on and apply in their investment decision making. The framework will give design professionals a step-by-step procedure to follow to understand the impact of their design decisions on those factors that are important for the property professionals. This will increase the quality and the level of confidence of their design recommendations.

## 1.5 **Limitation of Research**

Every proposed solution and analytic technique did not turn out perfect, or the execution perhaps too difficult or costly for current practical application, but the work is an admirable step forward, helping guide future research development of improved tools and methods to integrate value and risk into sustainable investment decision-making (Muldavin, 02/05/2012, dissertation review notes).

The main purpose of this research is to map a practical assessment process in detail that decision-makers need to go through evaluate the more reliable financial performance of sustainable options. The case study attempts to demonstrate a way of quantifying and integrating the value and uncertainty into the financial assessment process. The interest in this research is in process rather than the outcomes; the proposed procedure is not considered as the perfect product, “but rather as process and thus as an ever-developing entity” (Laws & McLeod, n.d., p. 17).

This research is not intended to create a decision-making tool for sustainability investment in real estate but to explore a detailed assessment process to assist decision-makers to consider factors that are often ignored in current cost-benefit analysis, including value, risk, and uncertainty, when evaluating sustainable options investment. It is expected that through this work the process will be well developed to serve as foundation for creating a fully functional tool that would allow practitioners to apply the process more effectively in their decision-making process.

The proposed framework is applicable for evaluating major green retrofit options for existing income-producing properties from the perspective of private owner, investors, and landlords. The case study is limited in utilizing an energy simulation program (eQuest) and demonstrating the generation of

distributions of the energy performance indicators (KWh and KW savings). However, the methodology of this research can be adaptable for addressing other types of decisions and decision-makers while evaluating the different combinations of sustainable options in other property types.

The case study is not intended to generate any new information about green systems' performance or their quantitative relationships with financial performance throughout this dissertation. Nor is it aimed to produce the most accurate numeric outcomes. The accuracy of the outcomes is limited to the opinions of the experts who participate, the findings from existing literature and tools and researcher's time and resource.

This research is a starting point for the creation of an in-depth process to financially estimate the costs and benefits of sustainable features from a private sector perspective, and is not considered to be the final product. It is hoped that the suggested process will be extended over time to incorporate more factors in sustainable property valuation, and will evaluate the interactive effect of the different combinations of sustainability options with more building performance indicators.

## **CHAPTER 2 LITERATURE REVIEW**

In this Chapter, first the definition, trend, cost, benefits and risks related to sustainable property investment are addressed, and then the three areas illustrated in Figure 1-2 in Chapter 1, including issues related to sustainable property performance and systems, issues related to risk and uncertainty in property valuation, and issues related to sustainable property valuation, are discussed.

### **2.1 Sustainable Property Investment**

‘The future of our planet depends on our willingness to act now to ensure that as we build to improve the quality of life today, we do not compromise the quality of life for future generations’ (“Review of Sustainable Construction 2006 - A Summary,” 2006, p. 1).

#### **2.1.1 Definitions**

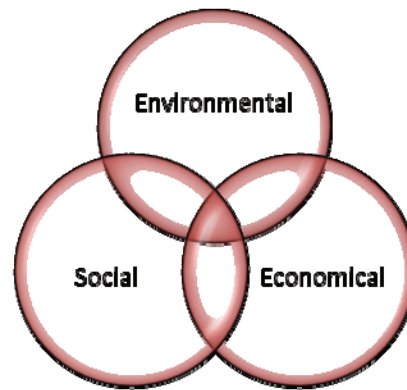
##### **2.1.1.1 Sustainable Development and Property**

**Sustainable Development:** The concept of sustainability and sustainable development is not new and has been discussed for more than fifty years in the U.S. The most common definitions of sustainable development as put forth by the United Nations World Commission on Environment and Development (WCED) in 1987 define sustainable development as development which meets the needs of the present without compromising the ability of future generations to meet their own needs. “This concept comprises two strong elements: (1) that of satisfying human needs and requirements (quality of life) and (2) that of intra- and intergenerational ethics (do not cheat your fellow citizens and children). To operationalize this concept the expression of the so-called ‘triple bottom line’ of sustainable development has evolved, i.e. sustainable development involves balancing economic and social development with environmental protection” (Thomas Lützkendorf & Lorenz, 2005, p. 213).

Pearce and Vanegas (2002) have suggested the following three key conditions which must be met in order for a built facility system to be sustainable. The conditions are 1) Stakeholder satisfaction  $\geq$  Basic needs met; 2) Resource base impact  $\geq$  No or natural impact; and 3) Ecosystem Impact  $\geq$  No or neutral impacts (p. 105).

It is generally accepted that sustainable development has three aspects: environmental, social and economical. However, there are different perspectives in the interpretation of sustainable development. For example, some view the three dimensions as being equal, as shown in Figure 2-1: Equal Dimensions,

while others believe the environmental aspect is the dominant aspect when seeking sustainable development.



**Figure 2-1: Equal Dimensions**

“The concept of sustainable development can be interpreted as the journey towards one final destination: ‘sustainability’. Sustainability is meant to be the desirable overall concept or goal of economies’ or societies’ development or evolution, respectively. The term circumscribes an equilibrium state of an economy or society with regard to environmental, economic and social conditions...Within property markets, several actors such as constructors, designers, engineers, researchers, governmental authorities, or certain occupiers and clients have been concerned with aspects of sustainable development for a considerable period of time.” (Thomas Lützkendorf & Lorenz, 2007, p. 645).

**Sustainable Property:** According to the American Institute of Architects (AIA) Committee on the Environment (COTE), “Sustainability envisions the enduring prosperity of all living things. Sustainable design seeks to create communities, buildings, and products that contribute to this vision”. They have determined 10 measures for sustainable design: Measure 1: Design & Innovation, Measure 2: Regional/Community Design, Measure 3: Land Use & Site Ecology, Measure 4: Bioclimatic Design, Measure 5: Light & Air, Measure 6: Water Cycle Measure 7: Energy Flows & Energy Future, Measure 8: Materials & Construction, Measure 9: Long Life, Loose Fit and Measure 10: Collective Wisdom and Feedback Loops (AIA website, COTE)

Muldavin (2009) has argued that from a financial perspective, sustainable property is what regulators, potential space users, and investors in the subject property defined as a sustainable property. “...it does not matter what the Consortium or anyone else says, only what regulators, potential space users, and



investors in the property being analyzed say. Proper financial analysis of a property requires explicit consideration of the potential benefits that will accrue through meeting regulator, user, and investor thresholds for sustainability” (p. 3 of Chapter III)

**‘Sustainable’ versus ‘Green’:** According to Lützkendorf & Lorenz (2007),

A sustainable building is meant to be a building that contributes through its characteristics and attributes to sustainable development. By safeguarding and maximizing functionality and serviceability as well as aesthetic quality a sustainable building should contribute to the minimization of life cycle costs; the protection and/or increase of capital values; the reduction of land use, raw material and resource depletion; the reduction of malicious impacts on the environment; the protection of health, comfort and safety of workers, occupants, users, visitors and neighbors; and (if applicable) to the preservation of cultural values and heritage. In contrast, a green building is meant to be a building that does not fulfill all the requirements of a sustainable building but which exhibits positive characteristics and attributes with regard to the following areas: energy efficiency, resource depletion, impacts on the environment as well as protection of occupant health and comfort. It needs to be noted that green building approaches do not necessarily cover all these aspects. Two common green building approaches are usually termed ‘building ecology’ (with a focus on energy, resources and the environment) and ‘building biology’ (with a focus and health and comfort). However, the boundaries between sustainable and green buildings overlap; and sometimes buildings that cover all aspects of sustainable development are termed ‘green’. In summary, although the transition from the green building approach to a sustainable building approach has started, it is far from being complete in terms of content and practical application. (Thomas Lützkendorf & Lorenz, 2007, p. 646)

However, sustainable buildings are often equated to ‘green buildings’. Muldavin (2009) has used the terms “sustainable” and “green” interchangeably in his report and has stated that:

often in the industry and media these two terms are used synonymously and interchangeably. Readers should be aware that the terms “green,” “sustainable,” and “restorative” design and construction are not well defined or consistently applied or understood in the industry. From a financial perspective, what is important is to understand a property’s combination of sustainable features or attributes and to recognize that a property’s “sustainability” is really a continuum: from making basic changes in operations and maintenance practices to the design and

development of restorative buildings that maximize benefits to the environment and community (p. 2 of Chapter III).

Kats (2003) has also regarded them as synonymous.

‘Green’ or ‘sustainable’ buildings use key resources like energy, water, materials, and land much more efficiently than buildings that are simply built to code. They also create healthier work, learning, and living environments, with more natural light and cleaner air, and contribute to improved employee and student health, comfort, and productivity. Sustainable buildings are cost-effective, saving taxpayer dollars by reducing operations and maintenance costs, as well as by lowering utility bills (p. v).

According to Sayce, Ellison and Parnell (2007),

This implies an environmental interpretation of sustainability based on resource consumption and pollution. It also implies that legislation may not reach a point at which there is a requirement to specify a green building: implicit within the specific definition quoted above is that sustainability is a moving goal with ‘green’ or sustainable being reserved for those that are built ‘beyond compliance’ with regulation (p. 631).

The term ‘sustainability’ is the preferred term in some regions such as Europe, while ‘green’ is a more common in others such as the U.S. and Canada. As introduced in section 2.4.3.3, most of the authors of similar studies around the world have used the term ‘sustainable property’ in their papers. Therefore, the term ‘sustainable property’ is used throughout this research. However, if sources that are analyzed or cited have used other terms such as ‘green buildings’ or ‘high-performance buildings’, the original terms are retained.

### **2.1.1.2 Socially Responsible Property Investment Approach**

“Responsible property investing (RPI) is a new approach in property investment that focuses on the "triple bottom line", which would take into account social, environmental, and financial returns on the investments. It has been referred to by the Wall Street Journal as “real estate's latest movement” (as cited by Pivo, 2008b, p. 21). According to Pivo and McNamara (2005), RPI means “maximizing the positive and minimizing the negative social and environmental effects of property investing, consistent with fiduciary responsibilities” (p. 130). Socially responsible investing (SRI) in general, according to the Social Investment Forum (SIF), means investing “that considers the social and environmental consequences of investments, both positive and negative, within the context of rigorous financial analysis” (as cited by Pivo, 2005, p. 15). It focuses on the ‘triple bottom line’, which would take into

account social, environmental, and financial returns on the investments. The goal is to help solve societal and ecological problems while also managing their associated business risks and opportunities. “Ethical and environmental investment criteria, collectively grouped under the title socially responsible investment (SRI), are becoming increasingly important factors in today's markets” (Jayne & Skerratt, 2003, p. 1). “The growth in SRI provides prima facie evidence that financial returns may not be the only criteria used by a significant number of investors, and that ethical and social considerations may also play an important role” (Williams, 2007, p. 43).

“Responsible property investing is defined as efforts that go beyond compliance with minimum legal requirements to better manage the environmental, social, and governance issues associated with property investing” (Pivo, 2008a, p. 235). Pivo (2005) has claimed that there are potentially large and growing opportunities for real estate investment focused on socially responsible property investment (SRPI). “The total dollars in socially responsible investing (SRI) of all kinds, including pension funds, mutual funds, foundations, religious organizations, and community development financial institutions all of which have a current or potential interest in real estate investing exceed \$2 trillion” (p. 18). Pivo (2008) has also found that 74% to 82% of the U.S. organizations are engaged in some form of RPI in different levels in implementing management strategies such as conservation and investing in properties such as green building (p. 244). According to Floca and Pivo (2007) “the rationale behind RPI is that real estate investors and developers increase the positive social and environmental externalities associated with development and ownership without sacrificing financial returns” (para. 3).

This emerging trend of Socially Responsible Property Investment in the international property sector suggest that the property industry has become mature enough to recognize that all three dimensions of sustainability could have impacts on the property value. “The inclusion of all three drivers of sustainability is central to any development of a potential property market response to sustainability” (Ellison, Sayce, & Smith, 2007, p. 192).

Substantial evidence shows that real estate investors are now becoming more concerned about the measurement of total real estate costs instead of focusing on operational cost savings by looking at issues, such as accessibility<sup>4</sup>, adaptability<sup>5</sup>, pollution<sup>6</sup>, etc. (social aspects) that influence cost and tenant demand,

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<sup>4</sup> In an office with poor accessibility, staff turnover is likely to be higher and therefore recruitment costs become higher and ultimately potentially tenant demand and therefore rental growth might be reduced.

<sup>5</sup> The ability to reconfigure space easily can increase useable space, potentially reducing space costs and ultimately increasing rental growth.

<sup>6</sup> Pollution might increase the risk of an environmental issue and associated cleanup costs, which may affect cash flow (Ellison, et al., 2007, p. 197).

and thereby affect rents and rental growth. Lützkendorf and Lorenz (2005) have also argued that “serviceability and functionality should be seen as an integral part of a building’s contribution to sustainable development. Taking all these requirements [the issue of satisfying users’ and occupants’ needs] into account, allows viewing property from a full ‘cost–benefit’ or ‘input–output’ perspective, respectively, including commonly accepted values and the interests of all stakeholders involved” (p. 214).

### **2.1.2 Sustainable Property Investment Trend**

“In recent years the acknowledgement of our impact upon the earth and consequent effects for the future, commonly referred to as ‘climate change’, has become a primary issue in all industries. In the property industry this has led to the development and promotion of sustainable buildings” (Myers, Reed, & Robinson, 2007, p. 2). Increasingly, sustainability and efficiency – going “green,” as it were – are explicit considerations in the planning and construction of major development projects. With heightened public awareness and concern about global warming and ongoing increases in energy costs, the case for green development seems to have gained mainstream acceptance (Smith, 2007, p. 1).

With the concerns for climate change, global warming, and rising energy costs, substantial evidence suggests that currently there is a dramatic shift in demand for sustainable property by space users, government regulators, and the real estate investors. Smith (2007) has stated that as more businesses conclude that green or sustainable practices address a myriad of competitive, organizational and, potentially, regulatory challenges, increasing demand for green space will create new risks and opportunities for owners and builders....the competitive advantages that green buildings offer tenants leave little doubt that perceptions will change, especially as the cost differential between green and non-green development narrows and the supply of green alternatives increases (p. 7).

According to Yudelson and Galayda (2008), the green building market is large and growing quickly. Between year-end of 2005 and the end of 2006, new LEED project registrations grew by more than 50 percent on a cumulative basis. In 2007, with new project registrations growing at a 75 percent cumulative rate from the end of 2006 (p. 15).

Nelson (2009), in a recent study on trends of sustainable real estate in the U.S. during the recession conducted by RREEF research, has concluded that savvy, cash-rich investors will find numerous opportunities to capitalize on these trends [sustainable real estate], even during the recession, while owners that fail to adapt quickly to the new standards may find their viability jeopardized (p. 1)

### **2.1.2.1 Existing Property Improvement Investment and Green Retrofits**

Improvement or green retrofits today are recognized as excellent investment opportunities among property investors and owner-occupants. The recent shift towards achieving LEED for Existing Building among the investor-owners suggests an increased awareness of potential returns inherent in improvement investment. These potential returns include higher employee productivity and recruitment, lower absenteeism, lower tenant turn-over, and lower operating costs.

As Ciochetti and McGowan (2009) have stated, new construction represents less than 2% of the entire stock of commercial buildings in the U.S. today. Of the nearly 4.6 million commercial buildings in the U.S., 75% (3.4 million) were built prior to 1990. Not surprisingly, most of these buildings have much larger carbon footprints and energy consumption needs due to design inefficiencies, outdated systems, and a general lack of understanding of the benefits that may accrue to investment in EEI (p. 6).

Historically investor-owners have less of an incentive to invest in improvements for their properties rather than owner-occupiers who tend to have a longer outlook on their real estate holdings. Investor-owners have until recently received little or no additional monetary reward for the improvements incurred from the marketplace. Ciochetti and McGowan (2009) have put forth five of the most compelling reasons for the recent increased interest in improvement investment in investor-owned buildings:

- 1) The Threat of New Green Construction
- 2) Green is a New Amenity
- 3) Tenant Demand
- 4) Investor Demand
- 5) Responding to Climate Change (pp. 25-28)

As Nelson (2009) said, investors in many markets will find that sustainability is a necessary and appropriate defensive strategy for preserving occupancy, particularly for owners of older office buildings and shopping centers most at risk of losing tenants to newer, greener buildings coming into the market (p. 15).

### **2.1.3 Cost, Benefits and Risks of Sustainable Property Investment**

There are scores of studies that discuss costs and benefits of sustainable property investment, some of which address the potential positive and negative risks. Below are presented some findings concerning costs and benefits of sustainable property investment:

Bowman and Will (2009) grouped the benefits of sustainable property investment based on their findings from eight case studies (Green Star buildings in Australia) into economic, social and environmental gains:

**Economical benefits:**

- Construction costs were equal to, and in two instances lower than, budget expectations.
- The owners/managers all believe that the buildings are future-proofed against rising energy costs, market rejection of non-green buildings and tightening regulations on building sustainability performance.
- Owners commonly made use of the asset's sustainability performance for marketing purposes, not only to assist in the sale of the asset or leasing of the space, but to demonstrate their green credentials to the wider market.
- Green Star rated buildings appear easier to sell – it is not possible yet to infer whether this also adds a price premium, but a faster sale potential alone should infer value via a tighter capitalisation rate.
- Let up periods were reduced by improved exposure and marketing from being 'green'.
- Attraction of 'blue chip' tenants was improved by meeting tenant requirements and briefs. Importantly, the case studies reveal that these tenants are prepared to pay for 'green'.
- Lease terms reveal a preference by green tenants for what, in the Australian marketplace, would be considered long-term leases, e.g. 15–20 years. This in turn leads to increased cash flows for owners.
- Green leases improve tenant certainties on costs (capital costs and long term recurrent costs).
- No significant changes to facility management contracts were evident.
- The market responded to Green Star ratings overall rather than to the individual designs and technologies used to achieve the rating. Some owners/managers felt that this may change as market sophistication increases, so valuers may need to identify individual sustainability features in much the same way as they do with say an attractive vista in conventional buildings.

**Environmental benefits:**

- Most of the case studies make optimum use of the sites on which they are located, i.e. how the land is prepared, orienting the building to maximize the use of solar power for heating and lighting, and shade for cooling.
- Green Star buildings reduce water consumption (e.g. low flow, recycling and capture), energy (e.g. lighting strategy controls, efficient lighting, use of natural light) and reduced waste. For example, the simulated carbon emissions from the Richmond Airbase building are equivalent to taking 50 cars off the road each year.
- The use of recycled and renewable materials, together with waste management plans, significantly reduces waste.

- All of the Green Star buildings studied claimed better Indoor Environment Quality (IEQ) compared to conventional buildings via improved ventilation, low emission finishes, better natural light and improved thermal comfort.

**Social benefits:**

- Green Star buildings claim improvements in productivity, wellbeing, and occupational health and safety. A number of the organisations have undertaken post-occupancy evaluations that support this, but direct evidence of better workplace productivity as a result is limited.
- Green Star buildings have served as demonstrations of how to build, operate and profit from green buildings, with flow-on benefits into the wider community understanding of sustainability.
- Green Star buildings preferentially select proximity to public transport and so discourage private car use (p. 20).

Kats (2003) in his study on cost and financial benefits of green building has concluded that the financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy (p. v).

Davis Langdon (2007), a global construction consulting firm, in their study of the costs of green buildings (LEED buildings) have found that there is no significant difference in average [construction] costs for green buildings as compared to non-green buildings. Many project teams are building green buildings with little or no added cost, and with budgets well within the cost range of non-green buildings with similar programs.

One of the most comprehensive lists of costs and benefits of sustainable property as well as risks associated with sustainable property investment was developed by the Green Building Finance Consortium (GBFC)<sup>7</sup>. The GBFC cost-benefit checklist is presented below:

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<sup>7</sup> Green Building Finance Consortium (GBFC) is explained in section 2.4.3.3.1.

## **I. Potential Building Benefits**

### **A. Reduced Development Costs**

1. Government incentives
2. Better private financing
3. Downsizing of some systems (HVAC, etc.)
4. Reduced number and magnitude of change orders
5. Reduced operational start-up costs

### **B. Reduced Development Risks**

1. Reduce construction risk
2. Reduce carry risk
3. Reduce exit/take-out risk

### **C. Increased Space User Demand: Higher Revenues**

1. Increased demand from space users concerned about enterprise value
2. Increased demand from government tenants with mandated sustainability
3. Increased demand from vendors/supply chain required by big customers (GE, Wal-Mart, etc.) to be more sustainable
4. Increased demand from tenants with direct tie to sustainability business—architects, engineers, consultants, contractors, lawyers, energy firms, product companies, etc. etc.
5. Increased demand from tenants wanting to “do the right thing”

### **D. Reduced Resource Use / Operating Costs**

1. Lower energy use
2. Lower water use
3. Reduction in sewage/storm water run-off
4. Reduction in building waste
5. Reduction in construction/demolition waste
6. Reduction in carbon footprint
7. Lower emissions
8. Lower property/casualty insurance costs
9. Lower maintenance costs

### **E. Improved Building Operations**

1. Reduced cost of changing space
2. Fewer tenant/occupant complaints
3. Reduced frequency of capital expenditures
4. Reduced tenant turnover/re-leasing
5. More reliable functioning of systems

### **F. Reduced Cash Flow/Building Ownership Risk**

1. Improved ability to meet future regulatory requirements
2. Ability to capitalize on future government incentives
3. Improved ability to meet changing space user demand
4. Improved ability to meet changing investor demand
5. Prevent risk of loss of “social license” to operate building
6. Limit liability due to building related health issues—sick building, mold claims
7. Limit exposure to future compelling health and/or productivity research
8. Reduced risk of reliance on grid (terrorism)
9. Increased flexibility/adaptability
10. Reduced risk of building not operating as designed
11. Limit exposure to energy/water cost volatility
12. Reduced exit/take-out risk



13. Overall reduced potential loss of value due to functional, economic and physical obsolescence

#### **G. Public Benefits<sup>8</sup>**

1. Infrastructure cost benefits
2. Environmental and resource conservation benefits
3. Land-use benefits
4. Reduced climate change
5. Economic benefits
6. Security benefits

#### **H. Increased Investor Demand**

1. Reduced capitalization and discount rates: higher values
2. Reduced exit/take-out risk
3. Increased FAR—zoning---density bonuses
4. Improved access to debt financing

## **II. Potential Building Costs**

#### **Increased Development Costs**

1. Certification, energy modeling, legal and commissioning costs
2. Higher cost specialized service providers
3. Higher cost products and systems
4. Higher tenant improvement costs for green improvements
5. Higher finance costs—more high cost equity; increased construction interest
6. Project delays

#### **Increased Development Risk**

1. Construction risk (cost and delays)
2. Legal/contractual risks
3. Exit/take-out risk

#### **Decreased/Unchanged Space-User Demand**

1. Excess investment cost relative to market demand
2. Space user demand does not meet expectations
3. Building operating problems

#### **Increased Operating Costs**

1. Higher maintenance costs--training, manuals
2. Vendor availability and pricing
3. Product or system failure/underperformance
4. More costly lease analysis and implementation
5. Higher real estate taxes
6. Costs of required additional monitoring/measurement
7. Resource cost increases

#### **Building Operating Problems**

1. Products underperform
2. Service providers underperform

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<sup>8</sup> Public benefits become private investor/landlord benefits when the investor/landlord can monetize the benefits through government regulatory relief, incentives, tax benefits, etc.

3. New systems learning curve for engineering staff/maintenance staff/etc.
4. New/different systems can reduce economies of scale for engineering staff for a concentrated portfolio of similar assets
5. Capacity/seasoning of service providers/contractors
6. Tenants do not cooperate

**Increased Cash Flow Risk**

1. Risk of rapid functional obsolescence
2. Process underperformance
3. Operating cost underperformance
4. Revenue underperformance
5. Value/sales price underperformance

**Limited/No Increase in Investor Demand**

1. Increase/no change in capitalization and discount rates
2. Energy cost declines increase pay-back periods, reduce value of sustainable investment
3. Existing leases limit ability to pass costs to tenants--capture sufficient benefits to justify costs
4. Failure of appraisers/brokers to accept value/enhanced performance (Muldavin, 2010, pp. 113-114)

**2.1.3.1 Sustainable Property Investment Risks**

Sustainable property investment process includes a certain degree of risks, both positive and negative, as well as uncertainties. “Reduced cash flow/building ownership is an important contributor to an increase in space user demand, which can directly improve revenues, and to an increase in investor demand, resulting in higher value through reduced discount and capitalization rate” (Muldavin, 2010, p. 136). As part of the investment decision-making process, understanding a full scope of risks both positive and negative, and uncertainties associated with key financial inputs are critical in making informed investment decisions.

As fully explained in section 2.3.2, risk is defined as probability of not achieving the final financial outcomes. To date, no method has been developed to present and articulate risks and uncertainties of sustainable property investment in form of probabilities and distributions. The decision-makers are in need of a system that gives them clear, reliable and understandable information about risks and uncertainties. As part of appropriate presentation of risks, Muldavin (2009) has recommended “a focus on better articulation of the probability of outcomes being achieved—a more clear and articulate statement of uncertainty—when probabilities are not known” (p. 78). This is one of the deficiencies that this research will attempt to address. Ellison, et al. (2007) has said,

Sustainability represents an additional and changing set of risks for property investors and as such needs to be examined systematically for those risks to be properly understood and mitigated. It seeks to make the bundle of issues referred to as ‘sustainability’ explicit within the appraisal

process in order that their impact on property worth can be more effectively examined and assessed from a property investment perspective (pp. 191-192).

It has been discussed that in real estate investment a substantial amount of negative risks can be mitigated if they can be fully understood. Risk can be mitigated through a variety of traditional methods such as legal contracts, insurance, guarantees, pre-leasing, or high quality due diligence. “Real estate people like risk; it is how money is made. They just want to be able to understand it well enough to properly price and mitigate it” (Muldavin, 2010, p. 134)

## 2.2 **Sustainable Property Performance and Systems**

### 2.2.1 **Building Performance**

“Property performance is a very broad concept and performance means different things to different people. But in a very general sense, it may be defined as behavior in use. More precisely, performance can be understood as the degree of compliance of user/ owner requirements with corresponding building characteristics and attributes” (Lützkendorf & Lorenz, 2006, p. 222). “Buildings don’t perform; the people who design, build, and use them do. Building performance then, is merely a reflection of designer, builder, and user performance” (Rush, 1986, p. 231).

“According to Cole (1998), the definition of building performance varies according to the different interest of parties involved in building development. For instance, a building owner may wish his building to perform well from a financial point-of-view, whereas the occupants may be more concerned about indoor air quality, comfort, health and safety issues. Using a single method to assess a building’s environmental performance and to satisfy all needs of users is no easy task. Therefore, an ideal environmental building assessment will include all the requirements of the different parties involved in the development” (Ding, 2008, p. 451).

In this section two different perspectives concerning building performance, one from the perspective of a design professional (architects/engineers) and the other from the perspective of a property professional, (real estate experts) are discussed.

#### **2.2.1.1 Building Performance from the Perspective of Design Professionals: The American Institute of Architects (AIA)**

Richard D. Rush, AIA (1986) editor of *The Building Systems Integration Handbook* published by The American Institute of Architects (AIA) has presented a model for building performance criteria, and has

explained the interrelationship of integrated building systems to each performance area. He has stated that “Fundamentally, performance is the measurement of the achievement against the intention. The communicated performance of the ultimately integrated system or building is a measure of the satisfaction of the various building clients. This satisfaction might be stated in terms of such goals as comfort, efficiency, and beauty or in terms of their physiological, psychological, sociological and economic desires” (p. 232). Rush (1986) has outlined the six performance mandates and has examined how building systems may contribute in each performance area. The six performance mandates include spatial performance, acoustical performance, thermal performance, air quality, visual performance, and building integrity. The building systems include HVAC systems, lighting systems, telecommunication, power, security, plumbing, and vertical transportation. The expanded outline of these six performance mandates has been illustrated in Table 2-1 in order to express the sets of conditions (created by building systems) that contribute to delivery in each performance area.

**Table 2-1: Six Building Performance Mandates (AIA) (Rush, 1986, p. 233)**

<b>1. Spatial Performance</b>	<ul style="list-style-type: none"> <li>A. Individual space layout: size furniture, ergonomics</li> <li>B. Aggregate space layout: adjacencies, compartmentalization, usable space, circulation/accessibility/way finding/signage/indoor-outdoor relation</li> <li>C. Conveniences and service: sanitary, electrical, security, telecommunications, circulation/transportation</li> <li>D. Amenities</li> <li>E. Occupancy factors and controls</li> </ul>
<b>2. Thermal Performance</b>	<ul style="list-style-type: none"> <li>A. Air temperature</li> <li>B. Radiance temperature</li> <li>C. Humidity</li> <li>D. Air speed</li> <li>E. Occupancy factors and controls</li> </ul>
<b>3. Indoor Air Quality</b>	<ul style="list-style-type: none"> <li>A. Fresh air</li> <li>B. Fresh air movement and distribution</li> <li>C. Mass pollutions</li> <li>D. Energy pollutions</li> <li>E. Occupancy factors and controls</li> </ul>
<b>4. Acoustical Performance</b>	<ul style="list-style-type: none"> <li>A. Sound source</li> <li>B. Sound path</li> <li>C. Sound receiver</li> </ul>
<b>5. Visual Performance</b>	<ul style="list-style-type: none"> <li>A. Ambient and task level: artificial light and daylighting</li> <li>B. Contrast and brightness: ratios (glare)</li> <li>C. Color renditions</li> <li>D. View/visual information</li> <li>E. Occupancy factors and controls</li> </ul>
<b>6. Building Integrity</b>	<ul style="list-style-type: none"> <li>A. Loads, dead loads, live loads, impact, abuse, vandalism, vibration, creep</li> <li>B. Moisture: rain, snow, ice, and vapor resulting in erosion, penetration, migration, condensation</li> <li>C. Temperature: thermal gradient (insulation effectiveness), thermal bridging, freeze-thaw cycle, differential thermal expansion and contraction</li> <li>D. Air movement: erosion, abrasion, tearing, air infiltration, ex-filtration and</li> </ul>

- 
- pressure differential
  - E. Radiation and light: environmental radiation, electromagnetic long wave (solar radiation), visible light spectrum
  - F. Chemical attack
  - G. Biological attack
  - H. Fire
  - I. Natural disaster: earthquake, flood, hurricane, tidal waves, volcanic eruptions, etc.
  - J. Man-made disaster
- 

According to Rush (1986),

The first five mandates compromise interior occupancy requirements (human, animal, plant, and artifact occupancies) and the elemental parameters of health, safety, and well being in relation to the spatial quality, thermal quality, air quality, acoustical quality and visual quality of spaces being designed. Responsibility for delivering these occupancy performance mandates has been divided largely along disciplinary lines. Architects have taken primary responsibility for spatial quality and delegated responsibility to mechanical engineers for thermal quality and air quality, to lighting engineers for visual quality, and to acoustical engineers for acoustical quality (Rush, 1986, p. 232).

The components in the right part of Table 2-1: Six Building Performance Mandates (AIA) (Rush, 1986, p. 233), especially for the first five mandates, indicate the criteria of building performance for each mandate. These factors, which result from the employed building systems such as HVAC systems or daylighting strategies, refer to building performance indicators in this research.

#### **2.2.1.2 Building Performance from the Perspective of Property Professionals: Green Building Finance Consortium (GBFC)**

Muldavin (2010), the executive director of Green Building Finance Consortium (GBFC) and the president of The Muldavin Company (a real estate company), has declared that building performance—with emphasis on sustainable property performance—include development costs, resource use, location & access, occupant performance, sustainability compliance, and public benefits. His outline for building performance is illustrated in Table 2-2:

**Table 2-2: Building Performance (GBFC) (Muldavin, 2010, p. 211)**

<b>1. Development Costs</b>	A. Hard/soft costs B. Timing C. Tax savings grants D. Financing costs
<b>2. Resource Use</b>	A. Energy B. Water C. Insurance D. Waste E. Disposal F. Cap Ex., Etc.
<b>3. Location &amp; Access</b>	A. Non-auto accessibility B. Accommodation of low-energy autos C. Environmental sensitivity of site
<b>4. Occupant Performance</b>	A. Satisfaction B. Health C. Productivity
<b>5. Sustainability Compliance</b>	A. Certifications B. Regulations C. Occupant Policy
<b>6. Flexibility/ Adaptability</b>	A. Design B. Materials C. Systems D. Energy Sources
<b>7. Public Benefits</b>	A. Infrastructure cost reduction B. Environmental benefits C. Land-use benefits D. Emissions improved E. Economic benefits

*“Sustainable property performance at the building level is the foundation for valuation and financial analysis. Understanding development costs, resource use, occupant performance, the level of sustainability achieved, and the location and flexibility of a building is critical to being able to assess potential demand for “sustainability” from the market.” (Muldavin, 2010, p. 61). The building performance information provides the basis upon which the market analysis could be conducted for understanding market demand and ultimately the value of a property.*

Given the focus of this research on financial analysis and valuation of sustainable options (green systems and strategies), building performance factors for analysis in this research will be selected based on the Table 2-2, suggested by GBFC, for sustainable property performance valuation.

## 2.2.2 Existing Tools Used for Sustainable Property Evaluation

Many techniques and assessment tools are currently used by decision-makers for evaluating the sustainable properties/options. In terms of the current requirements and capability of existing building assessment tools. Lützkendorf and Lorenz (2006) have argued:

Existing environmental and energy-related tools have been predominantly developed at universities and by research establishments and, thus, do not necessarily serve today's decision-makers' information demand. Although architects, construction industry representatives and marketing experts did participate in the development and testing of these assessment tools, the tools' application leads to a mismatch of information supply and demand. This is because the end users of information (e.g. investors, property valuation professionals, banks or insurance agencies) have neither fully recognized nor appropriately formulated their particular requirements for assessment results associated with investment decisions, property valuations or risk assessments.... there is an increased demand for comprehensible assessment results and applicable tools that can be used to validate a single building's contribution to sustainable development or their economic, environmental and social advantages. The linkage of assessment results with far-reaching financial aspects (e.g. taxation, lending and insurance conditions, valuation and reporting) will change the role of assessment tools and impose stricter requirements in terms of the traceability, liability, comparability and certainty of assessment results. In addition, assessing a building's contribution to sustainable development requires an integrated building performance approach that allows one to describe and assess buildings with respect to all dimensions of sustainable development including aspects of functionality and serviceability as well as the quality of planning, construction and management processes (pp. 336-337).

In this section, some of these tools are introduced and explained. The purpose of this section is to emphasize that *none of these tools on their own are sufficient to rely upon for making high-quality investment decisions at the property level.*

### 2.2.2.1 Building Simulation Program

Many simulation and evaluation software tools have been developed to assist design professionals such as architects, engineers and builders as well as owners in designing and planning their projects at the pre-development stage. These tools primarily provide users with forecasts of the impacts of design decisions on building performance mandates discussed in previous sections. Some of the tools also perform simple financial evaluations primarily based on simple payback and simple return on investment approaches.

They take the building systems and strategies as inputs, and evaluate and project the building performance or simple financial performance as outputs.

The U.S. Department of Energy (DOE) has developed a directory which contains information on 374 building software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings. The energy tools listed in this directory include databases, spreadsheets, component and systems analyses, and whole-building energy performance simulation programs. The tools are categorized in five types: energy simulation, load calculation, renewable energy, retrofit analysis, and sustainability/green buildings. A short description is provided for each tool along with other information including expertise required, users, audience, input, output, computer platforms, programming language, strengths, weaknesses, technical contact, and availability (The Department of Energy Website). One could go through these lists and select the appropriate tools based on the types of the decisions, building systems (inputs) and building performance (outputs) she/he is interested in evaluating.

Hien, Poh, and Feriadi (2000) have divided the tools based on the different building performance mandates in following categories:

- Energy analysis and HVAC system sizing, such as AkWarm, ASEAM, BLAST, Builder Guide, Building Design Advisor (BDA), BUS++, DesiCalc, DOE-2, ENER-WIN, Energy Scheming, Energy-10, ENERPASS, ESP-r, EZDOE, FEDS, etc.
- Ventilation and indoor air quality (multi-zone network models and computational fluid dynamics (CFD) models), such as BUS++, COMIS, IAQ-Tools, Indoor Humidity Tools, Vent-Air 62, EMISS, CONTAM96, FLOVENT, etc.
- Natural and electrical lighting, such as ADELIN, AAMASKY, AGI, COMCheck-EZ, ENVSTD and LTGSTD, FLEX, LIGHT, LIGHTCAD 2.0, LIGHTPAD 1.0, etc.
- Acoustical performance, such as finite element method (FEM) and boundary element method (BEM) (pp. 710-725).

### **2.2.2.2 Sustainable Certifications and Green Building/Energy Rating Systems**

Many certifications and rating systems have been developed by third parties to benchmark the design, construction and operation of sustainable properties. These tools include but are not limited to Leadership in Energy and Environmental Design (LEED), Building Research Establishment's Environmental Assessment Method (BREEM), Energy Star label, Green Globes, National Australian Built Environment Rating System (NABERS), and GB Tool. These systems are primary measurement systems designed to assess and rate the environmental performance of a building.



“A third-party green building rating system gives owners, managers and tenants, along with their professional team of engineers, architects and contractors, the ability to benchmark building design and performance. The purpose of assessing and benchmarking the performance of a design or operations of a building is largely to make measurement possible. Whether to comply with a government mandate or to differentiate a product, the more a developer or owner is able to measure green building performance, the better a management team can do its job. This adoption of standards, along with compelling financial savings, brings clarity and organization to the greening of construction and building operation within the commercial real estate arena” (Ciochetti & McGowan, 2009).

Although these tools /certifications have been designed to measure the environmental performance of a building, they can play a role in the financial assessment of sustainable properties. They provide a foundation upon which real estate investors and tenants may compare the building performance. Therefore, these certifications could have the potential to impact the investors’ and space users’ demand and ultimately financial performance of sustainable properties.

### **2.2.2.3 Building Performance-Based Techniques**

Decision-makers, both technical and financial, used a variety of techniques to evaluate the environmental, economic and social performance of sustainable properties.

According to Lützkendorf and Lorenz (2006),

The performance-based building approach has its roots in describing and assessing a building’s functionality, serviceability, and the compliance of user/owner requirements with corresponding building characteristics and attributes...However, research in the area of ‘green building’ has focused on the assessment of environmental and (to some extent) health-related attributes of buildings. The further development towards the ‘sustainable building’ approach led to the inclusion of economic and social aspects that resulted in a substantially widened scope of assessment criteria (p. 345).

These techniques include Life Cycle Costing (LCC), Life Cycle Assessment (LCA), Post Occupancy Evaluation (POE), General Cost-Benefit Analysis (CBA), and Value Engineering (VE).

### **2.2.2.3.1 Life Cycle Cost Analysis (LCCA)**

Many investment decisions regarding building construction and improvement are made based on outcomes of LCCA. According to the *Life Cycle Cost Analysis Handbook* developed by the Department of Education and Early Development (1999),

The National Institute of Standards and Technology (NIST) Handbook 135, 1995 edition, defines Life Cycle Cost (LCC) as “the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system” over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over period of time. Life Cycle Cost Analysis can be performed on large and small buildings or on isolated building systems...one can breakdown the LCC equation into the following three variables: the pertinent costs of ownership, the period of time over which these costs are incurred, and the discount rate that is applied to future costs to equate them with present day costs (pp. 2-4).

According to Lützkendorf & Lorenz (2006),

LCC calculations usually consist of the following elements: initial capital cost for design and construction or acquisition, management and operating costs, costs for maintenance and renovation, costs incurred or benefited from the building’s disposal. Recently, however, attempts are being made also to include the income generated by the property within the calculation (p. 223)

According to Bradshaw, et.al (2005),

Life-cycle costing accounts for factors beyond the initial design and construction cost of a building and includes costs that occur during the operational phase (e.g., energy, water, maintenance) as well as future costs... Unlike traditional costing, life-cycle costing takes into account the benefits associated with these future cost savings which offset, at least in part, the incremental purchase cost of systems such as better windows. Of course, future costs and savings must be adjusted to their equivalent value today, i.e. their “present value” (p. 35).

Thus, LCC would assist decision-makers in the selection of the investment alternatives by focusing on the full costs and costs saving over the life cycle of the property. Although it is a more robust approach than a simple payback or a simple return on investment—which primarily focus on initial cost—it ignores the non-cost benefits of the investment. It might be a helpful method for minor decisions, such as selection

between two types of HVAC systems with different cost and cost saving, but not enough for major investment decisions.

*The LCC method does not incorporate the environmental and social benefits of sustainability nor does it consider sustainability risks in its evaluation process. Therefore, it is not sufficient for thorough assessment of a sustainable property for the purpose of investment decision-making at the property level.*

#### **2.2.2.3.2 Life Cycle Assessment (LCA)**

According to The Swiss Federal Office for the Environment (FOEN),

A life cycle assessment gives a list of all the environmental impacts that a product causes during its entire life cycle. It is a useful way of making a practical numerical summary of the approach to products in terms of their life cycles in relation to their ecological effects. The method includes all significant adverse environmental impacts during the extraction of the raw materials, the manufacture and the use of the product, until it is disposed of as waste. Analysis using the method of life cycle assessment contributes to deepening integrated thinking (in business, in administration and amongst the public)...The use of this method in business helps in the understanding of product life cycles, which are becoming increasingly important in ensuring economic success (as cited in "The ICMIA Guide On The Basic Principles of Life-Cycle Assessment (LCA)," 2007, p. 3).

According to De Benedetto & Klemes (2009),

LCA involves the evaluation of specific elements of a product system to determine its environmental impact. The implementation varies depending on the adoption pattern and on the precision that needs to be achieved...It is composed of a conceptual framework and a set of tools that have been studied and developed in the last 30 years. The core of the concept is the assessment of the impacts at each stage of the product life cycle (p. 900).

According to Lützkendorf and Lorenz (2005),

LCA has been developed as a result of a more responsible attitude towards the environment. Usually LCA examines energy and mass flows in order to provide information on resource consumption and determine the origin of harmful environmental loads which have potential effects on global warming, acidification, ozone depletion, biodiversity, eco-toxicity, human toxicity and on occupational and living health...While current assessment schemes take the issue

of occupant health into consideration, there is less focus on occupant satisfaction, functional fit and productivity. They do not provide information on what kind of building solutions work best in practice and why. (p. 224).

Relative to inadequacy of LCA for marketing and valuation of sustainable properties, Lützkendorf and Lorenz (2006) have said that,

, existing LCA-based tools have been solely focused on the assessment of new buildings at the design and planning phase or shortly after completion. Methodical problems exist in connection with the assessment of existing buildings (e.g. the treatment of embodied energy). Another problem regarding LCA-based tools is that although approaches such as the ‘Eco indicator’ or ‘environmental impact scores’ exist, there is a lack of a commonly accepted method for summarizing or aggregating assessment results. In sum, there is a conflict between researchers’ claims and marketing demands that hampers the use of LCA-based results for marketing purposes (p. 338).

Currently, LCA is widely used as one of the best approaches for evaluating the environmental and some of the social aspects of sustainability. Some studies have been done for developing new approaches using the LCA concept in order to incorporate the environmental indicators with other dimensions of sustainability *However, to date, the LCA approach is unable to deal with some of the social aspects of sustainability, such as occupant satisfaction or productivity. Furthermore, it is not well suited to incorporate the full investment risks and thorough concept of value in the way that assists real estate investors to make specific investment decisions at the property level.*

*Life-cycle benefits may not have a market value, or they may be reduced. For example, a buyer may not be prepared to pay for the entire benefit of a geothermal system or energy reduction program, because it may be risky or have questionable life term. Thus, not all life-cycle value is captured in market value (Corps, 2007, p. 7).*

### **2.2.2.3.3 Value Engineering (VE)**

Value Engineering (VE) is a process of evaluating projects to find methods and materials that are less expensive than the specified requirement, but do not decrease the value of the completed project...VE is rigorous, systematic effort to improve the value and optimize the life cycle costs of a project. According to Dell’Isola three basic elements provide a measure of value to the user: function, quality, and cost. These elements can be interpreted by the following relationship:

Value = (Function + Quality) / Cost, where

Function = The specific work the project or design must perform

Quality = The owner's need, desires, and expectations

Cost = The life Cycle cost of the project, therefore, we can say that:

Value = The most cost-effective way to accomplish a function that will meet the owner's needs, desires, and expectations (as cited in Knutson, Schexnayder, Fiori, & Mayo, 2009, p. 89).

According to Value Engineering Manual (2004),

Value Engineering (VE) can be applied to any business or economic sector, including industry, government, construction and service. Using VE is a very successful long-term business strategy. VE is the systematic application of recognized techniques by multidiscipline team(s) that identifies the function of a product or service; establishes a worth for that function; generates alternatives through the use of creative thinking; and provides the needed functions, reliably, at the lowest overall cost. ...VE simply answers the question "what else will accomplish the purpose of the product, service, or process we are studying?"... Typically, a VE study may generate recommendations to eliminate ten to thirty percent of the project's construction costs. The designer usually accepts about half of these recommendations, providing savings of at least five percent ("Value Engineering Manual," pp. 1-6).

According to Muldavin (2010),

Unfortunately, in the real estate and construction sector, value engineering has become synonymous with "cost cutting." Rather than employ the more sophisticated process of value engineering, value engineers are typically brought in late in a project where budgets have been blown and short-term cost cutting is the requirement. *Accordingly, particularly with developers who will not hold the project property long term, "value engineering" decisions are made based on simple payback or an initial comparative cost basis, ignoring the longer term value that can be generated through operating cost, or replacement cost savings.*

Thus, value engineering fundamentally focuses on costs and cost savings—similar to the concept of LCC discussed earlier—and does not take into account the concept of value beyond the costs savings. (Sometimes applying the value engineering approach destroys the ideas of architecture employed in the design process, because of lack of understanding of value.) Therefore, it is not a suitable method for the decision-makers to rely upon in making specific investment decisions at the property level.

### **2.2.3 Comments on Financial Analysis of Sustainable Property Performance**

Many real estate experts have argued that evaluating the actual building performance is the best way to determine the financial performance of a property. The actual building performance can be understood by looking at the electricity or water bills. The problem with this approach in new construction or major retrofits is that most of the investment decisions need to be made when measuring the actual performance is not possible, when the building systems are not yet installed and operation data are not available. In these situations, the building performance should be projected by available tools or data. In fact, the simulation software tools that we discussed in section 2.2.1.1. are the forecasting tools that project the building performance indicators (mandates). Then, the decision-makers could look at the building performance indicators and project the building performance factors, such as resource use, health and productivity. Next, valuation professionals need to forecast the key financial performance indicators based on the information they collect on building performance.

Muldavin (2010) has argued that,

Strong performance at the process level is the foundation for successful sustainable property investment. Building sustainability is fundamentally a process of best practices that leads to “sustainable” outcomes. It is critically important to get these processes right in order to deliver a successful high performance building. Poor execution of these processes can lead to a variety of negative consequences, including underperforming systems, uncomfortable environments, or increased cost. Muldavin (2010) identified seven key sustainable property processes as both important and as sources of sustainable property failure and underperformance in the past. These processes include 1) Integrated design; 2) Contacts/legal; 3) Services quality and capacity; 4) Energy forecasting; 5) Regulation and code compliance; 6) Commissioning; and 7) Measurement and verification (p. 34).

Therefore, evaluating processes performance is a critical step toward a more comprehensive assessment of the building performance and ultimately the financial performance. Through the analysis of processes many negative risks inherent in the implementation of processes could be recognized and mitigated by utilizing traditional techniques such as contracts, insurance or a more experienced team.

Evaluating all the processes and identifying the risks inherent in those processes that could be mitigated might be beyond the scope of this research. Therefore, given the focus of this study on energy-related systems and strategies, this research will primarily focus on the issues related to energy use forecasting, which are discussed in Section 2.2.4.2.

### 2.2.3.1 Notes on Evaluating Health and Productivity

Scores of studies, including those by Lawrence Berkeley National Laboratory's Indoor Air Quality and NSF/IUCRC Center for Building Performance and Diagnostics at Carnegie Mellon University, have been conducted on the impacts of sustainable properties/options on occupant satisfaction, particularly health and productivity. The results of these studies confirm that there is a positive relationship between sustainability investment and health as well as productivity. It is widely believed that sustainable building design strategies create improved indoor environmental quality and should be associated with improved occupant comfort, satisfaction, health, and work performance relative to buildings designed around standard practices. "There is a general agreement that environmental and social features, particularly those improving health and productivity of workers, will impact the functionality of investment property" (Boyd, 2005, p. 1). Evidence shows that sustainable property can contribute to a reduction of sick building syndrome, improved respiratory health, headache reduction, reduction of colds, reduction of asthma, stress reduction, improved emotional functioning, etc. Research has confirmed the positive relationship between occupant productivity and improved indoor air quality (IEQ), temperature control, lighting/daylighting, and noise reduction. Below, a summary conclusion of studies by Fisk, Mirer, & Mendell (2009); Mendell and Heat (2005); and Seppänen, O., Fisk, W. J., & Lei, Q. H. (2006) on the relationship between ventilation rate and health is presented as an example:

According to Lawrence Berkeley National Laboratory's Indoor Air Quality Scientific Findings Resource Bank website,

**Ventilation**, as defined here, is the supply of outdoor air to a building. Ventilation rates vary considerably from building to building and over time within individual buildings. Throughout the normal range of ventilation rates encountered in buildings, increased ventilation rates are, on average, associated, with fewer adverse health effects and with superior work and school performance. There is also some limited evidence that occupants of buildings with higher ventilation rates have lower rates of absence from work or school. The main findings of related scientific research are as follows:

**Ventilation Rates and Respiratory Illness:** Substantially higher rates of respiratory illness (e.g., 50% - 370%) in high density buildings (barracks, jails, nursing homes, and health care facilities) have been associated with very low ventilation rates, presumably because lower ventilation rates are likely to result in higher airborne concentrations of infectious viruses and bacteria. Only a few studies have been performed.



**Ventilation Rates and Absences in Offices and Schools:** In offices, a 35% decrease in short term absence was associated with a doubling of ventilation rate from 25 to 50 cfm per person. In an elementary grade classroom study, on average, for each 100 ppm decrease in the difference between indoor and outdoor CO<sub>2</sub> concentrations there was a 1% to 2% relative decrease in the absence rate. Given the relationship of CO<sub>2</sub> concentrations with ventilation rates, for each 1 cfm per person increase in ventilation rate, it is estimated that the relative decrease in absence rates is approximately 0.5% to 2%. This relationship applies over an estimated ventilation rate range of 5 to 30 cfm per person, and should not be applied outside those limits. Data relating building ventilation rates and absence rates are very limited.

**Ventilation Rates and Sick Building Syndrome Symptoms:** Many studies have found that occupants of office buildings with above-average ventilation rates (up to 40 cfm per person) have 10% to 80% fewer sick building syndrome (SBS) symptoms at work. A statistical analysis of existing data has provided a central estimate of the average relationship between SBS symptom prevalence in office workers and building ventilation rate. This analysis indicates a 15% increase in symptom prevalence as the ventilation rate drops from 17 to 10 cfm per person and a 33% decrease in symptom prevalence rates as ventilation rate increases from 17 to 50 cfm per person. The uncertainty in these central estimates is considerable. ("Impacts of Building Ventilation on Health and Performance," Lawrence Berkeley National Laboratory's Indoor Air Quality)

Thus, several scientific studies have been conducted to suggest the positive relationship between sustainability performance indicators and health as well as productivity. However, the challenge is how to apply the findings of these studies to a specific property. Although these studies have been successful in establishing a general relationship between outcomes such as ventilation rates or better daylighting, their results may not be sufficient to be generalized. The specific characteristics of a building need to be considered when applying findings of these scientific studies. The application of quantitative conclusions of these studies may not be reliable; however, these benefits should not be ignored in the financial analysis of sustainable options as their potential impacts on cost savings might be very large. As shown in detail in Chapter 4, the employee salary is by far the largest expense of an office building, and therefore, even a very small gain in employee productivity in an office building could significantly influence the results of financial outcomes.

Relative to consideration of these non-energy benefits in valuation process, Muldavin (2010), has stated that,



Fortunately, in the real estate investment community, perfect science or knowledge about the potential health or productivity benefits of sustainable property investments is not required. What is required is appropriate caution in the use of health and productivity studies so as not to mislead decision-makers based on incorrect or incomplete presentation of results and caveats. Real estate investors are used to dealing with uncertainty. Accordingly, even if it is not scientifically possible to provide a specific quantitative estimate of health or productivity benefits that would result from a particular investment in sustainable properties, a thoughtful and independent analysis of the potential benefits to occupants, and how potential occupants for the specific building would react to such information, is particularly important (p. 71).

The approach suggested by Muldavin is utilized in the value-based analysis part of the case study in this research, presented in chapter 5.

#### **2.2.4 Energy Efficiency Investment**

According to Ciochetti and McGowan (2009),

The past decade has seen a marked increase in our awareness of the effect of climate change on the global environment. Real estate is directly responsible for 43% of all annual carbon emissions related to energy consumption (p.2). The market for energy efficiency upgrades is sizeable. Anecdotal evidence from the commercial real estate market suggest that upgrades can realize returns of 15-25% on capital invested, and that the overall market in terms of energy savings range from \$40 to \$200 billion annually (Binkley, 2007). When combined with potential carbon emission offsets, the annual savings for commercial real estate could range from \$45 to \$275 billion annually. By way of comparison, the market capitalization of the entire U.S. public REIT<sup>9</sup> industry currently stands at approximately \$191 billion (p.6). Of particular note is the fact that residential energy consumption is almost half that of commercial office buildings, at 43,700 BTU/Sq. Ft. as compared to 92,889 BTU/Sq. Ft. for office. In this study we focus our attention on office buildings since they: 1) constitute the largest investable commercial real estate sector in the U.S., and 2) since office buildings have a high level of energy consumption, there may be more opportunity for energy efficiency improvement (EEI) investments in this product type (p.9).

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<sup>9</sup> Real Estate Investment Trust

While there are many ways to measure the ‘greening’ of a building and associated benefits, investment in EEI stand out because of three important reasons:

1) The upward trend of energy prices: One of the most compelling motivations for investment in EEI is to lessen the reliance on energy and hence its’ cost in building operations. While crude oil prices have ranged from \$38 to \$144 per barrel over the past two years, most consumer energy prices in the U.S. have experienced a continued upward climb over the past fifteen years.

2) The potential for operational savings that increase net operation income: In a typical urban office building, energy costs can range from 15% to 25% of operating expenses. This variance depends on a number of factors such as building age, systems employed, location of property and predominate form of energy used in the building. From a small survey conducted, we determined that office buildings of the 90’s vintage had energy costs averaging between 15% and 17% of total operating expenses (excluding real estate taxes), while those from the 70’s averaged 22% to 26%. Large buildings in major urban centers averaged between 26% and 28%. P. 14

3) The potential U.S. regulatory actions around carbon emissions: On February 24th, 2009 President Obama invigorated the debate on climate change issues when he called on Congress to send him “legislation that places a market-based cap on carbon pollution and drives the production of more renewable energy in America (pp. 12-15).

According to Jackson (2008), energy efficiency investments in buildings include:

1) The purchase of new, more efficient energy-using equipment to replace existing equipment. 2) The modification of existing equipment of structural characteristics to operate more efficiently. 3) Redesign of existing energy-using systems, such as delamping (disconnecting existing lighting fixtures) and replacement of standard fluorescent light fixtures with light and motion detectors. Modifying constant air volume ventilation systems to variable air volume designs is another redesign example. 4) Installation of systems to change the operation of energy-using equipment. For example, energy management and control systems use computerized controls for everything from lighting to heating, ventilation, and air conditioning systems (p. 4).

#### **2.2.4.1 Financial Performance of Energy Efficiency Investment**

Substantial studies have been conducted to articulate the financial performance of energy efficiency investments. These studies, either case-based or causal-comparative, attempt to recognize the value added by investing in energy efficiency. As fully explained in section 2.4.2 Existing Financial Tools for

Evaluating Sustainable Property, these studies are generally helpful in providing decision-makers with an understanding of the benefits of energy efficiency. Their results are not appropriate to be directly applied for making specific investment decisions at the property level. Below, a few of their findings are presented:

Kats and Perlman (2006) in their study on *Financial Benefits of ENERGY STAR Labeled Office Buildings* have found that:

ENERGY STAR label office buildings provide benefits including direct energy savings, persistence of energy performance and savings, higher occupancy trend, increased asset value trend, better operations and maintenance, peak load, demand charges, and tiered rate, emissions reduction benefits and hedge against price fluctuations. ENERGY STAR labeled office buildings are one-third more energy efficient than average U.S. office buildings, and have annual energy bills that are, on average, at least \$0.50 per square foot lower per year, or 35 percent lower than the average building. The energy performance of ENERGY STAR labeled office buildings improves over the first several years, and these savings persist. Buildings that earned the ENERGY STAR label in six consecutive years are 20 percent more energy efficient in the sixth year than in the first year labeled. ENERGY STAR labeled buildings, when compared to an analogous subset from the national stock, were found to use 40 percent less energy (pp. 3-4).

Hicks and Neid (1999) in their studies on *An Evaluation of America's First ENERGY STAR® Buildings: The Class of 1999* have analyzed the energy performance of the first 90 buildings to achieve the ENERGY STAR label and compared them to the CBECS Database and the Building Owners and Managers Association International (BOMA) Energy Exchange Report 1997 (EER) data set. The authors have found that:

The site energy intensity of the ENERGY STAR buildings was on average 44% lower than that of the average building stock as represented by CBECS<sup>10</sup>. Similarly, the energy cost intensity of this group was \$0.50/ft<sup>2</sup>, or 30% — less than the average building stock as represented by CBECS and \$0.56/ft<sup>2</sup>, or 33% — less than the average building stock as represented in the EER. The reported vacancy rate among the 1999 ENERGY STAR Buildings was nearly half of that reported in the EER. Site energy, source energy, and energy cost intensities of the upper quartile

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<sup>10</sup> Commercial Buildings Energy Consumption Survey

of CBECS buildings suggest that this group is outperforming the 1999 ENERGY STAR Buildings on average which is itself a subset of the upper quartile ostensibly (p. 180).

### **2.2.4.2 Energy Performance Forecast**

As discussed previously, decision-makers are more concerned about the actual building performance when making any investment, and estimating the actual building performance for new construction or major retrofits is based on projection. Evidence shows that actual energy performance may differ from what was forecasted by energy simulation models, such as e-Quest or Energy-Plus. The accuracy of the modeling forecasts depends on various factors including type of software, skill level of modelers, time and budget that is considered for the modeling phase. Skilled modelers may develop supplemental programs or write additional algorithms to enable the software to account for features that might be otherwise outside the capability of modeling tools.

#### **2.2.4.2.1 Evidence on Inaccuracy/Error of Energy Models Forecasts**

There is inaccuracy/error inherent in energy simulation modeling tools; therefore, there is always a certain amount of risk associated with projecting the energy use based on design assumptions.

Dimond et al. (2006) in “Evaluating the Energy Performance of the First Generation of LEED-Certified Commercial Building” compared the modeled energy use (designed) with billed (actual) energy used in 18 selected buildings and found:

the mean value for actual consumption was 1% lower than modeled energy use, with a wide variation around the mean (p. 1) with a standard deviation of 46% (p. 11). For individual buildings, the ratio of actual to modeled energy use ranged from 18% to 225%.

$$18 \% < \text{Actual /Modeled} < 225\% \quad \text{and} \quad \text{Mean} \simeq 99\% \qquad \text{Equation 2-1: Range and mean for EUIs (1)}$$

Turner and Frankel (2008) in “*Energy Performance of LEED for New Construction Buildings*” concluded:

Program-wide, energy modeling turns out to be a good predictor of average building energy performance for the sample. However, as with the other metrics in the study, there is wide scatter among the individual results that make up the average savings. Some buildings do much better than anticipated (p. 3). Within each of the metrics, measured performance displays a large degree of scatter, suggesting opportunities for improved programs and procedures. Measured EUIs for

over half the projects deviate by more than 25% from design projections, with 30% significantly better and 25% significantly worse (p. 5)

Figure ES-4: Measured vs. Modeled EUIs shows that the ratio between actual and modeled EUIs for individual building ranged approximately from 50% to 280% and the mean value was approximately 99%.

$$50 \% < \text{Actual /Modeled} < 280\% \quad \text{and} \quad \text{Mean} \simeq 99\% \quad \text{Equation 2-2: Range and mean for EUIs (2)}$$

According to Newsham, Mancini, and Birt (2009),

Although building simulation experts are wary to suggest that modeled energy use equates to actual energy use, modeling results do create expectations among those who procure buildings. In fact, the average ratio between measured and designed EUI was remarkably close to unity, at 0.92, suggesting that modeled results over populations of buildings might represent a reasonable estimate of actual energy performance. However, the ratio for individual projects ranged from less than 0.25 to >2.75, suggesting that experts' caveats for individual buildings are well-founded, and that energy modeling can be a poor predictor of project-specific energy performance. The median predicted energy saving (relative to the code baseline) for the LEED buildings was 25%, whereas the median measured saving was is 28%. However, again the range for individual buildings was wide, with one-in-five buildings using more energy than their baseline.

$$25\% < \text{Actual /Modeled} < 275\% \quad \text{and} \quad \text{Mean} \simeq 92\% \quad \text{Equation 2-3: Range and mean for EUIs (3)}$$

While the average ratios suggest that energy modeling forecasts are reasonably reliable, the estimates for an individual building are very scattered, and the distribution of results are quite varied. Thus, the degree of inaccuracy/error can be large in some cases, and the modeling tools might not be a good predictor.

It is critical for decision-makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building performance when making decisions based on the actual performance. This research suggests introducing ranges and distributions for reporting the building performance indicators with the mean of modeled forecasts in order to incorporate the risks inherent in modeling projections—risk of not achieving the predicted outcomes.

### **2.2.4.3 Energy Simulation for Retrofit Investments Analysis**

In the last two decades, energy simulation programs, such as eQuest, DOE 2 or Energy Plus, have been widely used not only in designing a building but also in evaluating existing building performance.

Currently, many minor and major retrofitting decisions are made based on the outcomes of these tools. The models help decision-makers explore the potential energy saving, compare the various energy efficiency systems and strategies, and select the most cost-effective options. In the retrofit analysis of a building, it is important that simulation tools provide accurate forecasts of building performance indicators; the errors in simulation results could lead users to poor decisions for selecting the best available retrofit options.

In an energy performance study on an existing school, Jones and Navvab (1987) have demonstrated how the predicted energy consumption would be affected by using less effectively documented input information, such as architectural specifications that, for old buildings, often bear little resemblance to actual present building operations. Jones and Navvab (1987) have concluded that “there is a need for an accurate base model before energy management or retrofit studies are undertaken” (p. 500). According to Westphal and Lamberts (2005),

Building simulation tools have been used for testing retrofit alternatives worldwide. But results provided by software would not be [of] worth if the base case was not correctly calibrated, i.e., the virtual model of the building under analysis must represent faithfully the thermal and energy behavior of that building. To achieve this objective, one has to compare measured performance data with those values predicted by the software. In this task, the user finds out a lot of input parameters that can be adjusted to obtain the reference results (p. 1332).

#### **2.2.4.3.1 Energy Model Calibration Process**

Calibration methods have been suggested by many researchers as a critical part of the simulation process of existing buildings. Existing buildings are typically modeled based on the necessary data and information obtained from available plans and construction details, specification books and operating schedules. The results of initial simulations usually indicate that despite the careful attention in creating the models, the actual measured energy use is different from what was projected by models. This discrepancy is primarily due to the significant uncertainty or error associated with the simulation inputs. “The calibration process compares the results of the simulation with measured data and tunes the simulation until its results closely match the measured data” (Pan, Huang, & Wu, 2007, p. 651). The initial models need to be repeatedly modified to comply with the calibration requirement. “After several steps of calibration, energy model can accurately predict the actual energy usage of specific buildings” (Pan, et al., 2007, p. 657).

“Three standards govern the bounds within which a simulation model can be considered calibrated—these are ASHRAE Guideline 14 2002 (ASHRAE 2002), the International Performance Measurement and Verification Protocol (IPMVP) (Efficiency Valuation Organisation 2007) and the Federal Energy Management Program (FEMP) Monitoring and Verification Guide (US DOE 2008b). These documents primarily apply to Measurement and Verification (M&V) projects and recommend calibrated simulation as one of several means by which to quantify savings due to proposed ECMs [energy conservation measures]” (as cited in Raftery, Keane, & Costa, 2009, p. 1199). The three guidelines, which specify the acceptable tolerances for the calibration of simulation, are presented in Table 2-3

Table 2-3:

**Table 2-3: Acceptable tolerance for monthly data calibration (Pan, et al., 2007, p. 652)**

<b>Index</b>	<b>ASHREA 14 (%)</b>	<b>IPMVP (%)</b>	<b>FEMP (%)</b>
ERR <sub>month</sub>	±5	±20	±15
ERR <sub>year</sub>	-	-	±10
CV (RMSE <sub>month</sub> )	±15	±5	±10

Therefore, building simulation forecasts are suggested to be within one of the ranges mentioned above. If the models’ errors are out of the range, the calibration methods could be used to verify the input parameters initially entered in simulation models, refine the models, and reduce the errors until it closely represents the actual performance of the subject buildings.

As mentioned earlier, uncertainty and error associated with inputs of models are the primary reasons for discrepancy between actual energy use and models’ predictions. There are several useful mechanisms that are typically used to identify the errors and update the inputs. Primary methods that would help to reduce uncertainty associated with inputs of existing buildings’ models are as follows:

- Using the most accurate as-built information
- Site visits
- Surveys and interviews with building operation managers and occupants
- On-site measurement, such as temperature or light levels measurement
- Checking the utility bills data, such as electricity and gas bills.

According to Raftery, et al. (2009),

In the author’s experience it is imperative that any information obtained from a document, such as ‘as built’ drawings, should be verified by visible inspection and that physical surveys

of the building are the most reliable and useful source of information. A detailed survey at the zone level is required to verify and identify such inputs as geometry, constructions and air supply methods. On a systems and plant level a visual survey and building operator interviews are needed to verify such inputs as O&M information and operating schedules. A survey during the night and other unoccupied periods can also be an important source (p. 1200)

#### **2.2.4.3.1.1 Calibration Methodologies**

Researchers have suggested several calibration methodologies for simulated models of existing buildings, although none of them is accepted as a standard methodology.

Tamburrini, Palmer and Macdonald have suggested the following procedure for a simulation process:

1. Collect pertinent data to create a suitable model, including a site visit;
2. Create model and run calibration simulations;
3. Compare results with measured temperature data;
4. Adjust model if required;
5. Apply design changes to calibrated model and extract results (p. 1275).

Westphal and Lamberts (2005) have suggested using sensitivity analysis in the calibration process, and presented six stages for calibration of building simulation models:

1. Calibration of power and schedules of constant loads, such as lights and plug loads;
2. Simulation of design days for thermal loads analysis;
3. Sensitivity analysis over input parameter related to significant heat gains/loss;
4. Adjustment of input values of high level of influence and uncertainty;
5. Whole year simulation;
6. Final adjustments (p. 1333).

Pan et al. (2007) have also suggested six steps for the calibrated simulation procedure:

1. Produce a calibrated simulation plan;
2. Collect data;
3. Input data and run model;
4. Calibration of simulation model;
5. Refine model;
6. Calculate energy and demand savings (p. 652)



#### 2.2.4.3.2 eQUEST

eQUEST, a well-known energy simulation tool in the U.S., will be used to model the energy performance of the selected case study.

According to Ziai (2006),

eQUEST, which stands for QUick Energy Simulation Tool, uses an extended version of the simulation engine in DOE-2, the widely reviewed and validated industry standard for detailed whole building performance modeling, and uses wizards and graphics to make the experience more user- and specifically novice- friendly. The Building Creation Wizard helps the user design a model of the building based on building plans and specifications at either schematic or detailed levels, and the Energy Efficiency Measures Wizard allows the user to designate up to ten design alternatives to the “base” building (multiple parametric design alternatives are also available for those working through the optional detailed interface). On completion of the simulation, with the help of a range of automatically generated individual and comparative graphs, utility consumption and cost savings for the efficiency measures can be used to determine simple payback, life-cycle cost and ultimately, to determine the best combination of alternatives

One of eQUEST’s particularly useful extensions to DOE-2’s capabilities is the implementation of dynamic, intelligent defaults. Every input specification has an Indus standard default value that is dynamically determined based on the user’s previous entries. Whether exploring a project for which certain parameters have not yet been decided upon or user simply has no knowledge of them, eQUEST’s intelligent default system boosts usability by making the simulation setup faster and independent of level of expertise (pp. 3-4).

“eQUEST = Enhanced DOE-2 + Wizards + Graphics” (Hirsch, 2003, p. 3).

According to Hirsch (2003),

eQUEST calculates hour-by-hour building energy consumption over an entire year (8760 hours) using the weather data for location under consideration. Inputs to the program consists of a detailed description of the building being analyzed, including hourly scheduling of occupants, lighting, equipment, and thermostat settings. eQUEST provides very accurate simulation of such building features as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system types and controls.

eQUEST also contains a dynamic daylighting model to assess the effect of natural lighting on thermal and lighting demands (p. 4).

## 2.3 **Risk and Uncertainty in Property Valuation**

### 2.3.1 **Property Valuation**

According to French (2006), valuation is an estimate of price. The accepted international definition of value is market value, and this is a price definition. Market value will be the normal basis for the majority of valuations, and is defined as the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm's-length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently and without compulsion (p. 87).

Property valuation or real estate appraisal is the practice of developing an opinion of the value<sup>11</sup>—market value—of real property.

“A valuation is an opinion on the value or worth of a property given by a person qualified or experienced to do so. The purpose of a valuation is to forecast the future benefits of a property and calculate this into a current price. The accuracy of that valuation will depend on the ability and skill of the valuer in understanding the factors that determine values, and the weight that those factors hold.” (Bowman & Wills, 2008, p. 12).

Three basic approaches are traditionally used by property professionals to determine market value: the cost approach, the sales comparison approaches and the income capitalization approach. Valuers select a valuation approach based on the types and sizes of the property and information availability.

“In contrast to business valuation, or personal property valuation, all three approaches are commonly applied in real estate appraisals. In every real estate appraisal, market data is used in determining value. Market data can include sales and offering of similar properties and tracts of vacant land, current prices for construction materials and labor, rentals of similar properties and

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<sup>11</sup> There are several types and definitions of value sought by a real estate appraisal such as value-in-use, insurable value, investment value and liquidation value. “Market value’ is defined by the International Valuation Standards Committee (IVSC) as “the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arms’ length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently and without compulsion” (as cited by Myers, et al., 2007, p. 6)

their operating expenses, and current rates of return on investment and properties. From this data values may be developed for the land and the property as a whole” (Hitchner, 2003, p. 252).

### **2.3.1.1 Cost Approach**

This method estimates the value of a property based on the sum of the cost of the land and depreciated (present value) cost of reproduction and replacement of existing improvements.

“This can be a reasonable assumption in certain circumstances such as when a property is new and market conditions are stable. It is also often used when there is little or no evidence of market transactions, such as for public assets. Given current economic conditions in the United States and globally, this approach would likely prove less dependable, particularly for an older, existing property” (Chappell & Corps, 2009, p. 14).

### **2.3.1.2 Sales Comparison Approach**

This approach is based on the principle of substitution where a buyer would not pay more for a property when he or she could purchase a similar property in the market at a lower price. This method estimates the value by comparing the subject property with transaction data (sales data) of similar properties in the surrounding or comparable data. This approach could be most useful when sufficient empirical data of similar properties of the same general type (which have been sold recently or are currently for sale in subject property’s market) is available. According to Bowman and Wills (2008),

Sufficient recent, transparent and homogenous transactions are required for an accurate valuation. This methodology is seldom applied to rare or special-purpose properties because few similar properties have been sold in the marketplace (p. 13).

### **2.3.1.3 Income Capitalization Approach**

This approach estimates value based on the present value of the income stream produced by subject property. “Value is calculated by the capitalisation of the net annual income of the property using a market derived capitalisation rate” (Bowman & Wills, 2008, p. 12). According to Hitchner (2003),

The results of the income capitalization method are usually the primary value indicator for commercial, income producing real estate such as office buildings, retail shopping centers, multi-family apartment buildings, hotels and multi-tenant distribution centers. Investors expect a reasonable rate of return on their investment based on the ownership risks involved; this approach closely parallels the investment decision [making] process (p. 253).

Value is calculated by the capitalisation of the net annual income of the property using a market derived capitalisation rate. The capitalisation rate is the return required by a potential investor and is derived from the analysis of similar property transactions. The capitalisation rate is then adjusted to appropriately reflect variations in risk (Bowman & Wills, 2008, p. 13).

The methods used under the income approach primarily fall into the three categories: direct capitalization, discounted cash flow, and gross income multiplier. Discounted cash flow model, as the most common technique, is described below:

### 2.3.1.3.1 Discounted Cash flow (DCF) Model

One of the most common and powerful valuation methods currently used and widely accepted in real estate investment is the Discounted Cash Flow method (DCF). The DCF technique, which is a specific subset of the income capitalization approach, evaluates the present value of the projected future cash inflow and outflow over the holding period (generally a term of ten years for commercial office buildings). Therefore, it is based on future forecasts that can be modeled. The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate its related expenses, revenues, and risks simultaneously. French & Gabrielli (2005) have argued that the advantage of the discounted cash flow technique is that it makes the valuation more “transparent”. It makes explicit the assumptions (market expectations) on future rental growth, holding period, depreciation, refurbishment, redevelopment, costs of management and transfer, taxation and financing arrangements [and uses them as the model inputs] and thus by making these assumptions explicit, it will allow us to question the certainty of each of the input variables (p. 79). A schematic diagram of the function of DCF model is shown in Figure 2-2:

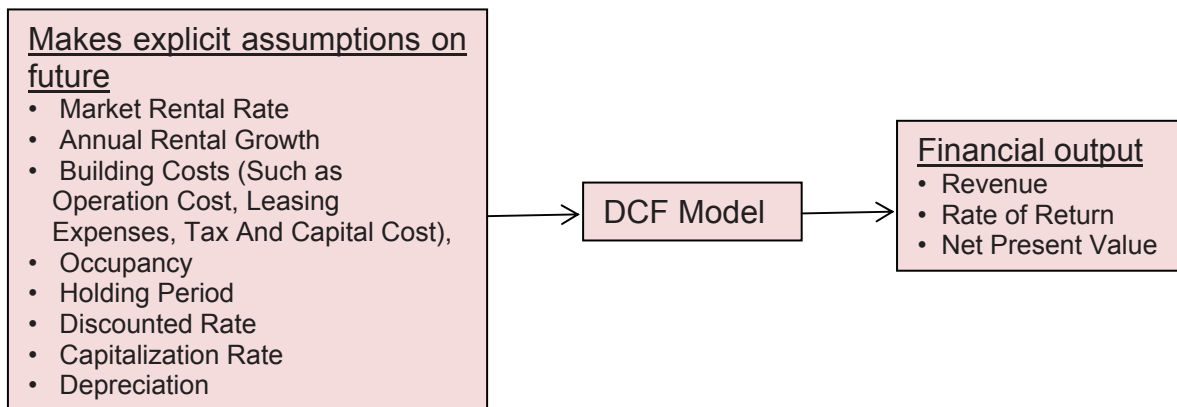


Figure 2-2: Discounted Cash Flow Model

“The DCF approach is the only valuation technique which explicitly accounts for such factors, though the accuracy of the valuation remains subject to the assumptions entered and, therefore, subject to the valuer’s knowledge and relevant expertise. The discount rate is a composite of the risk free rate (usually the ten year bond rate), the inflation rate and the perception of risk for the individual property asset. However, it can be any, all or none of these things, depending on the required valuation objective” (Bowman & Wills, 2008, p. 13).

### 2.3.1.3.1.1 Capitalization Rate and Discount Rate – Accounting for Risk in Valuation

The capitalization rate or cap rate is used to determine the value of a property based on the projected annual income. The capitalization rate, as shown in Equation 2-4, is defined as the ratio of net operating income (NOI) to current market value (V).

$$\text{Cap rate} = \text{NOI}/V$$

**Equation 2-4: Cap Rate and Property Value**

Thus, there is an inverse relationship between cap rates and value assuming a static income stream, a lower cap rate would imply a higher property value. This method is appropriate if the current net operating income is typical of future income streams. It is clearly not appropriate for distressed income-producing properties when the current income (first year income) is not stable and future income is hard to be projected. The cap rate is typically derived from the analysis of similar property transactions.

The discount rate is an appropriate risk-adjusted rate that is used in the DCF methodology to discount future cash flow. This is the rate of return that investors require to achieve in their investment given the level of risk they are taking, and therefore, it differs based on the nature of investment and types of decisions. The discount rate is a key indicator for investors to utilize in their decision-making process.

In the DCF approach, as shown in Equation 2-5, the property value is the present value (PV) of expected future cash flows (CFs), including expected net sale price or reversion proceeds (REV) at the end of an assumed “T” year holding period, discounted at required total return k:

$$V = CF_1/(1+K) + CF_2/(1+K)^2 + CF_3/(1+K)^3 + \dots + (CF_T + REV_T)/(1+K)^T \quad \text{Equation 2-5: DCF Valuation}$$

A discount rate has two components, namely the risk-free rate ( $k_{RF}$ ), or yield to maturity on default-free government bonds, generally determined by the yield on 10 year Treasuries, plus a real estate risk premium, RP. Real estate risk includes inflation, construction risk, contract risks, market risk, lease-up risk, etc. Thus, the higher degree of risk and uncertainty results in higher discount rate, which means that higher return is required to attract investors. Higher return requirements (higher discount rates) translate

to the lower the value for a given stream of actual or projected cash flows. Through the discount rate and the cap rate, the unmitigated risks are priced and included in the valuation process.

In the DCF method, the cap rate will be used to determine residual value of a stream of cash flows at the assumed time of sale or sale price. Last year's income will be capitalized using cap rate to estimate the sale price (typically 11<sup>th</sup> year income will be capitalized into a 10 years analysis). The capitalization rate is a measure of investor demand that reflects the return required by investors to acquire the stream of net operating incomes from a property. The cap rate can significantly affect the rate of return of a property. If a sustainable property generates increased investor demand, its cap rate will be lower, increasing residual value and net sales proceeds. The cap rate only accounts for risk associated with residual value prediction. The financial impact of the residual sales price is reduced because proceeds are received in the future and must be discounted back to the present, but is typically still significant in a real estate investment (Muldavin, 2010, p. 128).

Under certain simplifying assumptions, there is the following mathematical relationship between the discount rate (k), the expected rate of growth of property cash flows (g) and the cap rate (Equation 2-6):

$$\text{Cap rate} \approx k - g \qquad \text{Equation 2-6: Relationship between Discount Rate and Cap Rate}$$

Therefore, as shown in Equation 2-7, a cap rate has three key determinants:

$$\text{Cap rate} \approx (k_{RF} + RP) - g \qquad \text{Equation 2-7: The Key Determinants of a Cap Rate}$$

- Yield on government bonds ( $k_{RF}$ )
- Real estate risk premium (RP)
- Property income growth expectations (g) (Clayton & Glass, 2009, p. 5)

### 2.3.2 Risk and Uncertainty

“Risk and uncertainty relate to situations in which the performance measures have more than one possible outcome and the outcome is not known in advance” (Aven, 2003, p. 28). Risk is defined as a situation in which alternative outcomes and their probability of occurrence are known, where as uncertainty is a situation where information about future outcomes and their probability are not known.

Aven (2003) believed that under risk the probability distribution of the performance measures can be assigned objectively, whereas under uncertainty these probabilities must be estimated on a subjective basis (p. 28). Hargitay & Yu (1993) constructed a spectrum of uncertainty, ranged from certainty (full

knowledge) at one end to total uncertainty (lack of knowledge, information or historical data) at the other and two further points namely, risk and partial uncertainty in between (p. 35). “Uncertainty is anything that is not known about the outcome of a valuation at the date of the valuation, whereas risk is the measurement of the value not being as estimated” (French & Gabrielli, 2005, p. 81).

Although, by definition, risk is a different from uncertainty<sup>12</sup>, they are commonly used interchangeably in the context of property investment analysis. Adair & Hutchison (2005) have confirmed that “Unfortunately, the analysis [done by Mallinson and French, two valuation experts] does not distinguish uncertainty from risk and while they accept that the estimation of value is about balancing probabilities (risk) and managing uncertainty the two terms are used interchangeably” (p. 256). Mangano (2009) in his risk management professional course at Project Management Institute (PMI) has also argued that uncertainty refers to the lack of knowledge of future events, which can lead to risk, whether it be a threat or an opportunity; and managing risk is really about managing uncertainty.

In the context of investment, risk is defined “as the extent to which the actual outcome of an action or decision may diverge from the expected outcome” (Hargitay & Yu, 1993, p. 35)—the probability of not receiving the expected return. The variability of the expected return about its mean<sup>13</sup> (the range of possible outcomes) is used as a description of risk, and the most popular measures of variability is variance<sup>14</sup>—the spread of a probability distribution. Standard deviation<sup>15</sup> is commonly used as a measure of spread. Hargitay & Yu (1993) also accepted that “risk (unpredictability of financial consequences) and uncertainty are the same thing and consensus is to define and measure them with some measure of variability” (p. 43)—probability distribution of outcome.

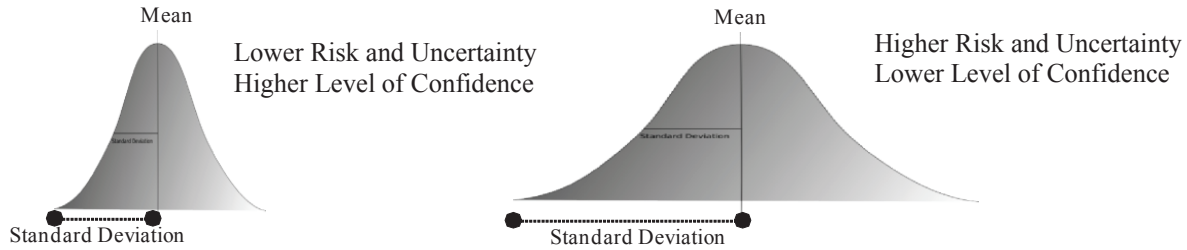
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<sup>12</sup> In this research, the term uncertainty refers to normal uncertainty and not abnormal uncertainty. “Abnormal uncertainty arises when some aspect of the property or the market means that the valuer is unable to value with the normal or expected level of confidence” such as the financial market turmoil or some legal difficulty related to the property (Adair, 2001, p. 89).

<sup>13</sup> The arithmetic mean or mean, of a set of measurements is defined to be the sum of the measurements divided by the total number of measurements (Ott & Longnecker, 2001, p. 73).

<sup>14</sup> The Variance of a set  $n$  measurements by  $y_1, y_2, \dots, y_n$  with mean  $\mu$  is the sum of the squared deviation divided by  $n - 1$  (Ott & Longnecker, 2001, p. 87)

<sup>15</sup> The standard deviation of a set of measurements is defined to be the positive square root of the variance (Ott & Longnecker, 2001, p. 88)



**Figure 2-3: General Interpretation of Shapes of Normal Distribution**

As shown in Figure 2-3, the tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and high level of confidence in achieving the expected outcome (mean). Flat distribution with large standard deviation denotes the great degree of risk and uncertainty and low level of confidence.

### **2.3.2.1 Risk Analysis Methods – Statistical Approaches<sup>16</sup>**

Measuring the uncertainty and understanding the potential risk is a critical step in the decision making process. As Clemen (1996) said, decision-makers who face uncertain prospects often gather information with the intention of reducing uncertainties. Information gathering includes consulting experts, conducting survey, performing mathematical or statistical analysis, doing research or simply reading book, journal, and newspaper (p. 435).

As part of investment decision-making process, some of the risk analysis methods used to describe the riskiness of investments include: expected value-variance analysis, analysis of Beta coefficient, sensitivity analysis, scenario building, project evaluation and review technique (PERT) and more sophisticated simulation methods such as Monte Carlo simulation. Sensitivity analysis, scenarios building and project evaluation and review technique (PERT) as more simplistic approaches to risk management are explained in this section. Monte Carlo simulation as a more sophisticated approach is explained in the next section.

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<sup>16</sup> These risk analysis methods are statistical-based approaches that attempt to identify the potential sources of risk and uncertainty, qualify and articulate them to decision-makers. However, as mentioned earlier, real estate people utilize a more qualitative approach to risk analysis. They identify risk through underwriting and due diligence process and attempt to mitigate through various mechanisms such as contracts, insurance, surety, or building commissioning. The unmitigated risks are then priced and included in the valuation model through discount rate and cap rate.



### **2.3.2.1.1 Sensitivity Analysis**

“The process of the exploration of the change of the projected outcome of the investment resulting from the change in one of the factors of the project is sensitivity analysis” (Hargitay & Yu, 1993, p. 163). Sensitivity analysis is a very simple quantitative method to use for understanding the potential risks and uncertainties associated with inputs. “Sensitivity analysis determines how sensitive the results of the analysis are to uncertainties in input variables...you can determine which parameters in the model have the most potential to affect your project” (Virine & Trumper, 2008, p. 177). “Sensitivity analysis is used to examine how robust the choice of an alternative is to change in the figures used in the analysis” (Goodwin & Wright, 2004, p. 47).

This analysis is useful in providing decision-makers with information and insight on how their initial assumptions or initial decisions impact the final outcomes. It attempts to answer the “what if...” questions. As Hargitay and Yu (1993) stated, “sensitivity analysis is not aimed at quantifying risk, but identifying the factors which are the potential source of risk. Sensitivity analysis is widely used because of its simplicity and ease of interpretation” (p. 163). “No optimal sensitivity-analysis procedure exists for decision analysis” (Clemen, 1996, p. 157). The development of models for performing sensitivity analysis seems to be science, but to a great extent, the determination of assumptions/inputs is art.

### **2.3.2.1.2 Scenario Building**

This approach groups the results into three groups of worst case or pessimistic, best case/optimistic and most likely case/realistic. Hargitay and Yu (1993) have argued that “The use of scenario can improve the structure of sensitivity analysis and the expected value-variance method by grouping the estimate to suit particular combinations of circumstances or scenarios” (p. 164). Ratcliffe (2000) has stated that the scenario method has been widely used by decision-makers in business, industry and government for over 30 years as a successful unrivalled technique to learn about the future before it happens. Ratcliffe (2000) has suggested the scenario building technique as one singularly relevant to the study of future property investment, development and management decisions and land use policy formulation (p. 127). According to Boyd (2002),

This approach determines defensible maximum, minimum and most likely figures for each variable. The limitations of this approach are that, firstly, only three values are considered (two of which are extreme values) and, secondly, when incorporated in a scenario study, the extreme values are linked to extreme values of the other variables resulting in highly leveraged, extreme situations. These studies should consider the covariances between the key variables as a means of reducing the extreme values. Within the scenario approach it is desirable to apply probabilities to

the best, worst and most likely situations because this will minimise the effects of the extreme values (p. 12).

### **2.3.2.1.3 Program Evaluation and Review Technique (PERT)**

Program Evaluation and Review Technique (PERT) is a technique that is mainly used in the field of project management for incorporating risks and uncertainties in project planning, construction scheduling and cost forecasting. PERT was developed in the late 1950's by a consulting firm and the U.S. Navy's special project office for the U.S. Navy's Polaris project which was the largest and riskiest research and development efforts the U.S. military had ever undertaken. They developed PERT to estimate the probabilities of meeting important milestones, and reduce the time and cost required to complete the project.

PERT essentially follows the concept of scenario building in identifying the three main scenarios: best case, most likely case, and worst case. However, instead of relying solely on two extreme values, it uses the following formula to estimate the expected outcome and standard deviation (for example: expected duration in case of scheduling):

$$\text{Expected Outcome (mean)} = (\text{Best Case} + 4 * \text{Most Likely Case} + \text{Worst Case}) / 6$$

**Equation 2-8: PERT Formula for Mean**

$$\text{Standard Deviation} = (\text{Best Case} - \text{Worst Case}) / 6$$

**Equation 2-9: PERT Formula for Standard Deviation**

PERT includes simple formulas to estimate the summary of statistics such as mean or standard deviation. PERT's results are more accurate and reliable than simple scenario building, therefore, provide a more robust quantitative way for addressing risk and uncertainty.

Virine and Trumper (2008) argued that if we use the optimistic or pessimistic cases, we will get misleading results. PERT by using the expected-duration approach, was a major step toward incorporating uncertainties in project management. However, despite the elegance of PERT, it has a number of limitations. For example, uncertainties associated with tasks are independent of each, or in estimation the expected outcome, by three points of optimistic, pessimistic and most likely, will be affected by anchoring heuristic—the most likely estimate will become an unwanted anchor, which will skew our ability to accurately estimate risk or project durations (p. 198).

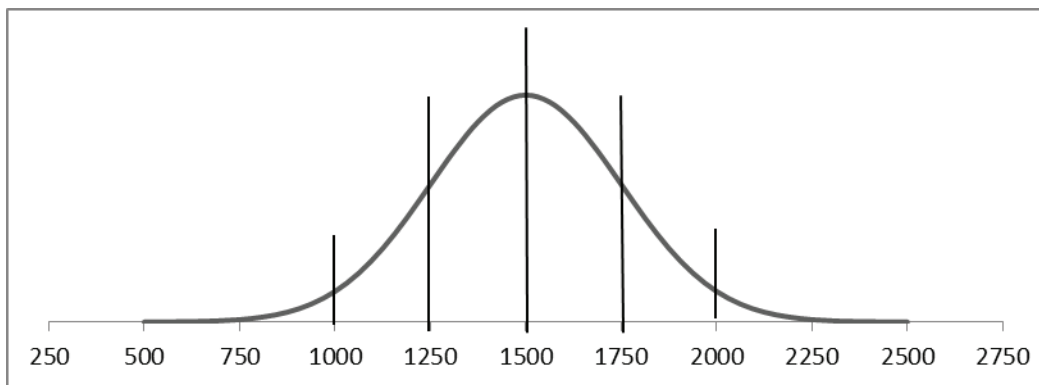
### **2.3.3 Value at Risk (VaR) and Probability Distribution**

VaR is defined as the metrics that probabilistically evaluate and measure the risk associated with a portfolio of financial investments by describing three statistic components: a time period, a confidence

level and a loss amount (or loss percentage). Portfolio managers became more interested in the VaR approach in expressing the investment risk after the stock market crash in 1973-1974; “risk was not a priority concern in portfolio market management strategies” (Jackson, 2008, p. 98). “VaR answers the question: how much can I lose with x% probability over a given time horizon” (Morgan & Reuters, 1996, p. 6). For example, what is the most I can expect to lose in dollars with a 95% or 99% level of confidence over the next year? Three methods have been suggested for computing VaR: the variance-covariance method, the historical method, and the Monte Carlo simulation.

Probability distributions are the primary quantitative vehicle used for explaining risk or VaR in the risk management analysis methods. The probability distribution describes a range of possible values and the probability of any value within any subset of that range. All variables that are uncertain could be represented with probability distribution, and their associated risks could be estimated using statistical approaches based on specifications of a range of most likely values or extreme values. Information provided by a probability distribution can be better demonstrated by the following example.

Figure 2-4: A hypothetical continuous probability distribution—normal distribution illustrates a hypothetical continuous probability distribution—normal distribution—of monthly rent rate of an office building where uncertainty is created by a lack of transaction data on its rent. The expected monthly rate—the mean—is \$1500 and its standard deviation is \$250.



**Figure 2-4: A hypothetical continuous probability distribution—normal distribution**

In the normal probability distributions, the area under the normal curve and over a specified interval is exactly equal to its corresponding probability. It is possible to answer any question posed on the likelihood of monthly rent rate. For example, in this case following statements can be made:

Probability is 34.1 percent that the monthly rate will be less than \$1500 and greater than \$1250;

Probability is 13.6 percent that the monthly rate will be less than \$2000 and greater than \$1750;

Probability is 2.2 percent that the monthly rate will be greater than \$2000;

There is a 68.2 percent chance that monthly rent rate falls between \$1250 and \$1750.

The maximum expected monthly rent variance at a confidence level of 95.4 percent is \$2000.

There is a 84.1 percent chance that monthly rate is not less than \$1250.

There are other types of probability distributions that can be considered for articulation of risk or VaR, such as triangular, uniform<sup>17</sup>, lognormal<sup>18</sup>, beta<sup>19</sup>, piecewise, etc. Normal and triangular distribution are explained in section 2.3.4.1.

### **2.3.4 Risk and Uncertainty in Valuation Process**

There is general agreement that there are risks and uncertainties associated with property valuation procedures that need to be identified, assessed, and reported in a way that can be understood and analyzed by investors or end users; for example, the uncertainty of DCF inputs (assumptions about future factors) and risk of not achieving value or rate of return as predicted in DCF (estimation of DCF outputs). “Risk and uncertainty are inherent parts of the valuation process as often the valuer is unable to specify and price accurately all current and future influences on the value of the asset” (Adair & Hutchison, 2005, p. 245).

“Uncertainty is a universal fact of property valuation. All valuations, by their nature, are uncertain” (French & Gabrielli, 2005, p. 77) and the acknowledgement of this fact would provide the investors with useful information about the level of confidence in receiving their expected return and therefore, a key insight into of desirability of proceeding. According to French (2007),

All valuations are opinions of the price that would be achieved at the valuation date. The degree of certainty will vary significantly. These variations can arise because of the inherent features of the property, the market place or in the information available to the valuer. Where uncertainty could have a material effect on the valuation, the valuer should draw attention to this, indicating

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<sup>17</sup> There is an equal probability that the parameter will be within a certain range (Virine & Trumper, 2008, p. 201).

<sup>18</sup> There is a positively skewed (nonsymmetrical) distribution, meaning that it has a longer tail to the right (Virine & Trumper, 2008, p. 201).

<sup>19</sup> This is a bounded distribution, which uses a mathematical formula that includes two coefficients. By changing two coefficients, beta distribution can take a variety of shapes; it can be symmetrical or nonsymmetrical (Virine & Trumper, 2008, p. 201).

the cause of the uncertainty and the degree to which this is reflected in the reported valuation (p. 7).

“Risk is recognised as an inherent element within the valuation process and in the absence of perfect data across the property market it is likely that this situation will pertain to varying degrees. If risk cannot be eliminated the valuer is required to manage the analysis of risk within the valuation process so that its impact is minimised and the end user of the valuation can have confidence in the value estimate” (Adair & Hutchison, 2005, p. 266). Forum/Investment Property Databank (2000) highlighted the shortcomings of current approaches to risk management within valuation and called for an enhancement of valuers' skills in providing a more sophisticated quantitative analysis of risk (as cited by Adair, 2001, p. 88).

As fully discussed in Section 2.3.1.3.1.1, real estate people tend to identify the risks and mitigate them. The unmitigated risks are then priced and reflected through the discount rate and the cap rate in the valuation models. In light of the above discussion, the selection of the discount rate and cap rate involves a certain level of uncertainty, which can significantly impact the results of the valuation. The more careful underwriting, detailed market analysis, and a better understanding of building performance and processes would help to reduce the degree of uncertainty associated with these two risk-reflecting variables.

#### **2.3.4.1 Reporting Uncertainty in Property Valuation**

As Boyd (2002) has said, in most cash flow studies the key input variables are included as single point estimates but this approach does not take into account of the uncertainty of these estimates. In order to incorporate a measure of reliability of the resultant figure, it is highly desirable to consider and quantify the probable range of values of the key variables (p. 12). French and Gabrielli (2005) have stated that “the reporting of uncertainty is helpful to the client and, if consistently introduced, will enhance the reputation of the valuation profession. The second point is that a statistical analysis of inputs and the resulting outputs is an appropriate way of reporting uncertainty in valuations. It does this because it recognizes that the estimate is a range and that forms a probability distribution” (p. 86).

**Normal Distribution:** Mallinson and French (2000) suggested that appropriate probability distribution would be a normal or bell distribution. In their previous work they have argued that “there were six items of information that should be conveyed when reporting uncertainty. These are:

- (1) The single figure valuation – market value (MV).
- (2) The range of the most likely observation (say, 5 per cent either side of MV).
- (3) The probability of the most likely observation.
- (4) The range of higher probability.
- (5) The range of 100 per cent probability.

(6) The skewness of probabilities” (p. 28)

French & Gabrielli (2005) later suggest a slight modification to this set of information as follows:

- (1) The single figure valuation – MV.
- (2) The certainty range at 5 per cent, 10 per cent, 50 per cent and 100 per cent.
- (3) The skewness of the distribution (reported as per cent at either end of range).

“The reason for this modification is twofold. One, brevity; it is important that the concept of uncertainty is provided with the valuation, yet it should be done so with the least points of reference as possible. Two, clarity; the three reference points above capture all the items identified in the original items but, by using the certainty range, in a more succinct form. The advantage of the certainty range is that it is easy to present in a tabular form that is readily understood by all users. Most users are not comfortable with statistical references such as mean, variance and standard deviation and this short data set can convey these concepts in lay terms” (p. 87).

**Triangular Distribution:** Another type of distribution that is suggested for reporting uncertainty is triangular distribution. Triangular distribution requires the valuer to provide the absolute figures; the most likely, the minimum and the maximum. “Minimum and maximum are not optimistic and pessimistic estimates; they are extremes” (Virine & Trumper, 2008, p. 201). This distribution is accepted as a simple and understandable approach for demonstrating the uncertainty. According to French and Gabrielli (2005),

The use of the triangular distribution, whilst not the most statistically robust, mirrors the thought process of the valuer and thus sits within their heuristic approach to valuation. By allowing for a range in the inputs, in either the all risks yield approach or the DCF method, the valuer is openly acknowledging that there will always be a degree of uncertainty in the choice of input variables that must mean that the output figure, the valuation, is not a single figure (p. 85).

There are debates about the appropriateness of the distributions for the purpose of articulating uncertainty in property valuation, but valuation experts such as French (2007) believed *that triangular approach is the most appropriate given the objective of expression of the uncertainty in a uniform and useful manner*. Jackson (2008) has also argued that “While triangular and piecewise distributions are not mathematically continuous..., they are applied in the same way as continuous functions and for our purpose [of energy-efficiency investment and risk evaluation] considered continuous. They are easy to develop and apply (p. 134). Virine and Trumper (2008) have also stated that if using a triangular distribution instead of normal will not completely skew the analysis as long as your range is accurate. “Risk and uncertainties that you have not accounted for will cause you more problems than an inaccurate distribution shape”(p. 206).

“Despite the unquestioned necessity for reporting a single point estimate of market value for particular valuation assignments (e.g. financial reporting, financial performance measurement, court valuations, etc.) valuers should not proceed in reporting this figure only and in ignoring elements of risk and uncertainty. Valuers cannot be expected to predict the future but they can be expected to be transparent with regard to their assumptions even if they are (by nature) subjective, highly uncertain and maybe wrong from an omniscient observers’ perspective” (Lorenz, Trück, & Lützkendorf, 2006, p. 429). “This identification of the most probable value and a range of values gives the client a measure of risk in the estimation of value. It translates the uncertainty in the key input variables into the final figures” (T. Boyd, 2002, p. 17).

*Therefore, risk and uncertainty need to be measured and considered simultaneously with other issues of the valuation process; otherwise the outcomes of the valuation process may be overestimated or even underestimated, and may lead to inappropriate investment decisions.*

#### **2.3.4.2 Monte Carlo Simulation in Property Valuation**

“Monte Carlo simulation can be used as a tool to quantify the very realistic and inherent uncertainties surrounding many of the estimates used to model long-term investment decisions” (Kelliher & Mahoney, 2000). “Monte Carlo analysis is a widely used numerical computational analysis tool that draws information from input probability distributions, applies the data in a process, and generates an outcome distribution” (Jackson, 2008, p. 137).

Monte Carlo simulation technique is able to account for uncertainties by allowing for a range for each input and their correlations at the same time, perform a random probabilistic sensitivity analysis and model a range of possible outcomes. The output will express the likelihood of the inputs’ and outputs’ occurrence along with their values’ probability distribution. The results—whether shown graphically or reported numerically with summary of statistics, such as mean, variance, standard deviation, skewness, etc.—provide decision-makers with more reliable information than a few discrete scenarios. “Monte Carlo simulation provides a structured approach that explicitly incorporates uncertainty into decision-making models” (Kelliher & Mahoney, 2000).

This technique is widely used in science, engineering, finance, industry, and statistical inference. Virine and Trumper (2008) have argued that Monte Carlo is an excellent tool for the situation when either reliable historic data is available (data that you can use to create a reliable probabilistic forecast), or “you have a group of experts who understand the project, have experience in similar projects, and are trained to avoid cognitive and motivational biases when defining uncertainties and provide estimates”(p. 209) .



The Monte Carlo simulation technique has been suggested by many real estate valuation experts to measure and express various risks and uncertainties in the valuation process by describing the range of possible values instead of a single-point estimate of value in the DCF model. Baroni, Barthélémy and Mokrane (2006) have compared using Monte Carlo simulation approach versus the classical DCF method in estimating the value of a real estate portfolio using the same assumptions, and have concluded that simulated cash flows provide more robust valuations than “traditional DCF valuations, permit the user to estimate the portfolio’s price distribution for any time horizon, [and] facilitate Values-at-Risk (VaR) computations”— estimation and presentation of risk with reference to the holding period and a confidence level (p. 17). According to French (2007), the Monte Carlo model is sufficiently easy, robust and accessible for the profession to consider as a possible means of expressing uncertainty in [property] valuation (p. 19).

Lorenz, et al., (2006) have stated that the Monte Carlo technique selects the three figures of triangular distribution randomly for each variable and produces a valuation figure before selecting another random input from within the set range and repeating the exercise (e.g. 50,000 times). “In doing so, a multiple of possible outcomes is produced that can be statistically analysed to provide an average outcome, a probability distribution, a range, a standard deviation, and skewness, etc.” (p. 405) “It provides a structured approach that allows the user to incorporate uncertainty into the analysis in a relatively simple form. Because each input is defined by the chosen probability density function. If there is more than one variable to be analyzed, then it is possible to allow for any interrelationship between the chosen variables. For example, DCF model, rental growth and exit yield should be negatively correlated” (French, 2007, p. 12). Boyd (2002) recommended at least 5000 trials in order to ensure adequate coverage of the probabilities (p. 16). “The importance of the statistics is that it is placing the single point valuation in the context of uncertainty of inputs and the corresponding risk pertaining to the output” (French & Gabrielli, 2005, p. 84).

The simulation incorporates the uncertainties of achieving the DCF inputs, such as rent, occupancy and tenant retention, and articulates the risk related to receiving these outcomes by looking at various combinations of inputs across their different distributions, performing multiple simulations (random sensitivity analysis), and generating a distribution of financial outputs. By using Monte Carlo, the correlations between inputs could be identified and their effect on the final outcomes could be monitored. In addition, a specific input that has the greatest effect on the outcome could be identified.

The resulting range and distribution of DCF outputs, such as revenue and rate of return provide useful information to the decision-makers that can help them to better think through risk and uncertainty, and



ultimately make a better investment decision. For example, the tighter the distribution of outcome (smaller standard deviation), the higher level of confidence that investors will receive the predicted outcome (mean).

The main challenge is identifying the range of the DCF inputs and their probability distributions which will be discussed and addressed throughout this research. “The accuracy of the simulation depends on the quality of the data used in the models” (French, 2007, p. 4). Regarding the accuracy of probability distributions of DCF inputs, Boyd (2002) has stated that

The property professional should source as much relevant secondary data as possible and thereafter make a reasoned subjective judgment on the probability distributions of the key variables. While accepting that the forecasts will not be accurate, the discipline of profiling the key variables enhances a reasoned approach because probable causal factors are explicitly considered (p. 13).

## 2.4 **Sustainable Property Valuation/Financial Analysis**

### 2.4.1 **Sustainable Property Valuation approaches**

As explained in Section 2.3.1, three basic approaches are generally accepted and widely used by property professionals for estimating property market value. However, all three approaches may not be applicable for all situations or may not result in accurate estimates for market value. Valuers must select the most appropriate approach based on the subject property characteristics (either existing properties or new ones) and available data, in order to provide the most accurate indication of market value. In this section, appropriateness of the three approaches for valuation of sustainable properties are explained:

#### **1) Cost approach:** According to Chappell and Corps (2009),

Given current economic conditions in the United States and globally, this approach would likely prove less dependable, particularly for an older, existing property. In addition to these limitations, there is currently no readily available national cost estimating database for high performance green development upon which valuers, investors, or other property analysts can rely. In addition, older assets may be more difficult to value using the cost approach as it employs the concept of depreciation from a variety of factors (e.g., obsolescence, functional depreciation, condition, technical impacts) to arrive at an estimate of value, thereby introducing yet another set of

variables into the analysis. Since sustainable features can have a longer life, this introduces further complexity in correctly depreciating a green asset (p. 14).

Therefore, this approach may not provide an accurate and reliable estimate of value due to limited cost data of sustainable features.

**2) Sales comparison approach:** according to Myers, et al. (2007),

In the current market, sustainable buildings have limited market data to make effective comparisons and the market is at a point of immaturity where the market's perception is still cloudy as to the value or value attributed to sustainable buildings. This inherently makes using this standard valuation methodology for determining the value of sustainable building difficult, and until the market matures or significant market evidence eventuates this approach remains inaccurate (p. 9).

Another important challenge in comparing sustainable property is that sustainability can be achieved through a variety of different features. Even two LEED certified buildings with the same level rating might have employed different systems and design strategies in achieving the same level certifications, and therefore, might not be considered comparable. As explained in Section 2.4.3.2 "Causal-Comparative" Studies, it is very difficult to derive the accurate market value of a sustainable property or option based on a building comparison approach at this point in time.

Therefore, sales comparison and cost approach cannot currently be considered as reliable approaches for estimating the accurate market value for a sustainable property.

**3) Income Capitalization Approach:** This approach currently is viewed as the most appropriate approach to provide a more reliable indication of market value of sustainable property. The Discounted Cash Flow (DCF) Model, which is a subset of the income approach, is known as the best technique to deal with valuation of a sustainable property. The DCF model is explained in section 2.3.3.1 and a more detailed description about using DCF for sustainable properties or options is presented in Chapter 3.

In the current economic environment, investors, analysts, valuers, and underwriters are finding that there is limited market data upon which to rely. However, there are still business decisions that have to be made every day, so those who are required to conduct proper analyses must rely on the limited information that is available. It is important to understand what useful information is available and the minimum factors that should be considered (Chappell & Corps, 2009, p. 16).

## 2.4.2 Existing Financial Tools for Evaluating Sustainable Property

There are many different types of analyses that decision-makers used for making sustainable investment decisions. Muldavin (2010) believed that these financial analyses alternatives can logically be separated into four categories.

a) Traditional Sustainability Financial Analyses: These methods have traditionally been used in the real estate industry to make energy efficiency/sustainability investment decisions for buildings, features and equipment.

b) Traditional Real Estate Financial Analyses: These methods integrate comprehensive cost, benefit, and risk information into measures of return and/or value. Rate of return or value estimates are based on detailed specification of financial model inputs such as energy costs, rents, occupancy, tenant retention, discount rates, etc.;

c) Sustainability Sub-Financial Analyses: These analyses and models provide quantitative insight/data that is typically combined with other information and analyses to aid valuers/financial analysts in their specification of key financial assumptions in a DCF analysis, or related Traditional Real Estate Financial Model. These types of analyses are done for every DCF analysis, but the ten Sustainability Sub-Financial Analyses listed in table 2 are a selection of some of the specialized analyses that have been developed in recent years to aid in the financial analysis of sustainable investment;

d) Public Sustainable Benefits<sup>20</sup> Analyses: These are financial analyses used to quantify potential public sector benefits. The concept is simple—if building owners can clearly and factually articulate the public benefits that arise from their building, they are more likely to convince regulators, tenants and investors to pay for those benefits (pp. 8-32 of Chapter V) The analyses are listed below in Table 2-4:

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<sup>20</sup> Such “monetization” of public value is created from governments or utility companies through enhanced entitlements/permitting, public grants, favorable financing, tax benefits, and carbon credits or payments, and from private companies through their contribution to Enterprise Value and resulting increases in space user demand (Muldavin, 2010, p. 32)

**Table 2-4: Sustainable Financial Analysis Alternatives (Muldavain, 2010, p. 101)**

<p><b>A. <u>Traditional Sustainability Financial Analyses</u></b></p> <ol style="list-style-type: none"> <li>1. Simple Payback</li> <li>2. Simple Return on Investment (ROI)</li> <li>3. Change in Asset Value: Direct Capitalization (CAV-DC)</li> <li>4. Simple ROI and General Cost-Benefit Analysis</li> <li>5. Life Cycle Costing (LCC)</li> <li>6. Value Engineering</li> <li>7. ENERGY STAR Building Upgrade Value Calculator for Office Properties</li> <li>8. ENERGY STAR Cash Flow Opportunity</li> <li>9. Life Cycle Assessment (LCA)</li> <li>10. Post Occupancy Analyses (POE)</li> </ol>	<p><b>B. <u>Sustainability Sub-financial Analyses</u></b></p> <ol style="list-style-type: none"> <li>1. Comparative First Cost Analysis</li> <li>2. DCF Lease-Based Cost-Benefit Allocation Models</li> <li>3. Sustainability Options Analysis</li> <li>4. Churn Cost Savings Analysis</li> <li>5. Productivity Benefits Analysis</li> <li>6. Health Cost Savings Analysis</li> <li>7. Government/Utility Incentives and Rebates Analysis</li> <li>8. Enterprise Value Analysis</li> <li>9. ENERGY STAR Financial Value Calculator</li> <li>10. Risk Analysis and Presentation (RAP)</li> </ol>
<p><b>C. <u>Traditional Real Estate Financial Analyses</u></b></p> <ol style="list-style-type: none"> <li>1. Cost Management</li> <li>2. Discounted Cash Flow Analysis             <ul style="list-style-type: none"> <li>• Change in Asset Value</li> <li>• Net Present Value</li> <li>• Internal Rate of Return</li> </ul> </li> <li>3. After Tax Cash Flow Analyses</li> <li>4. Valuation</li> <li>5. Total Occupancy Cost (Cost of Ownership) Analysis</li> <li>6. Economic Value Added</li> </ol>	<p><b>D. <u>Public Sustainability Benefits Analyses</u></b></p> <ol style="list-style-type: none"> <li>1. Reduce Infrastructure Costs</li> <li>2. Environmental &amp; Resource Conservation Benefits</li> <li>3. Land-Use Benefits</li> <li>4. Climate Change Reduction</li> <li>5. Economic Benefits</li> <li>6. Security Benefits</li> </ol>

Some of the methods which are listed under the traditional sustainable financial analyses such as LLC, LCA and VE were explained in Section 2.2.1.3.

### **2.4.3 Existing Research on Financial Performance of Sustainable Property**

As mentioned in Chapter 1, the studies about financial implications of sustainable buildings are categorized in three types including: case-based, causal-comparative, and fundamentals of sustainable properties valuation studies. In this section, a description for the application as well as examples for each type is presented.

#### **2.4.3.1 “Case-Based” Studies**

The majority of the studies on the benefits of sustainable building are case study-based. These types of studies provide evidence for financial performance of sustainability. More thorough case studies would improve the level of confidence of decision-makers when making investment decisions on sustainable property. For example, valuers may feel more confident in determining the incremental premiums for

sustainable properties or features if they have more evidence of outperforming similar (comparable) types of sustainable properties or features.

Case studies that were written from a valuation perspective would facilitate a better understanding of how employing green strategies may influence the property value and market positioning. They could also help decision-makers to understand how real estate valuers determine financial indicators such as rents, occupancy, etc. However, their results cannot be generalized for other sustainable building investment decisions. Two examples of recent case-based studies are presented below:

- *Valuing Green: How Green Buildings Affect Property Values and Getting The Valuation Method Right.* Bowman and Wills (2008) have interviewed with over 50 real estate practitioners and studied 8 Green Star buildings in Australia, and have concluded:

Construction costs were equal to, and in two instances lower than, budget expectations. A slight cost premium still exists for delivering buildings with a 6 Star Green Star rating.

Operating costs (including salaries) are below expectations. From examples in Canberra and Adelaide, Green Star buildings have achieved a reduced capitalisation rate to the order of 0.25-0.50% when compared with the rest of the market.

Green Star rated buildings appear easier to sell—it is not possible yet to infer whether this also adds a price premium, but a faster sale potential alone should infer value via a tighter capitalisation rate.

Let up periods were reduced by improved exposure and marketing from being ‘green’. Attraction of ‘blue chip’ tenants was improved by meeting tenant requirements and briefs. Importantly, the case studies reveal that these tenants are prepared to pay for ‘green.’

No significant changes to facility management contracts were evident.

The market responded to Green Star ratings overall rather than to the individual designs and technologies used to achieve the rating. Some owners/managers felt that this may change as market sophistication increases, so valuers may need to identify individual sustainability features in much the same way as they do with say an attractive vista in conventional buildings (pp. 20-21).

- *High Performance Green Building: What's it Worth?* According to Chappell and Corps (2009),

A building with LEED certification holds a strong competitive position relative to its peers at the same market in achieving higher rate, higher level of occupancy, quicker absorption period, and attracting and retaining high-quality tenant. Statistics in a case study, a 19 story office building in Portland, shows that “prior to its Gold LEED-EB certification, energy consumption escalated each year from 2004 through 2006. However, since the building’s LEED certification in 2006 and implementation of a variety of energy strategies, energy use declined in 2007 by 3.45% and in 2008 by 8.73%, reflecting increasing year-over-year reductions. From 2007 to 2008, overall operating expenses declined by 0.64%, and they are projected to decline by an additional 3.29% in 2009 (p. 9).

#### **2.4.3.2 “Causal-Comparative” Studies**

Some real estate researchers have compared larger sets of sustainable and non-sustainable property with statistical modeling to understand the incremental value added by sustainable labels. These studies claimed that sustainable buildings with green features and certifications, such as LEED or ENERGY STAR labels, on average have lower operating costs, higher rents, higher occupancy levels, faster absorption of tenants, lower tenants’ turnover rate and therefore higher market value. They attempted to quantify the increased higher value to statistically answer the question of “does green pay off” in order to encourage investors and lenders to invest in sustainable properties. However, it should be noted that these competitive advantages might be the result of a combination of variety of factors, but it is indisputable that green attributes play the significant role in marketing and running these green buildings. Lease structure in sharing incentives of sustainability is one the most important factors influencing the tenants behavior in demanding sustainable properties. In terms of reliability and applicability of the results of these studies, Muldavin (2009) has stated that,

The statistics/modeling-based financial analyses provide general support for a positive relationship between a green building certification (LEED or EnergyStar) and improved rents and sales prices for commercial properties. However, all of the studies have significant methodological, data, and statistical limitations that limit the reliability/applicability of the numerical conclusions to specific property valuations.

It is important to note that while the specific numerical results may be of limited reliability, it does not imply that the rent and sales price premiums are necessarily overstated, just that methodological and data limitations make it difficult to rely upon the numerical results. For example, one of the limitations of the studies is that they tend to focus on rents, while many other important value increasing attributes, like faster absorption, better lease terms, higher tenant

retention rates, and lower risks (discount and cap rates) are also possible indicators of tenant preference, but these variables are not evaluated in the existing studies.

According to Ellison, et al. (2007),

These [current studies] produce useful case studies demonstrating how cost savings and good value has been achieved with sustainable buildings. However, they fall short of developing a systematic means of capturing the risk or return that could be attributable to the presence of specific sustainability characteristics within existing buildings (p. 194).

The statistical modeling studies that have been reviewed in this research have been written by researchers including Norm Miller, Jay Spivey, Andy Florance, Piet Eichholtz, Niles Kok, John Quigley, Franz Fuerst, Patrick McAllister, Brian Ciochetti, and Mark McGowan. Below, two of these studies are presented.

- *Doing Well By Doing Good? An Analysis of the Financial Performance of Green Office Buildings in the USA.* Eichholtz, Kok, & Quigley (2009) have studied the impact of LEED and ENERGY STAR certifications on the rent and sales price of 893 buildings to determine a financial premium attached to green office buildings using statistical analysis (regression analysis). The result of their study has shown that

effective rents—rents adjusted for building occupancy levels—are about six percent higher and the selling price are about 16 percent higher in green buildings than in comparable office buildings nearby. And upgrading the average non-green building to a green one would increase its capital value by some \$5.5 million (that, of course, does not take into account of the cost of conversion, so this is not pure profit) (p. 9).

- *The CoStar Study.* The CoStar Group<sup>21</sup> has also conducted a study to evaluate the value added by sustainability on property by comparing returns—occupancy level, rental rate, and sale price—on comparable green office buildings to conventional ones from the entire United States.

“According to the CoStar study, LEED buildings command rent premiums of \$11.33 per square foot over their non-LEED peers and have 4.1 percent higher occupancy. Rental rates in ENERGY

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<sup>21</sup> CoStar Group, Inc., is the number one provider of commercial real estate research and information services for property investors and sales professionals in the United States and United Kingdom – covering more than 59 billion square feet of commercial property, including over 7 billion square feet of space for lease("Costar website,").

STAR buildings represent a \$2.40 per square foot premium over comparable non-ENERGY STAR buildings and have 3.6 percent higher occupancy” (Burr, 2008, para. 3).

Muldavin (2008) has declared that this study “provides an excellent vehicle to address the application and use of statistical data in sustainable real estate decision making [as opposed to case studies] due to its quantitative emphasis, important conclusions, and broad distribution” (p. 3). However, he believes that there are limitations on the applicability of the results of this study, such as small sample size in peer selection, low confidence level due to large variance of outcomes, and insufficient presentation of risks and rewards. From the result of this study, Miller, Spivey, & Florance (2008) have concluded “Green does pay off” and those buildings that do not reflect more efficient operating abilities as required by green buildings will become obsolete much faster...Even without higher rents, in recalcitrant markets we observe higher occupancy rates and faster absorption all of which translates into higher values that almost certainly exceed the marginal costs to go green (p. 16).

John Russell, founder and president of Russell Development Company—a private development company which owns a number of office buildings in Portland, Oregon, and its commitment to sustainable development principles and practices is well known—also has said that:

“there is growing market perception that incorporation of high performance green principles and practices is directly related to enhanced marketability and increased tenant attraction and retention.” As a result, Russell development continues to implement building improvements and has set a goal to achieve LEED-EB Platinum certification for its property. (as cited by Chappell & Corps, 2009, p. 58)

Therefore, the results of these studies are *generally* very helpful for decision-makers in providing more insight into sustainability investment while confirming that the financial performance of sustainable buildings outperforms the conventional ones. However, they are not sufficient for valuers to rely on in precisely forecasting the value shifts by the green features.

#### **2.4.3.3 “Fundamentals of Sustainable Property Valuation” Studies**

During the last decade, studies have been conducted around the world (especially in Germany, U.K. and Australia) to express and communicate the financial advantages of sustainable buildings in appropriate language in order to assist investors in understanding the value of sustainability and to make better decisions. These studies primarily address the key issues related to financial analysis and the valuation process of a sustainable property, fundamentally investigate the relationship between sustainability and



property market value, and provide different suggestions for deriving the financial performance of sustainable property

Lützkendorf and Lorenz (2006) stated that

There are three primary studies in this area, including: development of a methodology as the starting point for calculation of sustainable property worth; suggestions about market valuation procedures of sustainable properties; and initiating the use of the property rating system (adopted from credit scoring system in banking industries) as a means to measure the risk associated with sustainable building investment (p. 2).

In this section, some of the key researchers in this field are introduced and their studies are explained.

- Sarah Sayce, Louise Ellison and Judy Smith (2004-present) from the U.K. have conducted a study to develop a method to quantifiably examine and calculate the impacts of sustainability criteria on the property's worth in financial language. They are among the first researchers who started to link benefits of sustainability to key financial model inputs including rental growth, depreciation and cash flow risks. Their study, although it has many limitations, provides an invaluable starting point for academics and practitioners in the property industry to rethink about financial analysis of sustainable property. They have focused on the Responsible Property Investment (RPI) approach and have considered the environmental, social and economic impacts of sustainability in appraising the value of assets, utilizing the traditional valuation method. Below, a short summary of their methodology is presented:

The methodology implemented in their research includes the following steps: First, it demonstrates the seven key physical characteristics used to assess the sustainability of the commercial property. The assessing criteria include operational energy efficiency; climate control; waste management; water management; pollution; physical adaptability of the space; and accessibility. Second, it develops questionnaires and a scoring system based on consulting with property investment industry experts and property occupiers to measure the performance of the sustainable property and produce a weighed score for each sustainability criteria. Third, it develops a system to link the scores to an appraisal model and translate each sustainability criteria to quantifiable impact through the standard worth variables of rental growth, depreciation and cash flow. In essence, the aim of this process was to link the sustainability characteristics to investment performance to quantify the property sustainability parameters and estimate their impact on property worth. At the end of the research two examples are used to examine and demonstrate the developed model.

As mentioned by authors, their method is limited in number of sustainability criteria and number of key financial inputs upon which they evaluate the impacts of sustainable criteria. Another important limitation of this study was that their financial analysis does not include a sufficient discussion about sustainable feature performance, the influence of building performance on financial performance and risks and uncertainty associated with building performance, and these may reduce the accuracy and reliability of the research results.

Again, their methodology in considering and linking the triple bottom line of sustainability criteria to key financial inputs for assessing the sustainable property, using the traditional valuation method, made a significantly important contribution to the property industry.

- David P. Lorenz and Thomas Lützkendorf (2005-present) are two key leaders in the field of sustainable property valuation research from Germany. They have published a series of papers on a variety of topics related to fundamentals of sustainable property valuation, such as sustainability valuation, building performance analysis and reporting sustainability risks. Many of the suggestions provided by these two leaders have been used and cited frequently throughout this research. In summary, following issues have been addressed in their papers:

- They believe that a new generation of building assessment tools is required to meet the current and forthcoming requirements associated with the description and assessment of each building's contribution to sustainable development. They have said that existing design and assessment tools do not address the many economic, social and performance facets over the life span of a building, and do not provide building assessment results for all dimensions of sustainable development. They have suggested advanced techniques rather than the traditional financial model (DCF model).
- They have explored the relationship between the sustainability of construction on the one hand and market value, worth and property investment performance on the other hand. They have analyzed price movements and price differences caused by different property characteristics and have calculated a hedonic price index based on the estimated log-linear hedonic regression model.
- They have proposed and discussed practical approaches on how to address risk and uncertainty within valuation reports, particularly when there is only insufficient comparable transaction evidence available.
- They suggest the integration of sustainability issues into the processes used by the financial and insurance industries for assessing property assets, such as property risk assessment, rating systems, and valuation, in order to incorporate the risks of sustainability.

- They have explained the rationale for integrating sustainability issue into property valuation theory and practice and to provide initial suggestions for valuers on how to account for sustainability issues within valuation reports.

Some of their recent published papers include

- Sustainable property investment: valuing sustainable buildings through property (2005);
- Addressing risk and uncertainty in property valuations: a viewpoint from Germany (2006);
- Using an integrated performance approach in building assessment tools (2006);
- Integrating Sustainability Issues into Property Risk Assessment: An Approach to Communicate the Benefits of Sustainable Buildings Paper presented at the Rethinking Sustainable Construction (2006);
- Financing and Valuing Sustainable Property: We Need to Talk (2007);
- Exploring the relationship between the sustainability of construction and market value (2007);
- Integrating sustainability into property risk assessments for market transformation (2007);
- Exploring the relationship between the sustainability of construction and market value: Theoretical basics and initial empirical results from the residential property sector (2007);
- Sustainability in property valuation: theory and practice (2008); and
- Next generation of decision support instrument for property industry (2008).

Multiple studies have been conducted by academics and practitioners from Australia. The studies that have been reviewed in this research are authored primarily by Terry Boyd, Phillip Kimmet, Richard Reed, John Robinson, Georgia Myers, and Stefan Trück. These individuals have also provided an in-depth analysis and foundations about linking sustainable features to financial performance and value.

Scott Muldavin, president of The Muldavin Company, Inc., founder and executive director of the Green Building Finance Consortium (GBFC), a group dedicated to addressing the private sector's need for better valuation and underwriting sustainable property, has been working on issues related to sustainable property valuation since 2006. Among the extensive literatures from around the world that have been reviewed in this research, the author found the works done by Muldavin at GBFC, the most valuable, comprehensive and useful studies that have been done in the field of sustainable property valuation.

#### **2.4.3.3.1 The Green Building Finance Consortium (GBFC)**

The Green Building Finance Consortium (GBFC) is a group of leading corporations, real estate companies, and trade groups who have joined together to address the need for independent research and analysis of investment in Green or energy efficient buildings. The mission of GBFC is to enable the private real estate sector—corporations, investors, lenders, and developers—to

appropriately recognize the value and risk of investment in Green Buildings. To accomplish this mission, GBFC will develop the underwriting practices, tools and valuations methodologies required to assess, from a fiduciary perspective, investment or lending on Green buildings, and widely communicate the results of their work ("The Green Building Finance Consortium ", 2006, para. 1&2).

**Value Beyond Cost: Underwriting Sustainable Property Investment:** The Green Building Finance Consortium's Underwriting Sustainable Property Investment builds off the theoretical foundation [presented in previous section]. The Consortium's work expands beyond valuation to the broader context of sustainable property investment decision-making. Additionally, the Consortium attempts to provide not only the theoretical and background research necessary to understand sustainable property financial analysis and valuation, but additional insights and tools to enable better valuation and underwriting practices. While many of the research studies [discussed in previous section] touch on these issues, particularly those written by the valuation practitioners, the challenge of communicating the concept of sustainable valuation is that sustainable issues cannot be considered or evaluated in isolation from the hundreds of other non-sustainable factors that influence a property's value or financial performance.

The relevant findings of Underwriting Sustainable Property Investment have been cited frequently throughout this document. The framework suggested by Muldavin (2010) for deriving the financial performance of sustainable property, is used as a foundation in this research for developing a valuation process for evaluating the sustainable options. The framework is explained in detail in section 2.4.4.2.

#### **2.4.3.3.2 GBFC Principles for the Application of Existing Research**

Muldavin (2010) has provided general guidance for interpreting and applying the results of existing studies identified above, which are very important to be carefully considered. Failure to apply these principles by advocates, analysts, and the media has resulted in substantial confusion and misrepresentation of the evidence of sustainable property performance.

**Principle One: Different decisions require different types of market data.** Sustainable property market performance research can be interpreted and applied in many different ways. Unfortunately, if a user of market research does not understand the details of the market research, or the types of decisions that it is most applicable to, research results and conclusions can be misused and misunderstood. Sustainable Property Financial Analysis, general research, and surveys [case-based studies and causal-comparison studies] can be helpful, but much more detailed and granular data and analysis is required. It is improper and inaccurate to directly apply

the numerical results of statistics/modeling-based research done at a general level to any particular property-level analysis (p. 78).

**Principle Two: Failure to understand types of market research will lead to failure in interpretation and application.** It should be understood that the caveats and the hedging of conclusions that are often found in these studies [case-based and causal-comparison] is not a reflection of a lack of confidence in the general conclusions that they reach, but a recognition by experts that did the studies that any general conclusions based on detailed property analysis are difficult and always subject to caveats. Statistics/modeling-based financial analyses are primarily applicable to strategic decisions, where general conclusions about markets and properties can be quite valuable in moving enterprise level decision-makers to invest resources to better understand sustainable property investment, but have very limited use for property level decisions. Foundational background and theoretical research [fundamentals of sustainable property valuation studies] provides the necessary linkages and intellect required to develop sound market research methodologies and properly apply results (p. 79).

**Principle Three: Sweat the details when applying market research to property level decisions.** The most important guidance in interpreting and applying any types of studies is to sweat the details. If one is to attempt to apply statistics/modeling-based financial analyses to a property level decision, it is critical to fully understand the data, sample size issues, control factors, and other details (p. 80).

Muldavin (2008) has argued that there are three types of investment decisions: First, a strategic decision: should we invest in sustainable buildings? Second, a tactical decision: Which property? Which attribute? Third, a property-specific decision: are benefits sufficient to compensate for the risk taken? What is the property value? (p. 13). Current data and studies (case-based and causal-comparison studies) might be appropriate to address the strategic investment decisions for sustainable property, but they don't directly address the tactical and property-specific decisions due to their general nature and insufficient discussion on costs, benefits and risks of green features. "A more direct link between costs and value on specific projects would have to be established" (p. 4).

At best, these types of studies [case-based and causal-comparison studies] will provide general confirmation for financial assumptions that should be derived from more property-specific methods, and may affect the risk or uncertainty of a particular financial assumption (Muldavin, 2010, p. 80).

## **2.4.4 Deriving the Financial Performance of Sustainable Property**

### **2.4.4.1 Sustainable Options-Based Valuation**

It is very important to note that for deriving the financial performance or value of a sustainable property, sustainable certifications are not an accurate and reliable basis to establish a relationship between sustainability performance and financial performance. As mentioned previously, an important challenge in comparing the sustainable property is that sustainability performance can be achieved through a variety of different features. Even two LEED certified buildings with the same level rating might have employed different systems and design strategies in achieving the same level certifications. These buildings might have a different environmental, social and economic performance. It has also been argued that the best approach for evaluating the financial performance of a property is focusing on the actual building performance.

These suggest that more focus should be placed on the specific sustainable features and strategies employed in a sustainable property and their relation to value creation and risk mitigation, when evaluating its financial performance rather than simply focusing on sustainable certifications or ratings.

Furthermore, it is possible that buildings with many sustainable features don't receive any certification; focusing on certifications for evaluating the financial performance of sustainable property will underestimate the value of these properties.

Accordingly, this research has focused on evaluating sustainable options, and linking the sustainable options to financial indicators to derive the bottom line financial performance. However, unlike many sustainability tools and analyses, it has focused on building performance indicators and their linkage to financial performance indicators, as suggested by a few of the “fundamentals of sustainable property valuation” studies. Most sustainable cost-benefit analyses and sustainable property performance studies tend to stop at the building performance level, but fail to directly tie to financial performance. The suggested framework by GBFC, which is explained in more detail in section 2.4.4.3, will be used for building the skeleton of a proposed process in this research.

### **2.4.4.2 Determining the Financial Performance of a Property in the Real Estate Industry**

It is very important for decision-makers involved in sustainable properties to understand how real estate and property professionals determine the value of their property for the purpose of property-level investment decision making. According to Muldavin (2010),

If a sophisticated real estate investor wants to understand a specific property's market demand and potential value, they typically hire a market feasibility consultant, valuer/appraiser, or internal staff that is trained in these specialty areas. These analysts follow well-recognized procedures in data collection and analysis, focusing on direct comparable properties in the sub-market, market and economic trends for the local and regional markets, detailed assessment of tenant demands and preferences in the marketplace, and many other analyses. At the end of the analysis, they select specific inputs for their financial models and make a determination about the potential financial performance of their properties. These well recognized procedures include a substantial number of quantitative analyses including forecasts of supply and demand, structured analysis of comparable properties, and numerous other financial analyses of specific operating expense inputs, occupancy or absorption trends, and other key information that is then integrated in a more qualitative way into the final determination of financial variables.

*Real estate professionals do not make a final specific-property investment decision, such as acquisition of a specific property, based on the results of a statistical analysis—regression analysis—nor case studies. These types of statistical analyses are regularly used for the market forecast but are not the primary techniques that real estate professionals use to determine the market rents, occupancy, capitalization rate, or other key assumptions in their financial value analysis. The sophisticated professionals rely upon their qualitative and quantitative analysis of market to determine the tenants' and investors' demand to ultimately making judgment about value variables.*

#### **2.4.4.3 GBFC Sustainable Property Performance Framework**

The GBFC Sustainable Property Performance Framework is a new structure for organizing and evaluating the property performance in order to enable improved financial analysis, valuation and underwriting. This framework suggests that for evaluating the potential financial implications of a property with the specific level of sustainable performance, one must assess:

First, Process Performance, such as integrated design team and energy use forecasting;  
Second, Features/Systems Performance, such as energy/water consumptions and indoor air quality;  
Third, Building Performance, such as development costs, resource use, and occupant performance;  
Fourth, Market Performance, such as operating costs, and space user, investor and regulator demand;  
And finally, Financial Performance, such as key financial model inputs and risk assessment.

Muldavin (2010) argued that

There is no direct way to go from building performance to financial performance. Even if you know how much a building costs, how many resources it used, potential health or productivity



benefits and related building performance statistics, the only way to assess financial performance (return on investment, value and risk) is to assess the market's response to the specific performance of the building...Finally, financial performance of sustainable properties is determined by evaluating how the market's response to the sustainable building will affect its financial inputs including rent, occupancy, absorption, discount rates, cap rates, operating costs, entitlement benefits, and other key variables. Financial performance is measured by the resulting rate of return or value that result from the input of the key financial inputs into a discounted cash flow or related model (p. 33)

## 2.5 **Summary**

Over the past decade, demand for sustainability has increased dramatically in the real estate industry. Improvement or green retrofits today are recognized as excellent investment opportunities among the investors and owners of current properties. The recent shift towards achieving LEED for Existing Building among the investor-owners proves their increased awareness of potential returns inherent in improvement investment.

However, current sustainability tools and techniques, which are typically developed by design professionals, on their own do not provide the understandable, comprehensive, and reliable information in the context that enable decision-makers to make informed investment decisions at the property level. Most sustainable cost-benefit analyses tend to stop at the building performance level and fail to directly tie to financial performance. Real estate investors use their own methods and processes to recognize the value and risk associated with investment options when making investment decisions.

Sustainability offers more than cost savings to real estate. The true financial performance of a sustainable property is beyond the energy and operating cost savings. Non-energy benefits as well as potential value implications of sustainable options need to be taken into account in order to arrive at more comprehensive financial outcomes.

No single tool is sufficient to fully assess the financial performance of sustainable options. The technical tools (used by design professionals for evaluating building performance indicators) as well as valuation and statistical techniques (traditionally used by investors for assessing an investment options) need to be integrated to create a new procedure for estimating the financial performance of sustainable options in the way that investment decision-makers can rely and apply in their investment decisions. A holistic approach is needed that goes beyond the current practice of sustainability cost-benefit assessments to truly capture the financial performance while explicitly considering risk and uncertainty.



The complete financial performance assessment of green or energy efficiency investment needs a new integrated approach. It cannot be done by a single group of experts. The holistic assessment requires both design and property professionals to be involved, and both technical and financial/statistical techniques to be intelligently utilized in the evaluation process.

In this chapter, for the development of this new approach, three different domains were studied: 1) sustainable systems and building performance, 2) risk and uncertainty in property valuation, and 3) sustainable property valuation and financial analysis. Below is a summary of conclusions:

A clear and comprehensive assessment of sustainable features and their various performance indicators as well as risk associated with each building performance factor is critical for deriving the final financial performance. The building performance information provides the basis upon which the market analysis could be conducted for understanding market demand and ultimately the value of a property.

In order to better understand the risk associated with sustainable options investment, the investment analysis should start from a careful assessment of sustainable features. Various uncertainties inherent in the performance assessment need to be clearly measured and articulated, for example, uncertainty associated with actual EER of an HVAC system in an existing building. Ignoring the uncertainty associated with building systems and performance in this step could result in underestimating the ultimate risk which may lead to bad investment decisions.

Sufficient scientific studies have been conducted to suggest the positive relationship between sustainability performance indicators, such as ventilation rate or daylighting, and health as well as productivity; however, their results may not be sufficient to be generalized. The application of quantitative conclusions of these studies may not be reliable; however, these benefits should not be ignored in the financial analysis of sustainable options as their potential impacts on cost savings might be very large. Relative to their potential impacts on property value, the accurate quantitative estimates of health and productivity is not required for real estate investment decision making. The investment decision-making process in real estate (determining value parameters such as rents, occupancy, retentions, etc.) is more a qualitative process. What is important is that those benefits could be clearly analyzed and reported to real estate people, so they can assess the market response to those benefits and make judgments about the key value parameters.

Risk and uncertainty analysis is a critical part of every investment decision making process. In property valuation risk needs to be measured and considered simultaneously with other issues of the valuation

process; otherwise the outcomes of the valuation process may be overestimated or even underestimated, and may lead to inappropriate investment decisions.

The Discounted Cash Flow (DCF) Model, which is a subset of income approach, is suggested to be as the best technique to deal with valuation of a sustainable property. The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate the potential non-cost benefits and non-quantifiable risk associated with sustainability investment in generating investment' revenue.

The majority of the studies on the financial implications of sustainable property are either case-based or causal-comparative studies. The results of these studies are generally helpful for decision-makers in providing more insight into sustainability investment while confirming that the financial performance of sustainable buildings outperforms the conventional ones. However, they are not sufficient for valuers to rely on in precisely forecasting the value shifts by the sustainable features.

Real estate professionals do not make a final specific-property investment decision, such as acquisition of a specific property, based on the results of a statistical analysis nor case studies. The sophisticated professionals rely upon their qualitative and quantitative analysis of market to determine the tenants' and investors' demand to ultimately making judgment about value variables.

Accordingly, this research has gone beyond the current sustainable option assessment practice, and has proposed a step-by-step procedure for decision-makers to follow to arrive at more reliable financial outcomes. In the value-based analysis part of the process, focus has been placed on linking the building performance factors to financial model inputs for deriving the potential value-added by sustainability investment, as suggested by a few of the "fundamentals of sustainable property valuation" studies.

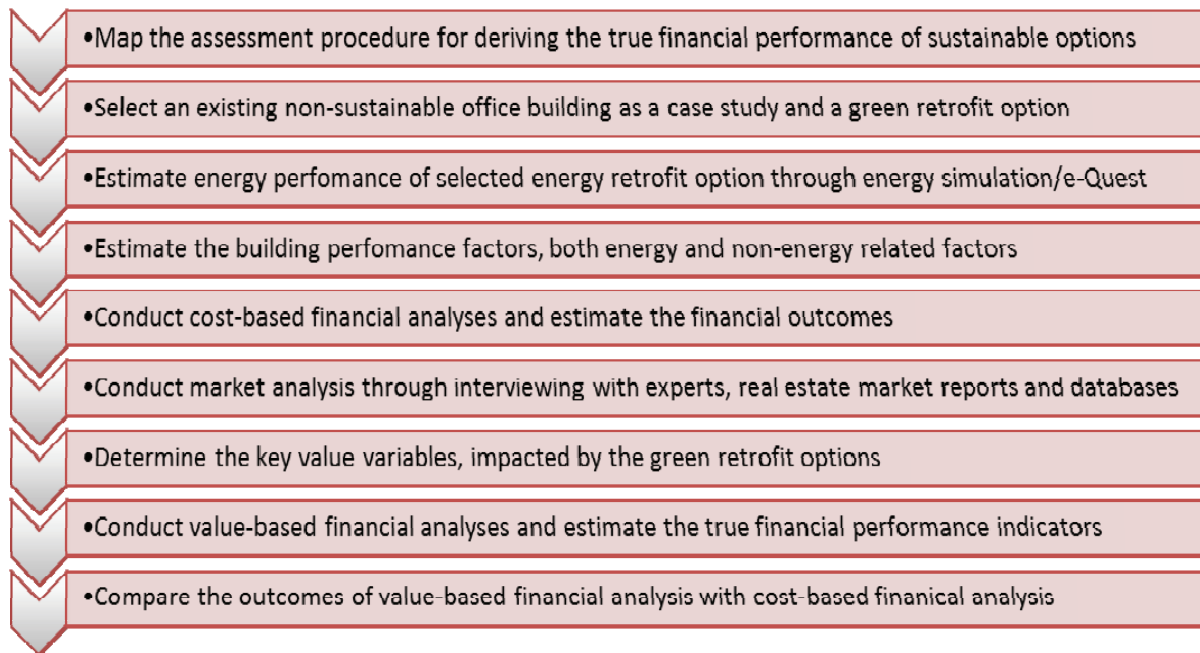
## **CHAPTER 3 RESEARCH METHODOLOGY**

The main purpose of this chapter is to set forth the rationales and foundations for the development of a new framework to include risk and uncertainty for assessing the financial performance of sustainable options investment in the context of value. This chapter focuses on mapping the assessment process, and explains the characteristics, challenges, approaches, and methods employed in this research. It also describes the case study approach that is utilized in this research to test and demonstrate the numeric application of the proposed framework.

**Overview of Methodology:** *The methodology in this research is a combination of both quantitative and qualitative approaches through integration of a case study and survey tactics.* An integrated approach was required in this research because the case study includes energy simulation, building performance assessment, real estate market research, and a value-based analysis. The parts related to energy simulation and cost-based analysis required a quantitative assessment approach. However, for the parts related to real estate market research and valuation a qualitative approach was needed for collecting the required information for determining the value parameters in real estate valuation. Combining qualitative and quantitative methods, as stated by Law and McLeod (n.d.) and Groat and Wang (2002), complemented the weak points of each other and made for a stronger research design resulting in more valid and reliable findings.

This research begins with mapping of an integrated assessment framework to derive the financial performance of sustainable options in major green retrofits of existing buildings. Then, an existing non-sustainable office building is selected as an instrumental case study in order to quantifiably demonstrate the application of the procedure. The case study includes two parts:

The first part, which is presented in Chapter 4, includes utilizing an energy model software and development of an Excel-based model for energy performance and cost-based financial analysis. The required assumptions in the modeling step were initially made based on the literature and researcher's professional judgment and then were verified through interviewing with experts from the related industry. The second part, which is presented in Chapter 5, includes the real estate market research and the value-based financial analysis. The research's tasks are summarized in Figure 3-1:



**Figure 3-1: Summary of Tasks**

### 3.1 **Overview of Problem and Objectives**

As more fully discussed in previous chapters, demand for sustainable property investment has increased dramatically, and investment decision-makers, the key drivers behind the investment property market, are in need of more comprehensive, reliable and understandable information about costs and benefits of sustainability. It is argued that it is the responsibility of design professionals, such as green consultants, to organize and communicate the information about costs and benefits of sustainable property in a way that the investment professionals, such as owners, can understand and incorporate in their decision making process—*translation from technical to financial language*. Lack of design professionals’ knowledge of finance, valuation, and risk analysis techniques—language of business—is one of the primary barriers for communicating value of sustainable features to the investment communities and enabling them to make informed decisions about investing in sustainable options.

Current sustainability tools and techniques, which are typically developed by design professionals, on their own do not provide the understandable, comprehensive, and reliable information in the context that enable decision-makers to make informed investment decisions at the property level. Most sustainable cost-benefit analyses tend to stop at the building performance level and fail to directly tie to financial performance. Real estate investors use their own methods and processes to recognize the value and risk associated with investment options when making investment decisions.

Sustainability offers more than cost savings to real estate. The true financial performance of a sustainable property is beyond the energy and operating cost savings. Non-energy benefits as well as potential value implications of sustainable options need to be taken into account in order to arrive at more comprehensive financial outcomes. Unfortunately, most of the current real estate decisions about investing in sustainability improvements, especially in existing buildings are made based on the energy cost savings. However, as the demand for sustainability and energy efficiency increases (similar to what we have seen over the past decade) and sustainability becomes a higher priority in real estate investment decisions, the value implications of sustainability investment will become a more important part of the financial assessment. In future, without considering incremental value as well as risk and uncertainty, the financial analysis of a sustainable option investment will not be complete and might result in inappropriate investment decisions.

The complete financial performance assessment of green or energy efficiency investment needs a new integrated approach. It cannot be done by a single group of experts. The holistic assessment requires both design and property professionals to be involved, and both technical and financial/statistical techniques to be intelligently utilized in the evaluation process.

Accordingly, the objectives of this research are as following:

- To develop a new framework to consider both cost savings and non-cost savings benefits of sustainability in evaluating the financial performance of a particular set of sustainable options, while simultaneously addressing the risk and uncertainty inherent in the assessment process.
- To develop a more complete approach to go beyond the current sustainability cost-benefit assessment and capture the financial performance of sustainable options in the context of value and risk, in order to enable decision makers to make more informed investment decisions when evaluating greening the existing properties.
- To bring together the technical tools—used by design professionals for evaluating sustainable building design decisions—and financial techniques—traditionally used by property professionals for evaluating a typical property investment decision—to create an integrated step-by-step procedure for decision-makers to follow to arrive at more reliable financial outcomes.
- To explain how outcomes of technical tools can be intelligently applied and integrated in the real estate decision-making process and how the uncertainty associated with building performance can be modeled and included in financial analysis.

- To bridge the gap between two distinct but interrelated communities: technical decision-makers—such as architects, engineers, construction managers, and green building consultants—and investment decision-makers—such as investors, owner-occupants, real estate developers, portfolio managers, real estate appraisers, and lenders.

*The main focus of this research is to map a structured framework in detail and express how financial performance of sustainable options investment in existing properties can be derived while presenting a better picture of value and risk associated with those options; but unlike the previous literature in this area, it is intended to develop a systematic model that can be applied for a particular sustainable option and represent the financial indicators, such as NPV and IRR, and their associated risk and uncertainty in the form of probability distributions as well as a standard summary of statistics. The case study, presented in Chapter 4 and 5, shows how the more complete financial assessment of sustainability can impact the investment decisions.*

### **3.1.1 Research Target Audience**

The outcomes of this research will communicate with property professionals, such as real estate investors, owner-occupants, developers, facility managers, lenders, and bankers in a proper language and benefit them in making high-quality investment decisions and appropriate choices among sustainable options. It will help them to understand the various risk and uncertainty sources in the assessment process of sustainable options which would impact the final financial performance and therefore the investment decisions—risk and uncertainty at the building performance level would directly influence the ultimate investment risk.

The process could also be very helpful for design professionals, such as architects, engineers and green building consultants, to go beyond their current technical approach and estimate the financial performance of sustainable options in the way that the property professionals can rely and apply in their investment decision making. The framework will give design professionals a step-by-step procedure to follow to understand the impact of their design decisions on those factors that are important for the property professionals. This will increase the quality and the level of confidence of their design recommendations.

As fully discussed in the paper entitled “The True Value of Sustainable Buildings: What Else Do Design Professionals Need to Know about Sustainability Investment?” by Bozorgi and Jones (2011),

Design professionals are not able to estimate and communicate reliable financial performance data for sustainable buildings if they solely rely on their current approaches and knowledge. They

need to utilize more sophisticated financial/valuation and statistical techniques in order to present the true value of sustainable buildings to property professionals. While designers are not expected to perform a thorough market analysis and predict accurate financial model inputs, they are expected to provide comprehensive, reliable and understandable information to their clients and assist them in making investment decisions. They are expected to acknowledge that benefits of sustainable building investment are beyond cost savings and to consider full costs, benefits, risks and uncertainties in their analysis (p. 416).

The full paper is included in APPENDIX G.

### 3.1.2 Specific investment context

Although the fundamental valuation process is similar for different sustainable properties it has been discussed that differences in investors<sup>22</sup>, type of properties<sup>23</sup>, type of decisions,<sup>24</sup> and locations significantly influence the financial model inputs as well as the form of the outputs from valuation analysis. For example, different investors may have various intentions regarding different property types with various performance needs, and therefore they may have various priorities when selecting among the green strategies. Each investment decision type has a unique context and requires unique analysis.

Therefore, in order to better demonstrate the application of the proposed model and best selection of the inputs in mapping the valuation process, this study focuses on the development of a process for *major green retrofits* (decision types) of *existing office buildings* (property types) from the perspective of *investors and owner-occupants* (investors types) in the *United States* (property location).

The investors and owner-occupants need to know what the possible options (systems and strategies) are for greening the building, and how each option affects the bottom line financial performance of their investment as well as risk associated with achieving the outcomes. They need to thoroughly know the return they might have received (considering risk and uncertainty) above the amount they would have received had they not invested in sustainable options. In other words, how might their decisions about sustainable options (green system level decisions such as HVAC system, lighting systems and daylighting) play a role in estimating financial performance (risk and revenue) of their office building and

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<sup>22</sup> Investor types: investor/landlord, owner-user, spec developers, tenant, lender/rating agency, public sector, institutional such as school, hospital, etc.

<sup>23</sup> Property types: multi family, office, industrial, retail, healthcare, school, hospitality, government and land.

<sup>24</sup> Investment decisions: build (new construction, major retrofit, commercial interior), buy, lease, operate and finance

how confident could they be about achieving projected performance from the selected set of options? For addressing these issues in their decision-making process, they need to fully understand all costs, benefits and risks pertaining to sustainable options—cost and non-cost benefits—as well as the knowledge of how to include that information in their financial model. This is a deficiency that will be addressed through this research.

*Through the new financial assessment framework, this research aims to improve the final decisions about whether or not to proceed with investing in a particular green retrofit option in an existing income-producing property, and also assists the decision-makers in selection of the best set of possible green options.*

As explained in detail in Chapter 2, many suggestions have been made about the following three major areas:

- Issues related to sustainable options and their performance projections (energy-related systems investment);
- Issues related to sustainable property valuation process and incorporating sustainability into the financial model (DCF model); and
- Issues related to incorporating and communicating the uncertainty in energy simulation as well as property valuation process by utilizing the probability-based model.

*This research attempts to incorporate these three domains into a new single model to evaluate the possible green retrofit options and determine their range of financial performance in a way that can be utilized by decision-makers for making more informed investment decisions about greening their buildings.*

## **3.2 Mapping the Assessment Process**

### **3.2.1 Approach**

As mentioned before, for a complete financial assessment of green retrofit options non-energy benefits as well as potential value and risk implications of sustainable options need to be considered along with energy cost savings. One of the suggested methods for measuring the financial performance of a sustainable property in the context of value is measuring the actual building performance and linking this to the standard financial model inputs, such as rent, tenants absorption, etc. However, the problem with this approach is that most of the investment decisions need to be made before the green features are

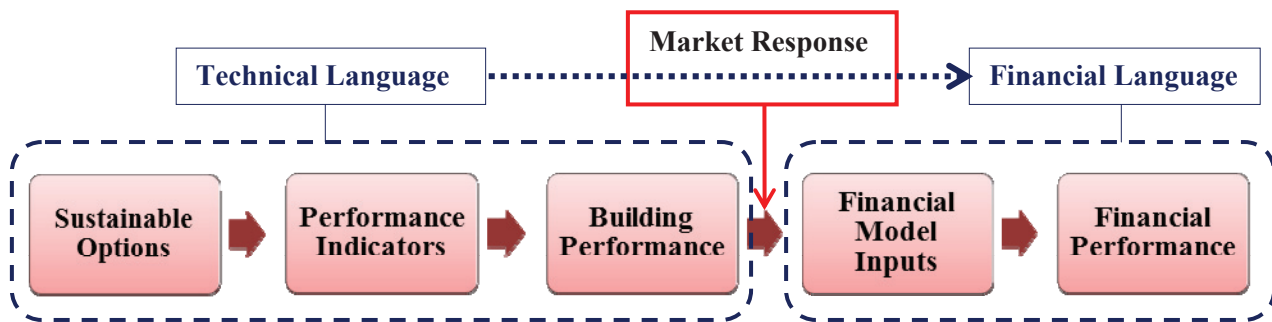


installed. Therefore, understanding the value implications part of financial performance of sustainable systems mainly depends on the decision-makers’ predictions about the building performance and market response to these predictions.

While valuers and underwriters of existing properties focus on actual building performance, this is not possible for new construction or major/moderate retrofits that would add certifications and/or change operating performance of a property. In these situations, valuers and underwriters must form judgments about forecast building performance, and the market’s response to it. Their job is to do as much research and due diligence as possible to reduce uncertainty in building performance forecasts (Muldavin, 2010, p. 8 of Chapter IV).

Most of the current studies in the area of green buildings performance focus on the assessment of the green features’ performance and building performance indicators, and does not directly tie them to financial performance. However, Muldavin (2010) has developed a “Green Building Finance Consortium (GBFC) Sustainable Property Performance Framework” which links the building performance to the financial performance through the assessment of market performance. The GBFC framework is explained in more detail in Chapter 2: section 2.4.4.2.

This research generally follows the process shown in Figure 3-2—adapted from the “GBFC Sustainable Property Performance Framework”—to derive the bottom line financial performance of sustainable options:



**Figure 3-2: A Process for Deriving the Financial Performance of Sustainable Options**

This process is a translation path that decision-makers, either technical people (design community), such as architects, engineers, any green building consultants, etc., or property professionals (investment

community), such as investors, owner-occupants, lenders, asset managers etc., should go through in order to fully understand the effect of their selection of green systems/strategies on the building financial performance at the pre-development stage. It translates the sustainable options impacts into the financial language to be included in a financial model and communicates the financial performance indicators to the end users in reliable and understandable terms.

### 3.2.2 The Process and Components

The proposed process,

- takes the selected sustainable options—investment alternatives—as inputs;
- estimates selected options-related performance indicators;
- projects their related building performance factors;
- links the building performance outcomes to the financial model inputs by evaluating the market’s responses—users’, regulators’ and investors’ responses—to the building performance;
- and finally, analyzes those inputs in the financial model to derive the bottom line financial performance. The components of the valuation process are shown in the Figure 3-3:

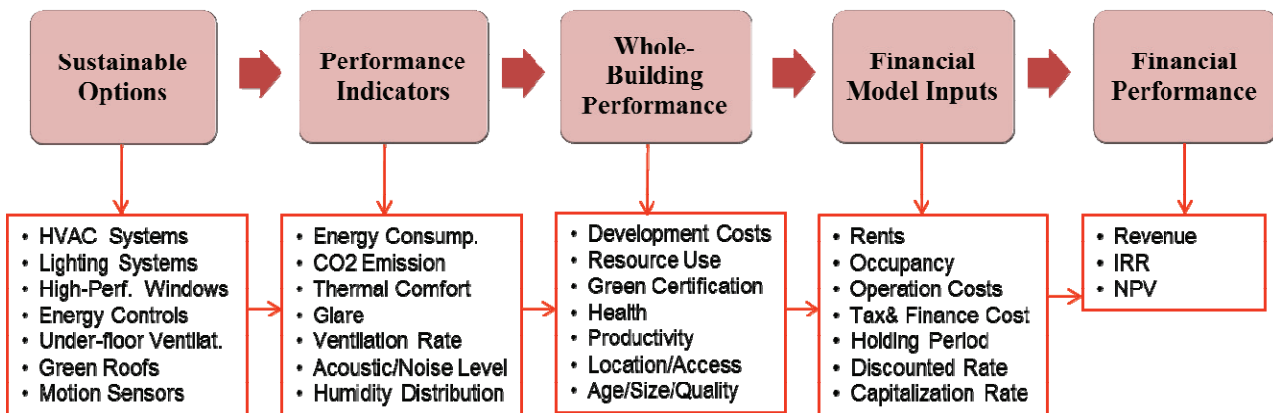


Figure 3-3: Components of the Valuation Process

**Sustainable Options:** in this research sustainable options refer primarily to the green systems and strategies used in green buildings. These include high-efficiency HVAC systems, lighting systems, daylighting, green roof, under-floor ventilation, motion sensors, high-performance windows, water saving

systems, solar hot water heating, operable windows, wind turbines, acoustic tiles, building commissioning, etc.

**Performance Indicators:** measure the performance of sustainable options/features. These include energy consumption (electricity bills, water bills, etc.), indoor air thermal/thermal comfort analysis, daylighting analysis, CO2 emissions, solar shading analysis, natural ventilation, lighting, acoustic analysis/noise level, moisture transport, temperature and humidity distribution, air flow analysis, contaminant analysis, fluid dynamic, glare, illumination, etc.

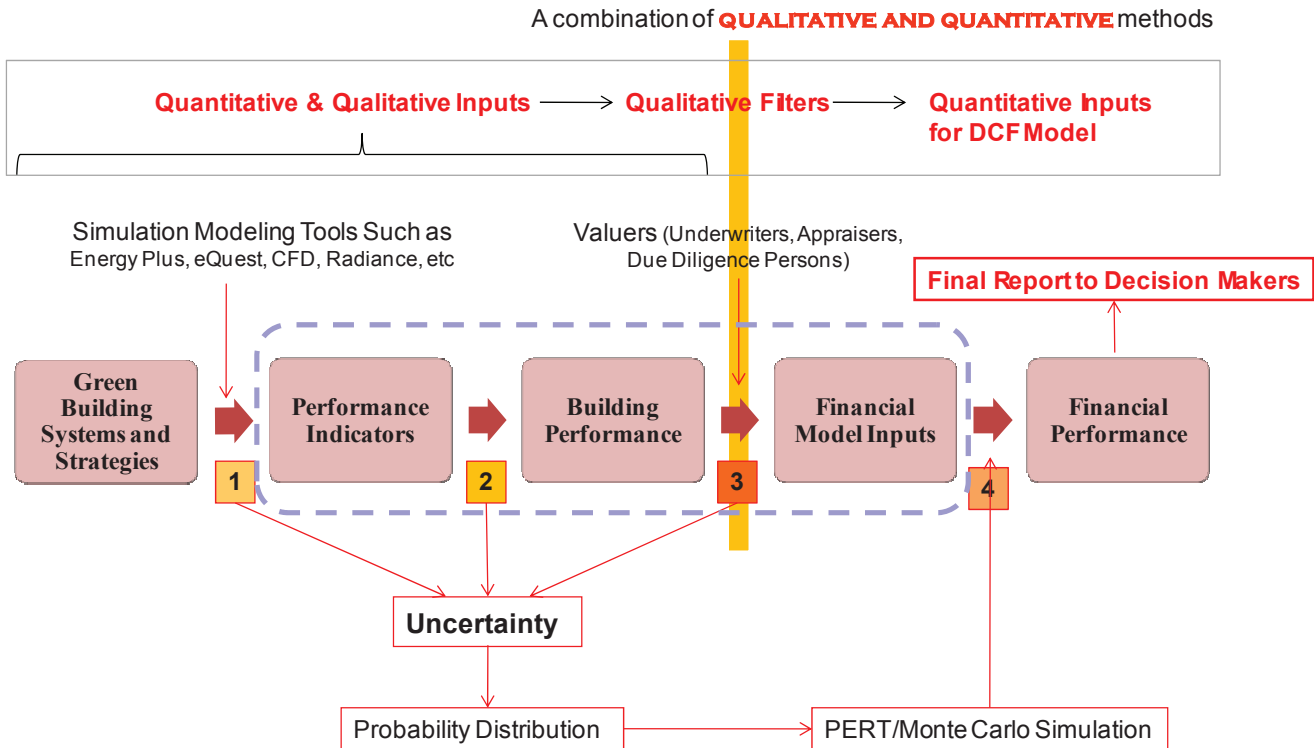
**Whole-Building Performance:** includes both sustainable building performance and non-sustainable building performance. Sustainable building performance, which are the factors related to the green retrofits, include development costs (hard/soft costs, timing, tax savings grants and financing costs), resource use, occupant satisfaction, health, productivity, contribution to green or energy certifications, achievable government incentives, reputation, marketability, public benefits, development and cash flow risks, etc. Non-sustainable building performance, which are the critical factors in valuation of a property and not related to the retrofits, include location, access, age, size, security, market condition, etc. This research is more concerned with factors that have a more explicit relationship with green systems and strategies, and are from the perspectives of private investors/owners, such as development costs, achieved green certification or government incentives, increased marketability, health and productivity.

**Financial Model Inputs:** the financial model suggested for this process for estimating the financial performance is a traditional Discounted Cash Flow (DCF) model. The inputs of the DCF model for estimating the revenue of the building include: market rental rate, annual rental growth, building costs (such as operation cost, leasing expenses, tax and capital cost), occupancy, tenant retention, discount rate and capitalization rate.

**Financial Performance:** contains factors that people from investment communities are primarily concerned with when making decisions. These include revenue, risk, internal rate of return, net present value, etc.

### 3.2.3 The Process Steps, Methods and Considerations

There are four main steps in the proposed process that decision-makers need to go through in order to better understand the financial performance of the selected sustainable options. The four steps and methods used in the process are graphically shown below in Figure 3-4: Process Steps and Methods.



**Figure 3-4: Process Steps and Methods**

### 3.2.3.1 Step 1: Simulation Modeling

For each selected system's or strategy's performance, certain performance indicators can be determined, for example, energy consumption as an indicator of energy performance, air temperature and humidity as indicators for thermal performance, ventilation rate and pollution concentrations as indicators for indoor air quality, luminance as an indicator for lighting or daylighting strategies. Then, depending on the system and its performance indicators, the selected systems can be modeled through the appropriate modeling tools, which are recognized by the U.S. Department of Energy for different types of decisions, in order to estimate the building performance indicators.

As discussed in Chapter 2, the U.S. Department of Energy has suggested a list of "whole building simulation" tools that one could look at, and select the ones that are more appropriate for those particular indicators and types of decisions one is concerned in evaluating. The users need to identify the potential indicators they are interested in evaluating, carefully assess the capability of available modeling tools, and ultimately select the most appropriate tools that match their requirements. For example, if the users are only looking at evaluating energy consumption, they might use eQuest or Energy Plus, but if they feel that the energy efficiency improvement strategy might have impacts on indoor air quality or daylighting

quality, they might need to model the building with a Computational Fluid Dynamics (CFD) modeling tool or Radiance Interface.

A comprehensive assessment of performance indicators is important in a value-based analysis, since any building performance indicator that is of interest to occupants could play a role in the financial performance of a building. Several studies have confirmed that the outcomes such as thermal comfort, indoor air quality, or acoustical performance would affect the occupant performance, such as occupant satisfaction, health and productivity. These factors potentially increase demand, influence the financial model inputs such as absorption rate, vacancy rate, etc., and ultimately improve the bottom line financial performance.

More detailed discussion about energy performance evaluation is presented in “A Framework for Estimating and Communicating the Financial Performance of Energy Efficiency Improvements in Existing Commercial Buildings While Considering Risk and Uncertainty” by Bozorgi and Jones (2010) which was presented at the IEECB’10 conference in Frankfurt, Germany. The full paper is included in APPENDIX G.

### **3.2.3.2 Step 2: Whole-Building Performance Forecast**

It has been argued that actual building performance is the primary basis for determining the financial performance of a property. Building performance indicators that have been estimated in the previous step could be a foundation for forecasting the actual sustainable building performance. As discussed previously, two types of building performance factors are identified: sustainable and non-sustainable. Sustainable building performance includes factors that could be influenced by the sustainability investment. Performance indicators estimated through Building Simulation Programs (BSPs) in the previous step are a foundation for forecasting the sustainable performance factors.

When evaluating a specific property, development and operation costs, resource use, and possible achievable certifications and incentives, can be estimated relatively easily based on available data, guidelines, regulations, and modeling tools. However, factors such as users’ satisfaction, and health and productivity are more difficult to measure precisely.

As mentioned in Chapter 2, scores of studies have confirmed that there is a positive relationship between sustainable building performance indicators and space users’ satisfaction, health, and productivity. However, these studies are not sufficient in order to establish a quantitative relationship that decision-makers rely on to precisely determine the required level of building performance, such as the required ventilation rate or daylighting for a certain level of health and productivity. Other types of studies show

that there is a positive relationship between social dimensions of sustainable properties, such as health and productivity, with their market value. Again, however, these studies cannot establish a robust relationship between the level of health/productivity and property value especially for the purpose of property-level investment decisions.

Currently, establishing the precise quantitative relationship between performance indicators, health/productivity and market value seems to be almost impossible, due to limited data and difficulty in obtaining required information in a way that can be used directly in property level decision making. However, as Muldavin (2010) has argued, in the real estate world, perfect science or exact knowledge about the potential health/ productivity benefits of sustainable property is not required. The current studies are sufficient to give the decision-makers information and insight, but they need to be very careful in applying the results in their decision-making process. Therefore, it is particularly important that decision-makers acknowledge the potential benefits to occupants and consider the occupants' response to those benefits that result from investment into sustainable features, even if the exact quantitative data is not available.

The second type of building performance includes the non-sustainable factors, such as location, access, age, etc. The good news for a value-based financial analysis of existing properties is that most of these non-sustainable factors do not change after implementation of the green/energy retrofits. Having considered all non-sustainable factors being equal in property valuation, all changes in the projected cash flow will be related to the DCF assumptions that are influenced by the selected sustainable options.

### **3.2.3.3 Step 3: Financial Modeling**

Financial models are tools that enable investors to translate their opinions and knowledge on the costs and benefits of a sustainable property investment into a measure of financial performance. Private sector investors typically require a financial model and analysis as part of the broader due diligence and underwriting of any investment decision (Muldavin, 2010, p. 97). As mentioned previously, the financial model suggested for this process of estimating the financial performance is a traditional Discounted Cash Flow (DCF) model. This analysis is able to deal with the complexity of various factors involved in real estate valuation, and incorporate the potential indirect costs, benefits and risks associated with sustainability investment (such as development risks and cash flow risks) in generating the investment's revenue.

As described in Chapter 2, discount rate in the DCF model is an indicator for the market's perception of risk associated with generating the cash flow, and is positively related to the amount of risk. This means a

lower risk premium and thereby a lower discount rate would be selected when evaluating an investment option which has a lower market risk. Lower discount rate will result in higher net present value. Discounted rates are typically estimated based on the quantitative analysis of market evidence. However, this may not be the case for a sustainable property as there is not currently much sales evidence available to enable a reliable statistical analysis. The selection process now is more a qualitative process.

Considering that many studies have claimed that sustainability offers benefits such as increased revenue and reduced future market risk, the DCF approach is well suited to incorporate those benefits simultaneously in performing a value-based analysis for a sustainable property/option. The result of a study by Bowman and Wills (2008) has confirmed DCF as the most suitable method for assessing the valuation of green buildings (p. 19). “Even though hard data is limited, the DCF approach allows valuers to factor in assumptions about the future shifts in value of Green Star buildings” (Bowman & Wills, 2008, p. 23). Muldavin (2010) has also concluded that,

Discounted cash flow analysis provides a conceptual framework and model that enables the user to integrate quantitative and qualitative analysis to measure sustainable property financial performance. Most importantly, it provides the means to translate the “intermediate” sustainable property cost and benefit outcomes like health or productivity benefits, expedited permitting, or lower operating costs into financial measures like rate of return or net present value traditionally used by real estate capital providers (p. 98).

There are two important challenges in determining the DCF inputs:

- One is the nature of this analysis, which requires a simultaneous consideration of all the factors impacting value, both sustainable and non-sustainable, when determining the DCF inputs. In order to understand the marginal financial implications of sustainability, it is necessary that sustainable factors be assessed in the context of the non-sustainable factors traditionally considered by real estate valuers. The traditional DCF approach is well suited to deal with this matter. Furthermore, the impacts of sustainable factors on the financial model inputs are typically limited when compared with the non-sustainable factors and therefore, improvement or decline in financial performance of a green building could be primarily due to other non-sustainable factors.

This is one of the reasons that it is very difficult to precisely determine the distinct impacts of sustainable features on financial model inputs. Real estate people are still not able to accurately determine an incremental value for investment in lobby versus landscaping or design. They rely on their market experience and judgment of what users may require based on their qualitative and

quantitative analyses. Accordingly, it should be possible to start integrating sustainability as a building component, such as a lobby or property landscape, into the valuation and decision-making process with having a specific number for every incremental financial input or specific ROI for every sustainable option investment.

- Another challenge is related to the valuation process of all property types, either sustainable or non-sustainable: that is a consideration of both quantitative data and qualitative judgment in determination of DCF inputs. Many statistical techniques and sustainability sub-financial analysis methods have been developed and used by real estate individuals to quantitatively assess and predict the impacts of a property's condition related to financial performance. The statistical analyses include regression analysis and sales comparison, the sub-financial analyses include Sustainability Options Analysis, Health and Productivity Benefits Analysis, Enterprise Value Analysis, etc. (Muldavin 2010). It is important to note that these analyses and quantitative data do not result in specific data that can be used directly in financial models, although they provide very useful information and insight into the assessment of financial model inputs.

In order to select financial inputs, for each specific property the valuers (underwriters, appraisers, due diligence persons) have to do as much research as possible in order to collect all related quantitative results, as well as other qualitative information. They must consider these results and information simultaneously and assess the expected behavior of regulators, investors and space users (key driver of property value) for that particular market.

“While the impact of green strategies may be clear in one market, it is the valuer’s responsibility to determine the market environment for high performance green features on a case-by-case basis” (Chappell & Corps, 2009, p. 39). The large number of studies into valuation variance confirms the “subjective nature” of property valuation. Adair & Hutchison (2005) also pointed out that “while the final single point estimate of value may become a statement of fact in the minds of the users of the valuation it nevertheless remains the opinion of an expert [valuer]” (p. 254). Hargitay & Yu (1993) have also said that value assessments usually rely on subjective judgments based on measures of past performance (p. 31). “Specific investment decisions regarding sustainable properties will be based on a combination of quantitative analyses informed by the qualitative factors and the judgment of underwriters, appraisers, and decision-makers” (Muldavin, 2008b, p. 16).

Therefore, the final financial model inputs are determined based on the valuers’ qualitative judgment and interpretation about market response (regulators, space users and investors’ demand) to the building performance factors determined in the previous steps. It is not possible to develop a robust tool in order to



perform this translation and produce the final financial inputs, such as a rent, to be directly included in the DCF model. *Data has to go through a qualitative filter.* Valuers are the ones who do this translation from technical language to financial language by integrating quantitative data from simulation tools or other assessment techniques with other qualitative information about specific subject property, and evaluating market response to the data and information in a specific situation. This is where qualitative and quantitative data come together for final qualitative decisions to be made. It is very difficult or impossible at this time to determine a quantitative link between a specific sustainability benefit, such improved productivity or contribution to a LEED certification, and the valuer's judgments about value variables.

### **3.2.3.3.1 Market Analysis**

As mentioned earlier, the financial model inputs are selected based on the market response to sustainable and non-sustainable building performance. Thus, as part of a value-based analysis of green retrofit, market research should be conducted to understand how sustainability or green retrofit options are important to the current tenants as well as the tenants that are expected to lease space in the building. This research could be done through an independent survey among tenants, brokers, property managers, investors, or other real estate professionals who are familiar with the sub-market. Type of questions that might be asked for a specific existing building are:

- How important you do think that sustainability or energy efficiency benefits such as better lighting and working environment, meeting compliance requirements such as LEED, higher productivity and satisfaction, are to the current tenants? Are these benefits important enough to influence their decisions about staying in the building when their current leases are due? Do they have any minimum standards relative to green/energy efficiency for the space they are occupying?
- What is the mix of potential tenants for this building, if the current tenants leave the building at the end of their leases? And how important are sustainable features for them?
- What percentage of potential tenants in this sub-market are asking for these green features?
- Who are the potential buyers for such buildings in this sub-market? And how important is sustainability for them?
- Do investors value the green features in this sub-market? If there are two buildings with the same Net Operate Income (NOI), and one has green features and one does not, would they value those differently?

Thorough market research provides a foundation upon which valuers could judge the DCF inputs. It also provides additional insights about rollover risk<sup>25</sup>.

#### **3.2.3.4 Step 4: Uncertainties Associated with the Process**

As discussed in Chapter 2, there is some uncertainty associated with measuring the outcomes of each step in the valuation process. Some of these uncertainties include:

- Uncertainty in Step 1: The degree of uncertainty associated with predicting the building performance indicators. For example, suppose early in the design process an architect or an energy consultant predicted that a designed HVAC system would reduce energy consumption by 20 percent based on her/his energy simulation analysis, but the building ended up with a 15 percent actual energy consumption reduction. This would mean the decrease in observed actual energy consumption would be 25 percent less than the predicted energy savings. (Inherent inaccuracy of energy models was discussed in Chapter 2)
- Uncertainty in Step 2: The degree of uncertainty in determining the building performance, such as health and productivity based on projected building performance indicators, such as ventilation rate, daylighting, level of noise, lighting, etc. Particularly, in the case of predicting health and productivity, the degree of uncertainty is substantial, due to the following reasons:
  1. Complexity and great variation of health and productivity performance in different situations—different property and green systems/strategies;
  2. Difficulty in simultaneous consideration of a large number of factors influencing health and productivity;
  3. Potential inaccuracy associated with experts' subjective judgments.
- Uncertainty in Step 3: The degree of uncertainty about selecting the financial model inputs due to limited sales data and absence of a robust pricing model on sustainable building as well as the difficulty of precisely determining the impact of sustainability on a property value. Suppose an owner of an office building used high efficacy lighting and HVAC systems in a major retrofit, and as a result of utilizing those systems, the monthly utility costs were reduced by 40 percent and the LEED silver certification was achieved. He predicted the new tenants would pay 10

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<sup>25</sup> Rollover risk refers to the risk of not being able to secure new tenants at favorable rates and terms when existing tenant leases in a building terminate. The risk also incorporates the leasing and tenant improvement costs to resign new tenants if tenants choose not to renew their leases. The rollover risk of a property will be unique to its particular portfolio of leases and markets conditions (Muldavain, 2010, p. 130).

percent more for the new condition, but tenants only agreed to pay 5 percent more for their rent. That would mean the rent of the green office building would increase by only 50 percent of the owner's projection. (Uncertainty in predicting future DCF inputs has been discussed in Chapter 2.)

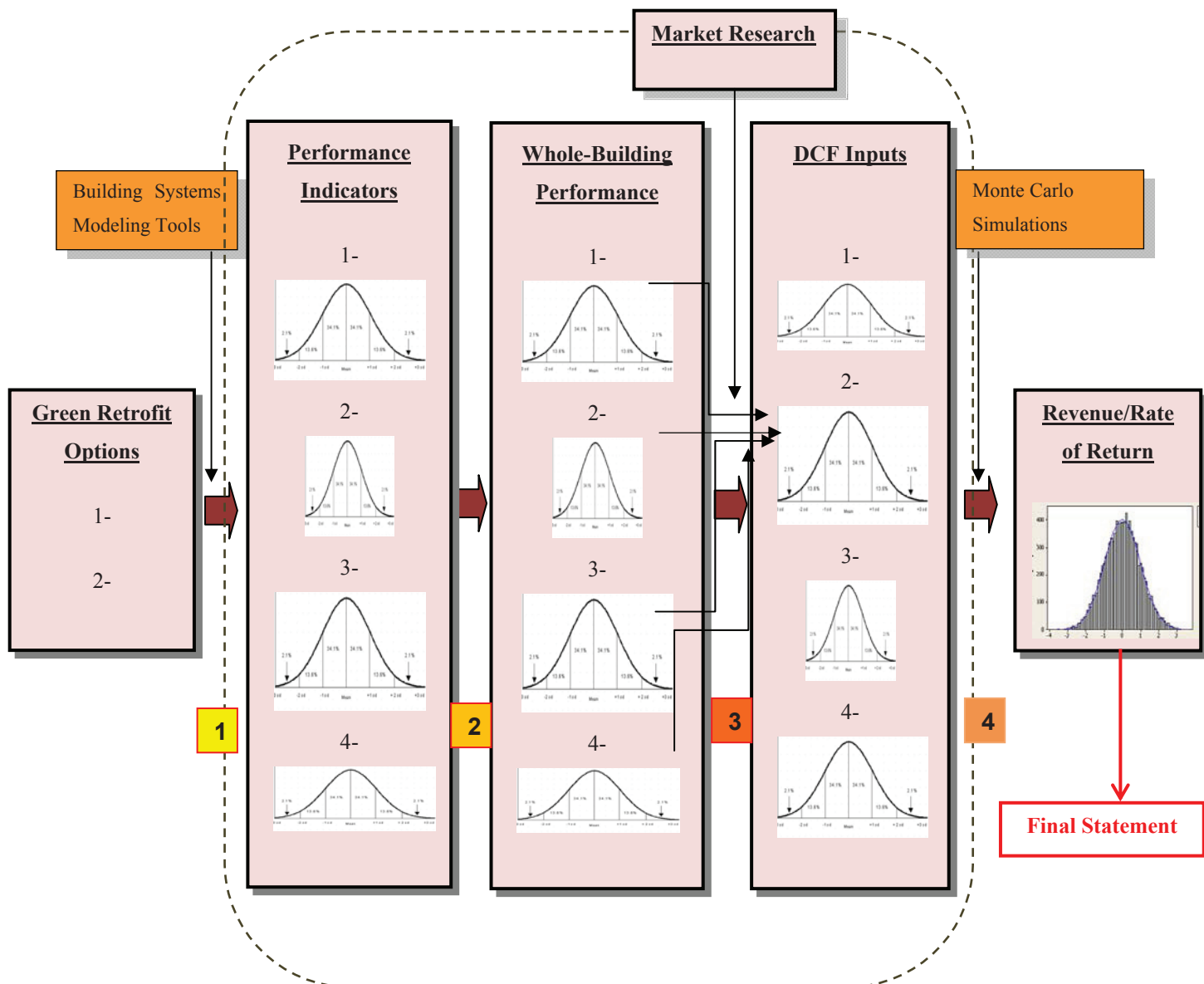
These are examples of the types of uncertainty associated with the sustainable property valuation process that this research aims to identify and describe. This research suggests specifying a probability distribution in order to express the uncertainty of all variables that are uncertain<sup>26</sup>. A clear and well-supported presentation of risk and uncertainty of achieving the expected value of sustainable buildings, both at the building performance and financial assessment levels, is critical in preventing underestimation or overestimation the financial performance of sustainable building.

A schematic diagram demonstrating the function of the proposed valuation process is shown in Figure 3-5. In summary, the four main translation steps shown in the figure are as follows:

1. identification of energy systems and estimating a probability distribution;
2. determination of a probability distribution for each building performance factor;
3. determination of a probability distribution for each DCF input; and
4. calculation of a probability distribution for final financial performance indicators.

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<sup>26</sup> Triangular distribution, which determines three points including range of possible inputs, the best, worst and most likely, could also be used. Whilst it is not the most robust statistical approach, it acknowledges that there is a degree of uncertainty in the choice of input variables and the output is not a single figure.



**Figure 3-5: A Schematic Diagram for Demonstrating the Function of the Proposed Assessment Process**

Program Evaluation and Review Technique (PERT) as a simplistic approach and Monte Carlo analysis as a more sophisticated approach are suggested in order to incorporate and articulate uncertainties of the process. Decision-makers can consider one of these approaches based on their types of decisions, levels of sophistication and the requirements of their tasks.

As fully explained in Chapter 2, PERT will calculate the expected return (mean) and standard deviation with a simple formula by looking at these three scenarios: worst case/pessimistic scenario, most likely scenario, best case/optimistic scenario.

Monte Carlo simulation has been suggested by many valuation experts, such as French and Gabrielli (2005), Adair and Hutchison (2005), Lorenz, Trück and Lützkendorf (2005), Boyd (2002), Baroni, Barthélémy and Mokrane (2006) and Jackson (2008), as the most appropriate approach for dealing with risk and uncertainty related to DCF modeling and sustainability/energy investment issues. The analysis will apply and measure various uncertainties in the valuation process by ascribing the range of possible outcomes, in order to communicate how the selection of the green systems and strategies impact the range of possible expected value with its confidence interval. Monte Carlo analysis applies repeated draws from each specified distribution, and calculates a distribution of financial outputs, such as revenue and rate of return. Lorenz, Trück, & Lützkendorf (2006) have also argued that future predictions are not precise and valuers have to address risk and uncertainty in their valuation report, and have suggested Monte Carlo analysis as an appropriate technique for articulating the risk and uncertainty (p. 400).

*This model will apply and measure various uncertainties in the valuation process by ascribing the range of possible outcomes, in order to communicate how the selection of sustainable options impacts the range of possible expected value with its confidence interval. The resulting ranges and distributions (mean and standard deviation) would reflect the uncertainty related to the estimation of DCF inputs and articulate the risks related to achieving the DCF outputs.*

### **3.2.4 Final Statement for the Decision-makers**

Finally, the results of the process will be reported to decision-makers in the form of a more simple and understandable statement. The simulation results, along with a description of alternative outcomes and their probability of occurrence, will be presented either in simple matrices or clear graphics. This final statement must be very clear and easy to understand for end users. The details of the development of the input data and simulation processes do not need to be included in the report for investment decision-makers.

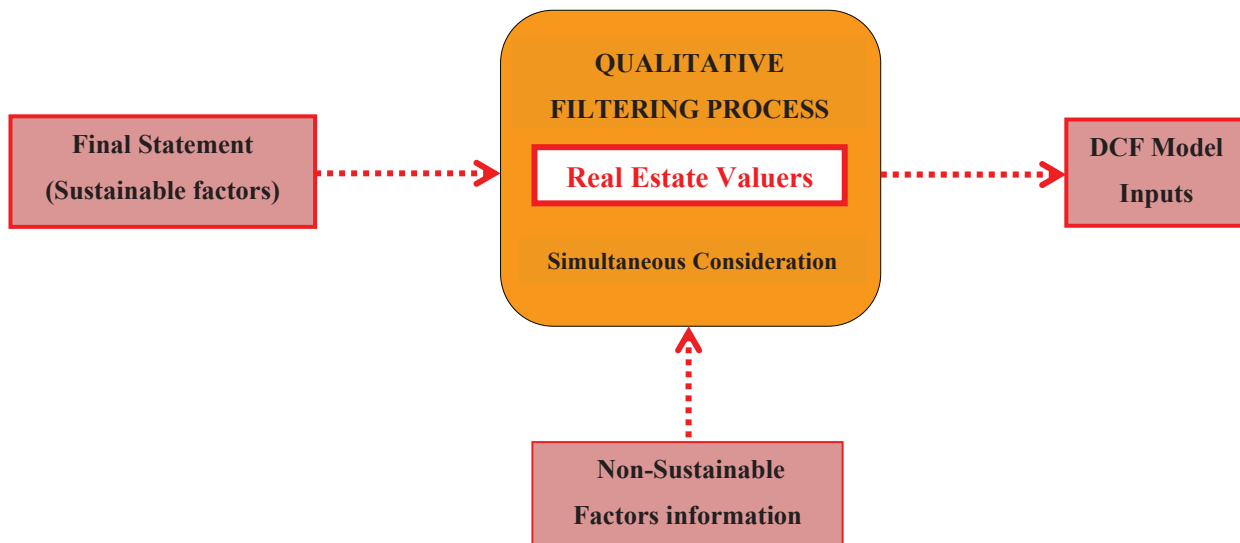
As mentioned previously, investment communities are more concerned with the final key financial indicators, as opposed to the technical details in the process. However, the details should be available to the decision-makers if they would like to check the assumptions in the valuation process to increase their level of confidence.

This information provides decision-makers with a much more comprehensive view of investment outcomes, as opposed to traditional single-point estimates of conservative payback and Internal Rate of Return, and a clearer idea about inherent risks and uncertainties in the assessment process. Therefore, the process results can help final users, either architects/engineers or owners/investors, to better understand

the costs and benefits of sustainable options, evaluate risk and uncertainty, and ultimately make a better decision in selection of the best possible sustainable options for greening their buildings. By comparing the final financial outcomes to the current financial performance of the subject property, decision-makers can estimate the range of possible marginal return resulting from sustainable options investment, which would lead to a more informed decision about whether or not to proceed with green retrofits.

It should be noted that the outcomes of this research—an approximation of sustainable features' impacts on sustainable property financial performance—could be also utilized by valuers as part of the information they need for their simultaneous consideration of sustainable and non-sustainable factors in the valuation process of sustainable property.

As mentioned earlier, there are many sustainable and non-sustainable factors impacting the financial performance those valuers need to consider simultaneously in their sustainable valuation analysis in order to determine the final judgment about financial model inputs. The process of qualitative filtering is presented in Figure 3-6. Accordingly, this process could be used as a sub-financial analytic to assist valuers in the selection of DCF model inputs for a sustainable property valuation.



**Figure 3-6: Qualitative Filtering in Sustainable Property Valuation Process**

### 3.3 Case study

This research is grounded through a case study which aims to test and demonstrate the application of the proposed assessment framework. In the following sections, the characteristics of the selected building are described and case study process and methods are introduced.

#### 3.3.1 Overview of Case Studies Method

The case study approach to research is a way of conducting mainly qualitative inquiry, commonly used when it is impossible to control all the variables that are of interest to the researcher (Laws & McLeod, n.d., p. 4). Merriam (1998) has also pointed out that the unique strength of the case study approach is its ability to deal with a full variety of evidence, including documents, artifacts, interviews and observation (p. 8).

“The purpose of a case study was to gain an in-depth understanding of the situation and meaning for those involved. The interest was in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation” (Laws & McLeod, n.d., p. 4). Sander (1981) commented that, “case studies help us to understand processes of events, projects, and programmes and to discover context characteristics that will shed light on an issue or object” (p. 44). Merriam (1988) defines a case study as “an examination of a specific phenomenon, such as program, an event, a process, an institution, or a social group” (p. 9). Thus, the case study method can be used to explore and test the application of a hypothetical process in the real world situation.

“Stake (1998) distinguishes between what he calls the *instrumental* case study and the intrinsic case study. For researchers using the former, the case is of secondary interest to the theory that can be established from it. In the intrinsic case study, the research is “undertaken because one wants better understanding of this particular case” (as cited in Groat & Wang, 2002, p. 355)

Merriam (1998) has classified case studies as descriptive, interpretive and evaluative. A descriptive case study presents a detailed account of phenomenon under study. Interpretive case studies are used to develop conceptual categories or to illustrate, support, or challenge theoretical assumptions held prior to data gathering. An evaluative case study involves “thick description”, is grounded, is holistic and life-like, simplifies data to be considered by the readers, but most importantly, weighs the information to enable a judgment to be made. (pp. 22-29) “Evaluative Case studies involved description, explanation, and judgment” (S. B. Merriam, 2009, p. 49)

Yin (2003) has stated that a case study can be based on a single or multiple cases. Yin suggests that case studies are appropriate where the objective is to study contemporary events, and where it is not necessary to control behavioral events or variables. Yin further suggests the single case studies are appropriate if the objective of the research is to explore a previously un-researched subject, whereas multiple-case designs are desirable when the intent of the research is description, theory building, or theory testing. Then, he classified case studies as exploratory, descriptive, or explanatory. An exploratory case study (whether based on single or multiple cases) is aimed at defining the questions and hypotheses of a subsequent study (not necessarily case study) or at determining the feasibility of desired research procedures. A descriptive case study presents a complete description of a phenomenon within its context. An explanatory case study presents data bearing on cause-effect relationships—explaining how events happened (p. 5).

### 3.3.1.1 Selecting a Single Instrumental/Evaluative/Exploratory Case Study

In order to thoroughly demonstrate the translation process and the numeric application of the proposed procedure, a conventional four-story office building located in Rockville, MD was selected as an instrumental/evaluative/exploratory case study in this research. The building, known as “Twinbrook Metro Center I” (TMC), is owned by a private owner, the president of Davis Construction Company. TMC has been the headquarters of Davis Construction Company which currently occupies about two thirds of the building. The characteristics of the building are summarized in Table 3-1:

**Table 3-1: Building Characteristics**

Building Name	Twinbrook Metro Center 1 (TMC)
Location	Rockville, MD
Gross Area (SqFt)	89,035
Number of Floors	4 + A Basement
Building Type	Commercial Office Building
Year of Built	2000
Owner-Occupant	Davis Construction Company
Property Management	Cushman and Wakefield of Maryland, Inc.
Utility Provider	Pepco
Number of Tenants	6
Number of Workers on the Main Shift	239





**Figure 3-7: Twinbrook Metro Center 1 (TMC) Building**

As the president of one of largest general contractors in the Washington DC area, the owner is considering greening his building and exploring the potential of achieving a LEED certification. He is currently evaluating some green retrofit options which were proposed to him by an energy consultant company, CQI Associates.

Based on the classification offered by Stake (1998), Merriam (1998) and Yin (2003), this case study is a single instrumental, evaluative and exploratory case that aims to test the suggested methods and hypotheses, explore and explain the function of the proposed framework, shown in figure 3-2 XXX, in numeric terms, and indicate its applicability in the real world.

The following types of information were needed from TMC for conducting this case study:

- **General information:** Location, age, size, building condition, operating schedule, systems upgrade, current electricity and gas bills and details related to current energy consumption.
- **Data required for energy modeling:** Architectural and mechanical drawings, as-built drawings, construction details, building/systems specifications, occupants behavior related to energy consumption, and information about building systems upgrades.
- **Data required for financial modeling:** Historical cash flow (current Discounted Cash Flow inputs, such as current rent, current occupancy, current operation expense, etc.) information about lease lengths, tenant retention, or leasing commissions paid.

The general information as well as initial data required for energy modeling was obtained through interviews with the director of sustainability of Davis Construction Company who is also an occupant of TMC. More specific systems data required for energy modeling as well as data required for financial modeling were obtained through a questionnaire and interview with the senior property manager of TMC. Interview with a principal at CQI Associate, the energy consultant for TMC, was also conducted to receive his insights about appropriate energy retrofit options for TMC and retrofit options assessment strategies for a commercial property.



**Figure 3-8: Interior of TMC**

It should be noted that the main purpose of this case study, similar to what Laws & McLeod stated, was gaining an in-depth understanding of the proposed procedure. *The interest is in process rather than the outcomes; the proposed procedure is not considered as the perfect product, “but rather as process and thus as an ever-developing entity” (Laws & McLeod, n.d., p. 17).* It was hoped that the proposed process would be improved by the information produced during this case study.

*Therefore, the primary goals of conducting this case study were as follows:*

- 1) Test and demonstrate the numeric application of the proposed process;*
- 2) Enrich and improve the final framework;*
- 3) Demonstrate the process of collecting, translating and presenting the information in the process.*

*The case study was not intended to generate any new information about green systems' performance or their quantitative relationships with financial performance throughout this dissertation. Nor was it aimed to produce the most numeric accurate outcomes. The accuracy of the outcomes is limited to the opinions of the experts who participate, the findings from existing literature and tools and researcher's time and resource.*

### **3.3.2 Methods and Procedure in the Case Study**

Several interviews with the sustainability directors of Davis Construction and a principal at CQI Associates were conducted to solicit their feedbacks on appropriate green systems and strategies for retrofitting TMC. This case study primarily focused on the energy-related systems as a retrofit option to evaluate.

Some strategies were initially evaluated by the energy consultant at a planning grade<sup>27</sup> assessment level. Strategies include efficient lighting fixtures, lighting wattage reduction, daylight sensors, energy management program for controlling the temperature set points and demand management, natural gas boilers, and renewable energy opportunities such as geothermal, solar thermal, wind, and solar photovoltaic.

For the purpose of this case study, a combination of lighting control systems was selected as a retrofit option to be taken to the procedure as an input. The financial performance of this option was statistically calculated and presented in detail in the following sections. Again, the goal here was to demonstrate the process of a more complete financial assessment of those retrofit options while considering the risk and uncertainty. The lighting option was evaluated through an eQuest model to show how various uncertainties inherent in the modeling process could be addressed and more reliable performance estimates could be derived when using an energy simulation tool.

A market research was conducted through real estate databases, such as COSTAR and GBIG, and interviews with real estate experts. Through interviews a summary of case study objectives, current building characteristics, current financial data, and new green retrofit impacts resulting from previous performance analysis (new sustainable building performance distribution) was provided to the experts to

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<sup>27</sup> According to a principal at CQI Associates, there are two level of analysis: 1) Planning grade assessment which is a very basic cost-benefit calculation 2) Investment grade assessment which includes a more sophisticated feasibility and financial analyses.

collect their opinions about three-point estimates of future DCF inputs. A new cash flow was then projected and net present value (NPV) and internal rate of return (IRR) were estimated with the new DCF inputs.

The current market situation, property conditions and all other non-sustainable factors influencing DCF inputs were assumed to not change after implementation of the green retrofits. Having considered all non-sustainable factors being equal, all changes in new projected cash flow were related to new DCF assumptions that were influenced by selected retrofit options. It should be noted that in property valuation practice, all sustainable and non-sustainable factors need to be considered simultaneously to determine reliable estimates for financial inputs. However, this study is more concerned with developing a new financial assessment process and not so much with the property valuation issues. This approach allowed us to focus on the value implications of green retrofits.

Therefore, the procedure measured and numerically communicated the value added by investing on the selected retrofit options. Making distinctions between the impacts of sustainable factors and other factors influencing value in the financial analysis of a sustainable property is difficult and has been one of the primary challenges that sustainable property professionals face when estimating the value added by sustainable features.

*Accordingly, through the four major steps, this case study was intended to demonstrate a systematic procedure for estimating an approximation of the financial performance of the sustainable features, while risk and uncertainty have been factored in and presented. The case study demonstrated the assessment and inclusion of risk and uncertainty associated with green systems and strategies, both at the building performance and financial performance level, in the process.*

The four steps of the case study include: 1) Estimation of energy performance indicator distributions; 2) Estimation of whole building performance ranges and cost-based financial analysis; 3) Market research and estimation of triangular distributions for key financial model inputs; and 4) Value-based financial analysis and estimation of financial performance indicator distributions. Steps 1 and 2 are presented in Chapter 4 and steps 3 and 4 are presented in Chapter 5.

The methods and data collection procedure for assessing the lighting control systems option are presented in Figure 3-9:

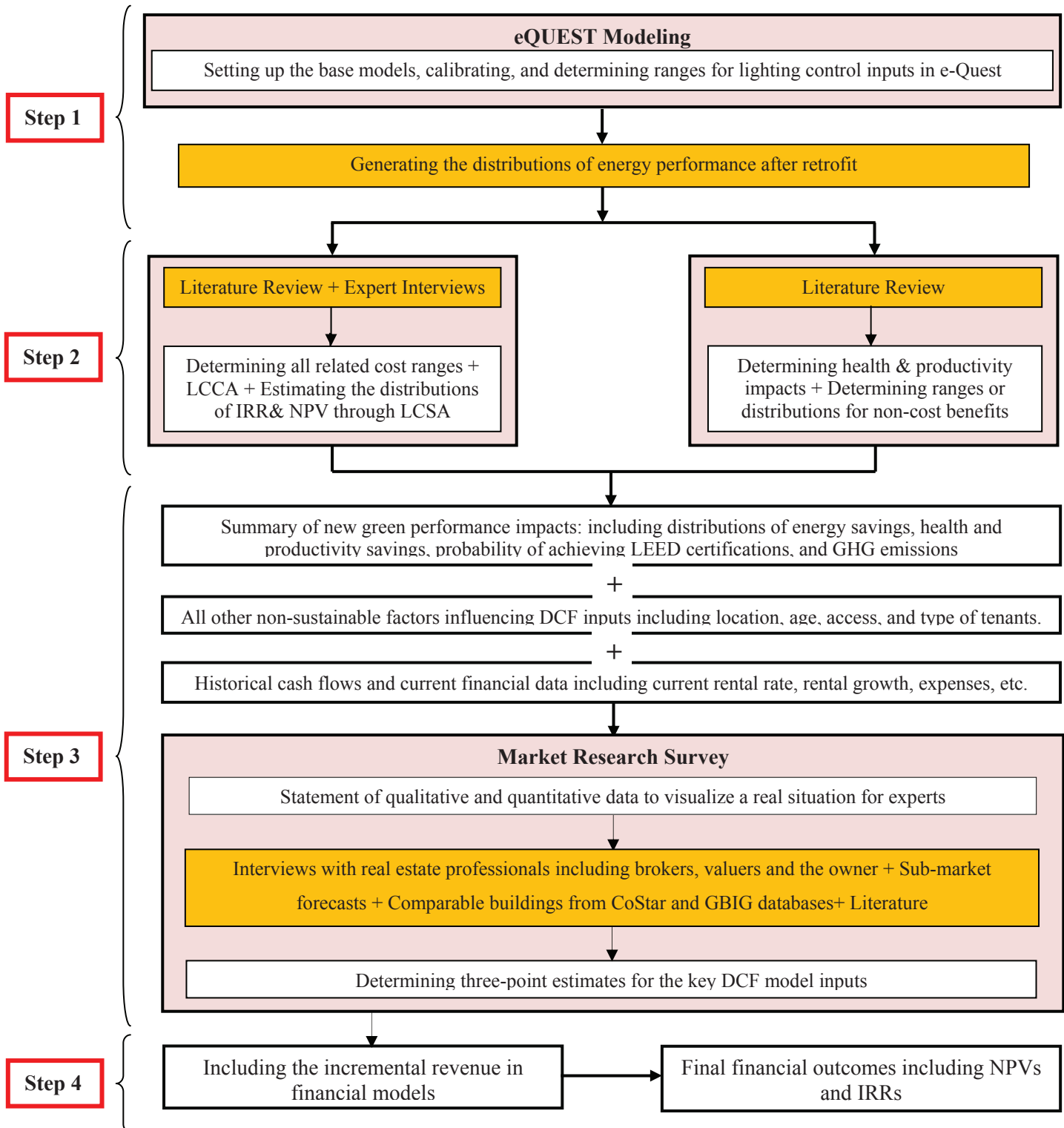


Figure 3-9: Case Study Methods and Data Collection Procedure

### 3.3.2.1 Contingent Valuation Method

Contingent Valuation (CV) method is a well-accepted and widely used method for assessing the economic value of environmental improvement through eliciting the users' willingness to pay. The CV method seems to be an appropriate technique for this case study. However, in this section it has been explained that this method may not be well suited for addressing the issues of this study.

According to Portney (1994),

The contingent valuation method involves the use of sample surveys (questionnaires) to elicit the willingness of respondents to pay for (generally) hypothetical projects or programs. The name of the method refers to the fact that the values revealed by respondents are contingent upon the constructed or simulated market presented in the survey (p. 7).

“Contingent valuation (CV) is a survey-based approach to putting an economic value on goods that are not ordinarily bought and sold in the marketplace” (Carson, Neil, & Paul, 2001, p. 13272) “The CV method is a widely used nonmarket valuation method especially in the areas of environmental cost–benefit analysis and environmental impact assessment. Its application in environmental economics includes estimation of non-use values nonmarket use values of environmental resources” (Venkatachalam, 2004, pp. 89-90). In simple term, “CV uses survey techniques to elicit people’s willingness to pay (WTP) to obtain a particular good” (Ahmed & Gotoh, 2006, p. 11); or a “change in the provision of a good’s quantity or quality. CV is controversial, generally because it involves asking individuals directly about monetary valuation related to given hypothetical changes in the provision of an amenity” (Veisten, 2007, p. 205). Since the elicited WTP values are contingent upon the particular hypothetical market described to the respondents, the approach came to be called the contingent valuation method (Ahmed & Gotoh, 2006, p. 11)

“CV is primarily developed by economists and is theoretically founded on neo-classical demand theory” (Veisten, 2007, p. 204). It first came into use in the 1960s and since then “it is frequently used in benefit–cost analyses of environmental amenities ranging from clean water and wildness areas to health risks and outdoor recreation” (Carson, et al., 2001, p. 13272)

Portney (1994) has also stated that

Contingent valuation surveys usually elicit information on the socioeconomic characteristics of the respondents (age, race, sex, income, education, marital status, and so on), as well as information about their environmental attitudes and/or recreational behavior, usually with an eye

toward estimating a willingness-to-pay function that includes these characteristics as possible explanatory variables. They may also include follow-up questions to see if the respondent both understood and believed the information in the scenario and took the hypothetical decision-making exercise seriously (p. 6).

Below, the primary reasons to why this approach is not appropriate for deriving the financial inputs are presented:

1. In this survey, participants will be asked to estimate the value for the benefits of sustainable options improvements (green systems and strategies) such as installing high efficiency HVAC systems or windows, which may result in less energy consumption and improved indoor environmental quality. The benefits are both tangible, such as reduced costs, and intangible, such as reduced long-term investment risk, increased health and productivity. Most people may not have enough knowledge concerning the potential tangible and intangible benefits of sustainable improvements. If they are going to be selected as respondents, substantial time and effort are needed to educate them before conducting the survey. Furthermore, having knowledge about the benefits of a product will not necessarily enable people to state a true and reliable dollar value for those benefits. In particular, the intangible benefits of sustainability are more difficult to be monetarily valued without a sufficient amount of knowledge and experience.
2. Participants may not take the questions seriously, and may respond unrealistically, since they know that they are not required to pay. They may state a willingness to pay a premium for sustainability in order to show that they place importance on improved health and productivity, while in reality they are not willing to pay for the investment. They may report a much lower or even no expected value if they knew they had to pay for an option. This is referred to as a “hypothetical bias” in the CVM literature.
3. The survey aims to obtain estimates of key Discounted Cash Flow inputs such as rents, occupancy, capitalization rate, etc. This survey addresses the question of willingness to pay for rents; determining many factors, such as capitalization rate or turnover rate, and requires sophistication and experience with the real estate market and valuation process. A sample of potential occupants may not be capable of reliably judging those factors.



4. If this CVM is going to be a primary method for survey, additional surveys might be required. This method is not capable of collecting all the information expected to be captured through survey, such as capitalization rates.
5. Capturing a reasonably accurate and reliable result from the CVM in this research requires the survey to be conducted among a large and diverse sample of knowledgeable participants. Conducting the survey using this method would be very time-consuming and probably expensive, due to the required extensive pre-testing process.

### 3.4 **Summary**

The methodology in this research is a combination of both quantitative and qualitative approaches through integration of a case study and survey tactics. In this chapter, a new systematic assessment framework for deriving the financial performance of sustainable options was first presented. An existing non-sustainable office building was then introduced as an instrumental case study in order to test and demonstrate the numeric application of the proposed framework in a real world situation.

The proposed framework presents a more complete approach that goes beyond the current sustainability cost-benefit assessment and connects building performance estimates from the design professionals to the more sophisticated financial tools used by property professionals to capture the financial performance of sustainable options. The financial outcomes incorporate both cost and non-cost benefits of sustainable options in the context of value while explicitly considering risk and uncertainty. The process provides decision-makers with a much more comprehensive view of investment outcomes, as opposed to traditional single-point estimates of conservative simple PB or ROI, and would enable them to make more informed investment decisions when evaluating greening the existing properties.

In summary, the following key principles were suggested throughout this chapter for evaluating financial performance of a sustainable option and were also considered in development of the proposed assessment framework:

- There is inaccuracy/error inherent in estimating the performance indicators. The actual building performance may differ from what was projected by technical tools such as energy simulation software. It is critical for decision-makers to consider this inaccuracy/error to avoid overestimating or underestimating the building performance when making decisions based on the actual performance.



- A comprehensive assessment of performance indicators is important in a value-based analysis, since any building performance outcome that is of interest to occupants could play a direct role in the financial performance of a building. It is not just energy cost saving that matters. It is important to utilize different tools and techniques to evaluate as many performance outcomes as possible that might have impacts on occupant performance.
- True financial performance of sustainable options is beyond cost savings. Simple cost-based financial methods, such as simple PB, simple ROI or LCC, fail to address the value implications of sustainability investment, and therefore ignore the potential revenue and market risk reductions. Instead, more sophisticated valuation techniques such as the DCF approach needs to be utilized to capture the potential value impacts of sustainable options in addition to other cost-based benefits.
- As part of a value-based analysis of sustainable options, a thorough market analysis should be conducted to understand how sustainability or green retrofit options is important to the current tenants as well as the tenants that are expected to lease space in the building. This research could be done through an independent survey among tenants, brokers, property managers, investors, or other real estate professionals who are familiar with the sub-market.
- There is a degree of uncertainty associated with the forecasts in each step of the assessment process, both at the building performance level and valuation level. Careful consideration of uncertainty is of vital importance in providing more reliable data to decision-makers. Probability distributions are suggested to be developed for reporting the forecasted factors in each step in order to incorporate and articulate the risks and uncertainties inherent in the process. Chapter 4 and 5 presents in detail how to create ranges and distribution in each step.
- Risk analysis methods, such as the Monte Carlo simulation or PERT, need to be used for accounting for uncertainties associate with the valuation process, when estimating the final financial performance indicators. The base model for this simulation, which describes the relationship between inputs and outputs, should be built based on the DCF approach. This probabilistic model takes and analyzes the same DCF input and outputs, but replaces single estimate points with appropriate ranges and probability distributions.

## **CHAPTER 4 CASE STUDY- ENERGY MODELING AND COST-BASED ANALYSIS**

This chapter presents the first part of the case study which fully explains steps 1 and 2 of the proposed framework, described in Chapter 3. It includes 1) the development and calibration of an energy model through eQuest for estimating the distributions of energy performance indicators associated with the selected green retrofit option, 2) the development of an Excel-based model for calculating the whole-building performance and cost-based financial analysis.

A lighting control systems package is selected as the green retrofit option to be evaluated in the case study to numerically demonstrate the application of the proposed process. In this chapter, development of ranges and distributions of energy performance indicators, step 1 of the framework, and green building performance factors, step 2 of the framework, resulting from employing the lighting controls option are described in detail. Financial analyses are performed based on the costs and cost savings for both energy and non-energy benefits, including health and productivity, and distributions for simple payback, simple ROI, NPV, and IRR are generated.

### **4.1 Retrofit Option: Lighting Control Systems**

A lighting controls package was selected as a green retrofit option for evaluation in this case study using the eQuest energy modeling software. This option, lighting control systems, was a combination of four lighting control strategies including daylight harvesting, occupancy sensing, high-end trim, and personal dimming control.

**Daylight harvesting:** dims electric lights when daylight is available to light the space. The daylight sensors/photocells continually measure the level of ambient daylight and adjust light output from the digitally addressable ballast to reduce unnecessary electric lighting and provide even illumination throughout a space. The sensors can operate both on/off switching systems and continuous dimming systems. Continuous dimming systems cost more than switching systems but they have greater user satisfaction because the changes in the lighting levels are not as noticeable.

Scores of studies have reported a 15%-30% lighting energy savings for employing daylight sensors ("Design Brief: Lighting Controls," 2004; DOE, 2000; Lutron). Daylight sensors need to be kept well calibrated as poorly calibrated sensors could result in little or no savings from daylighting. "Daylight

sensors that are placed where they are exposed to an amount of daylight not proportionate to the daylight at the desktops being served will not properly control lighting levels and will likely result in dissatisfied users who may attempt to disable the control system” (DOE, 2000).

Daylight sensors were suggested by the energy consultant of TMC as there are many areas in the building, including the main entrance and lobby, which could benefit from natural light.

**Occupancy sensing:** turns lighting on when a space is occupied and off or dimmed when a space is vacant after a suitable time delay period. Occupancy sensors detect the presence of people / motions in a space. This was a perfect candidate strategy for this case study, as many spaces in this building (such as conference rooms) were occupied occasionally. Some spaces such as a large training center and fitting room in the basement were unoccupied 70% of the time or more.

The occupancy sensors option was also one of the first retrofit options that was suggested by the director of sustainability of Davis Construction Company. According to her, “sometimes I come back late to this office, half of the building is on, nobody remembers to turn the lights off. There are simple things like that you should look at first.”

Occupancy sensors should be properly located to ensure that the entire area controlled by that sensor can be detected. Placement of controls should take into account furniture placement as much as possible. They must be able to sense all occupants to avoid turning off lights while the space is occupied. The delay time period should be appropriately set to ensure enough time between the last motion in a space and when the lights shut off.

Lutron claims that occupancy/vacancy sensors on their own could save 15% of lighting energy (Lutron, n.d.). The potential savings of sensors varies depending on the area size, type of lighting, and occupancy pattern. A report by ENERGY STAR presented lighting energy savings of 20%-75% depending on the room type (ENERGYSTAR, 2007, p. 15). A case study of a federal office building, as presented in a report by the U.S. Department of Energy, also shows 25% average savings due to occupancy sensors (2000).

**High-end trimming/tuning:** sets the maximum light level based on customer requirements in each space. This is a very common and inexpensive strategy that is used by lighting manufacturers. When digitally addressable ballasts are used for occupancy or daylight systems, the high end of those ballasts can be set to 80%, so that the ultimate lighting output will be trimmed by 80%. Therefore, 20% lighting energy saving is realized on top of lighting output.

According to a sales manager from Lutron Electronics, this is the second low hanging fruit lighting strategy that can be employed. “Most of the lighting consultants tend to over-light an area by 20%-25%. When we want 40 foot-candles for a space, 50-55 foot-candles is typically maintained the day the person takes ownership of that space.” (Lutron sale manager)

**Personal dimming control:** gives the ability to occupants to control the light level closer to their personal preference. This will increase the level of lighting comfort and therefore, occupant satisfaction and productivity. According to Lutron Electronic, a typical lighting level, which is fine for paperwork, is usually 2 to 3 times brighter than is ideal for computer work. With remote controls individuals are able to adjust lighting levels for different tasks, from cube to office to conference room (Lutron, 2011b).

Studies show that personal dimming control generally could offer energy savings relative to a fixed lighting installation. Occupants with personal control tend to dim the light levels more frequently and therefore, less energy would be consumed. “Local control allows individuals to choose whether or not to switch on when they arrive at work or to switch off during short absences. Switching off, or leaving the lighting off, is unlikely when control is not local, but are observed for local control” (P. Boyce et al., 2006, p. 9). According to a study by Manniccia (1999) incremental benefits of manual lighting control in private offices, manual switching and dimming provided a total of 15% added savings above the 43% achieved by motion sensors” (p. 497)

## 4.2 **Step 1: Estimation of Energy Performance Indicators Distribution**

The first step in the analysis was to generate distributions of building performance indicators in order to express the uncertainty associated with projecting the performance of the energy efficiency systems/strategies employed. When evaluating the lighting control systems in this case study, focus is on the lighting energy consumptions/savings. The eQuest simulation program was used to assess the impacts of lighting retrofit on monthly and annual consumption (KWh) and electricity demand (KW). Given the primary goal of this case study, the building was not modeled separately with other tools such as Radiance, Rayfront, Lightspace, Relux 2004 Vision, or other sophisticated daylight modeling software to evaluate the impacts such as glare and visual comfort of the lighting controls package.

In general, an important issue in evaluating the outcomes of energy systems is that most of the energy-related systems and strategies, which are typically employed in retrofitting existing buildings, have more benefits than just lowering energy consumption. For example: employing a new energy efficient HVAC system may reduce the energy consumption but at the same time may improve the ventilation rate, reduce the air pollution, reduce the noise level and therefore, improve indoor environmental quality. Also, they

might have opposite results. For example, utilizing an insulating strategy may perform well for energy efficiency but badly for moisture control. Implementing a daylighting strategy may improve energy efficiency but increase glare and thereby, lower the user's satisfaction and productivity.

Unfortunately, today most of the evaluations related to energy efficiency are based on the simulation of energy-related systems in a single energy simulation program, such as DOE 2, and therefore, these other potential impacts on performance, such as indoor air quality, thermal comfort, vision performance, acoustic performance, etc. are ignored. Thus, the contribution to performance for energy-related systems and strategies are beyond the direct energy cost savings, but they do impact other building performance mandates. As stated previously, these indirect-impacts on building performance or “non-energy cost savings” could play a direct role in the financial performance of a building and therefore, are important to be considered in performance valuation. Understanding all of the building performance indicators may require modeling the project through different tools, for example, e-Quest for energy modeling and CFD for indoor air quality modeling.

However, as mentioned previously, for the lighting control systems option in this case study, modeling with other simulation tools was thought to not be necessary. Inclusion of the non-energy benefits as well as non-cost benefits of this option into the assessment process are discussed in detail in Sections 4.3.3 and 4.3.4. The first step in assessing a retrofit option for an existing building includes developing a base model of the building, which is explained in an eight-step procedure in Section 4.2.1:

#### **4.2.1 Energy Simulation and Calibration Process**

*One goal of the energy simulation process is to build a reliable model to serve as a base case for evaluating the energy performance and generating ranges/distributions of energy performance indicators, resulting from selecting a new retrofit option—lighting control systems. It should be noted that the main purpose of this section is to demonstrate the calibration process of a simulation model and not to estimate the most accurate outcome. A thorough calibration process requires on-site measurements, surveys and interviews with occupants, etc., which are beyond the scope of this research, given its main goal of demonstrating the process.*

The model was made as reliable as possible based on the available data. As-built data was not available for the building. No measurement or experimental study was performed for collecting the actual data other than actual utility records. No survey or interview was conducted with occupants other than the director of sustainability of Davis Construction for collecting the data in this step.

The subsequent steps were followed in order to arrive at a reliable model and estimate possible ranges/distributions of outcomes when a new green retrofit option is employed. More information about different calibration methodologies and a detailed calibration process are also presented in “A Procedure for Linking Projected Energy Performance Uncertainty with Investment Decision-Making” paper by Bozorgi and Jones (2010). The full paper is included in APPENDIX G.

1. The initial model was set up in eQuest based on the data collected from the architectural and mechanical drawings, construction details, researcher’s visit, pictures, and interview with the director of sustainability of Davis Constriction Company who was also an occupant in the building. The annual and monthly electricity consumptions were calculated based on the initial model. The building is all electric and there is no gas usage.

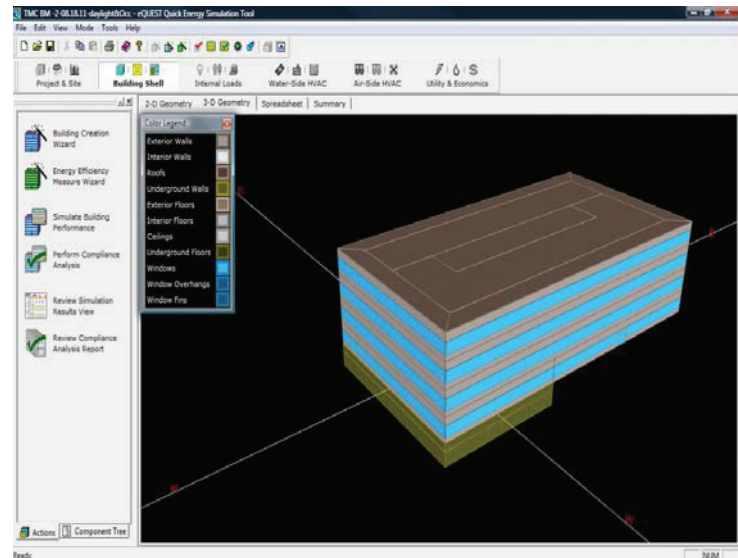


Figure 4-1: eQuest Model

A Typical Meteorological Year (TMY) file was used in the simulation process and not the actual weather file of 2009 which the modeled consumptions was compared with. This could be one of the sources of inaccuracy associated with modeling outputs.

2. The actual annual and monthly electricity usage (KWh) was gathered by looking at 12 months of electricity bills in 2009. Adjustments were then made to those estimates in order to correspond to the calendar months.

Utility records are not normally first of the month to last of the month, the simulation outcomes from energy modeling, however, are first of the month to last of the month. Two possible

procedures for dealing with this include: if available, sum the daily simulation values to correspond to the measured records; or normalize the measured records to correspond to the simulated monthly values (weighted average approaches). This could be another potential source of inaccuracy associated with the modeling outputs.

In this case, the weighted averages of actual electricity records were estimated to correspond to the calendar months. Table 4-1 and Figure 4-2 show the actual KWh from the electricity bill and the weighted average consumptions for each month:

**Table 4-1: Actual monthly electricity usages from 2009 bills and monthly weighted average usages**

<b>Electricity Bills for 2009</b>			<b>2009 Monthly Weighted Average</b>	
<b>Start Date</b>	<b>End Date</b>	<b>Energy Use (kWh )</b>	<b>Month</b>	<b>Energy Use (KWh)</b>
12/24/2008	1/26/2009	296,160.00	1	<b>285,180.97</b>
1/27/2009	2/23/2009	228,090.00	2	<b>227,532.86</b>
2/24/2009	3/25/2009	224,970.00	3	<b>213,519.68</b>
3/26/2009	4/24/2009	165,810.00	4	<b>165,108.00</b>
4/25/2009	5/26/2009	162,300.00	5	<b>160,737.10</b>
5/26/2009	6/24/2009	152,610.00	6	<b>153,264.00</b>
6/25/2009	7/24/2009	155,880.00	7	<b>160,913.23</b>
7/25/2009	8/24/2009	178,170.00	8	<b>174,959.03</b>
8/25/2009	9/23/2009	163,950.00	9	<b>163,215.00</b>
9/24/2009	10/23/2009	160,800.00	10	<b>166,683.87</b>
10/24/2009	11/23/2009	183,600.00	11	<b>185,770.00</b>
11/24/2009	12/23/2009	192,900.00	12	<b>219,547.74</b>

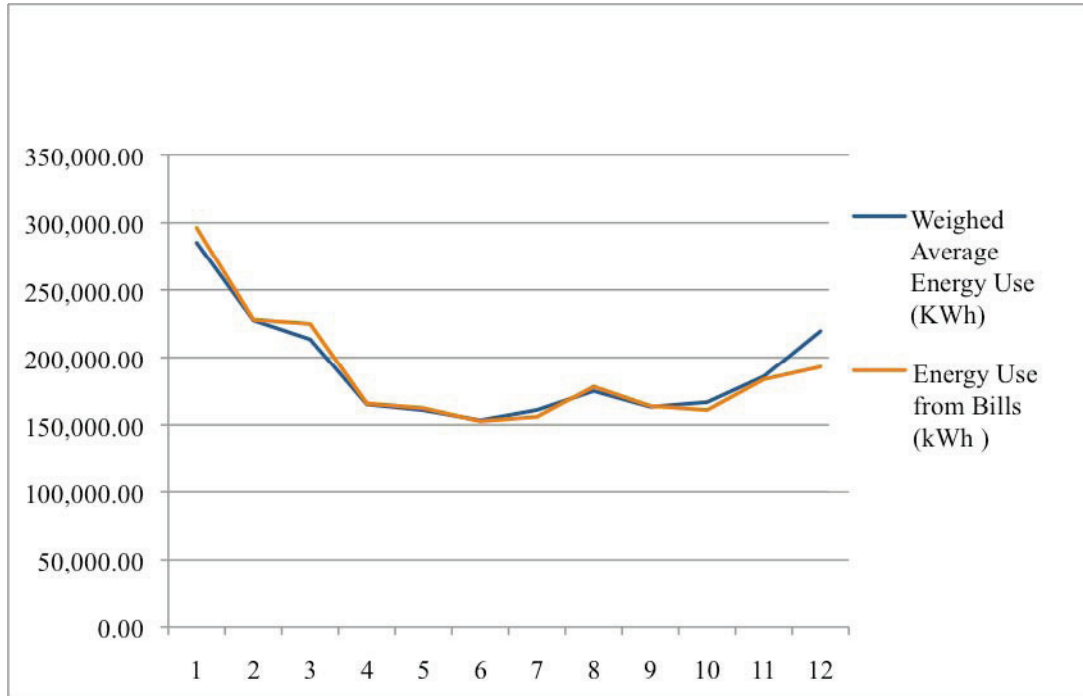


Figure 4-2: Actual KWh from Electricity Bills Vs. Actual Weighted Average

- The actual weighted average electricity usages were compared with those predicted by the simulation model, and the annual and monthly Mean Bias Error (ERR) % and Coefficient of Variation of the Root-Mean-Squared Error (CV RMSE)—error indicators—were calculated by formulas presented in Equation 4-1:

$$ERR_{\text{month}} (\%) = \left[ \frac{(M - S)_{\text{month}}}{M_{\text{month}}} \right] \times 100\% \quad (1)$$

$$ERR_{\text{year}} (\%) = \sum_{\text{year}} \left[ \frac{ERR_{\text{month}}}{N_{\text{month}}} \right] \quad (2)$$

where  $M$ : measured electricity (kWh) or fuel consumption;  $S$ : simulated electricity (kWh) or fuel consumption;  $N_{\text{month}}$ : number of utility bills in the year.

$$CV (RSME_{\text{month}}) (\%) = \left[ \frac{RSME_{\text{month}}}{A_{\text{month}}} \right] \times 100\%$$

$$RSME_{\text{month}} = \left\{ \frac{\left[ \sum_{\text{month}} (M - S)_{\text{month}}^2 \right]}{N_{\text{month}}} \right\}^{1/2}$$

$$A_{\text{month}} = \left[ \frac{\sum (M_{\text{month}})}{N_{\text{month}}} \right]$$

where RMSE: root-mean-squared monthly error;  $A_{\text{month}}$ : mean of the monthly utility bills.

**Equation 4-1: ERR and RSME formulas (Pan, et al., 2007, p. 657)**



The calculated EER% and CV RMSE% were checked to see if they fall in any of the three accepted tolerances for data calibration suggested by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 14, International Performance Measurement and Verification Protocol (IPMVP), and Federal Energy Management Program (FEMP) (presented in Table 4-2)

**Table 4-2: Acceptable tolerance for monthly data calibration (Pan, et al., 2007, p. 652)**

<b>Index</b>	<b>ASHRAE 14 (%)</b>	<b>IPMVP (%)</b>	<b>FEMP (%)</b>
ERR <sub>month</sub>	±5	±20	±15
ERR <sub>year</sub>	-	-	±10
CV (RMSE <sub>month</sub> )	±15	±5	±10

The error percentages of the initial model did not agree well with the above acceptable ranges, and therefore, the initial model was not appropriate for evaluating the new retrofit options.

- Further investigation was performed to collect more updated information about the inputs that might have higher impacts on the energy consumption and/or were not clear from the drawings—Information about current HVAC and lighting systems including: types of cooling source; Roof Top Units (RTUs) zoning; HVAC schedule; thermostat set points for summer, winter, occupied, and unoccupied times; cold deck resets type and temperature; economizer system; lighting plans; desk lamps; and exterior lights and their schedules.

Through a survey and a follow up interview with the property manager of TCM, most of the needed information was obtained and possible input changes were identified. For example, for thermostat set points which have significant impacts on energy consumption, the property manager could not provide exact values. She indicated that this has varied significantly in the past.

- The initial model was calibrated and updated based on the new information from the property manager. The new modeling outputs (KWh) were compared with the actual usages by calculating error indicators—monthly and yearly ERR as well as CV (RMSE). The new estimates were much closer to the acceptable ranges suggested by the aforementioned guidelines, however, they were still not within acceptable ranges.
- The calibration process continued by varying the inputs, which were more uncertain based on our interviews and on-site visits, over reasonable ranges. The input changes included thermostat set points, lighting power density, task lighting and equipment power density, cold deck reset

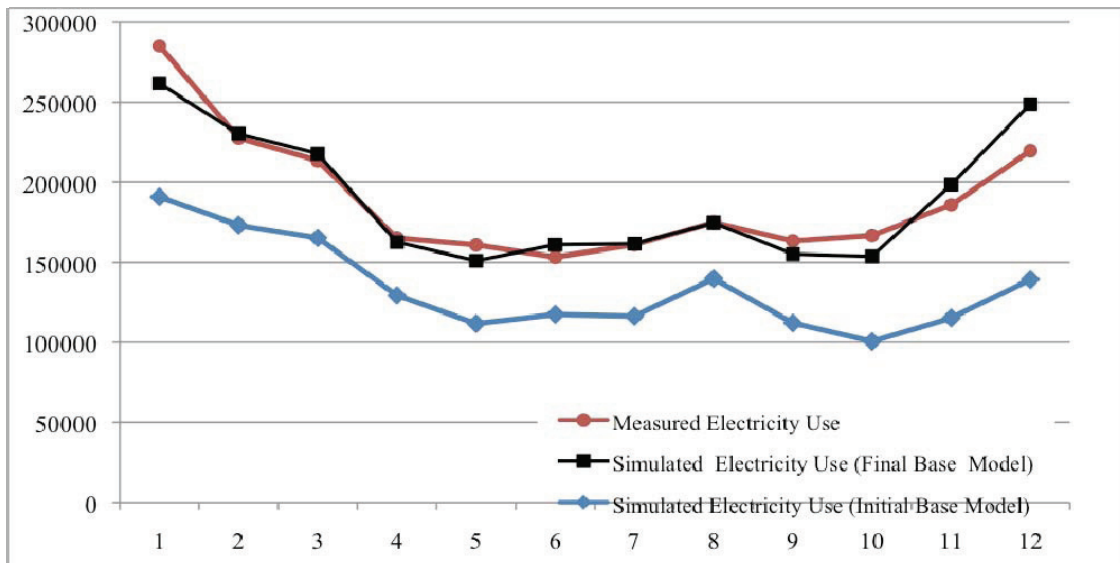
temperature, energy efficiency ratio (EER), minimum air flow, etc. More than 80 models were created and their calculated error indicators were compared with those suggested in Table 4-2.

A model with error indicators that complied with the ranges suggested by FEMP and were very close to those suggested by ASHRAE 14 and IPMVP, was selected as the best model. This calibrated model was thought to be sufficiently accurate to serve as a reliable base case for evaluating the new retrofit options. Table 4-3 shows the comparison of the energy consumptions predicted by this model and actual usages as well as related error indicators:

**Table 4-3: Final Calibrated Model Error Indicators in Compare to Actual Electricity Usages**

	<b>Max</b>	<b>Min</b>	<b>Average</b>
Measured 2009 Monthly Energy Use KWh	285181	153264	189703
Simulated Monthly Electric Use KWh	261700	151000	189708
EER month	<b>8.23%</b>	<b>-13.32%</b>	<b>0.00%</b>
Measured Total 2009 Energy Use KWh		2,276,431	
Simulated yearly Electric Use KWh		2,276,500	
EER year		<b>0.00%</b>	
CV (RMSE m)		<b>6.79%</b>	

Figure 4-3 shows the monthly electricity use as predicted by both the initial and final models. Through an iterative calibration process (creating and testing more than 80 models) the model predictions was improved until they closely matched the actual consumptions—the EER<sub>year</sub> of the best model was zero.



**Figure 4-3: The eQuest Model prediction vs. actual consumption**

7. The next step of the process was to model a retrofit option—lighting control systems—using the calibrated base model. The base model was varied by changing the key lighting inputs that were uncertain to generate the distribution of energy savings. The lighting control systems modeling process and assumptions are discussed in detail in Section 4.2.5. The procedure for generating the final distribution of energy savings in this case study is presented in the following section.

## 4.2.2 Final Distribution of Energy Savings and Interaction of Base Models

In current practice and literature, typically, a model that falls in any of the three accepted tolerances for data calibration stated in Table 4-2 and matches most closely with actual consumption—overall lowest monthly and yearly EER as well as  $CV_{RMSE}$ —will be used as a base model for existing buildings. New retrofit options will then be entered to this base model to be assessed and compared.

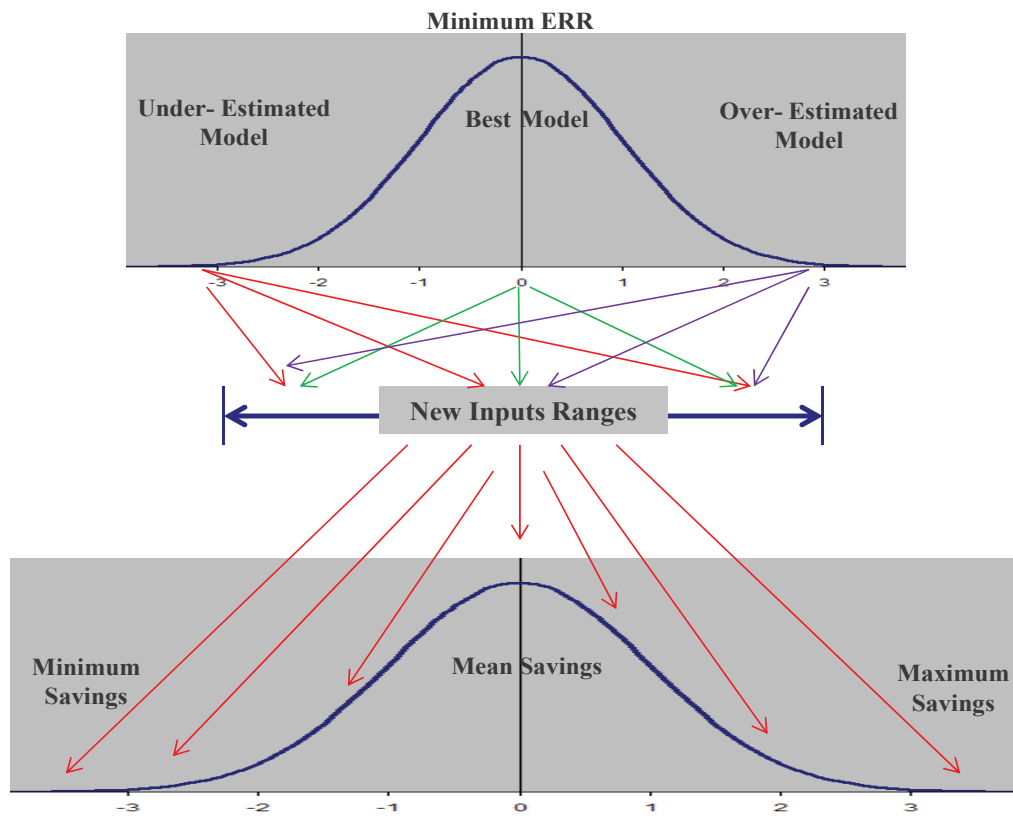
However, base models themselves often involve a certain level of inaccuracy as they are typically calibrated based on the final modeling outputs, *which could be results of different inputs*. For example, the predicted energy consumption (KWh) of an energy model with certain assumptions about air conditioner Energy Efficiency Ratio (EER) and lighting power density could be very close to the one with a lower EER but a higher lighting power density assumptions. And both base models might be qualified as acceptable models, based on the aforementioned guidelines, due to their close predicted energy consumptions. In fact, this is very common in the calibration process as selecting a certain/accurate value for some inputs can be difficult in existing buildings.

Therefore, there might be several base models within the acceptable ranges that have different inputs, outputs, and error indicators. *A model with lowest error indicators is not necessarily the one that replicates the actual performance most accurately*, due to the uncertainty associated with inputs. Furthermore, selecting the lowest error indicators sometimes is not very straightforward, because a model might have a lower  $ERR_{month}$  for most of the months, but have a higher  $ERR_{year}$  or  $CV_{RMSE}$ .

It is very important to note that while the final outputs (KWh) of acceptable models might be very close, they could produce different outcomes when evaluating the performance of new retrofit options. This is primarily due to interactive modeling effects of new retrofit options inputs with the base models. Therefore, ignoring the impacts of the variability of inputs for the base models on the outcomes might result in different investment decisions when comparing different retrofit options.

In summary, there are two factors that could influence the distribution/variance of savings associated with new retrofit options in the simulation of existing buildings: 1) ranges of assumptions for new retrofit options and 2) the inaccuracy of base models. In other word, as shown in Figure 4-4, the final simulation

output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy of base models, is often ignored.



**Figure 4-4: Interaction of base model inaccuracy in generating the final simulation outcomes**

In this case study, given its primary goal of improving the investment decisions by including risk and uncertainty, lighting control systems were modeled with multiple base models to assess the potential impacts of different base models on simulation outcomes. The objective of this analysis was to understand how this approach could improve the final decisions about retrofit options investment and if the results were worth the effort of running additional scenarios.

As mentioned previously, many minor and major investment decisions about green retrofits are currently directly made based on the simulation outcomes. *Therefore, it is very important to examine the potential strategies that could help modelers to improve the level of confidence associated with simulation outcomes to ultimately enhance the quality of investment decisions. This is the goal of this part of the case study. It should be noted that the results of this single analysis could not be generalized; but it may*

*encourage modelers to consider the accuracy of base models when analyzing retrofit options and providing recommendations to decision-makers.*

### **4.2.3 Creating Multiple Base Cases for Evaluating a New Retrofit Option**

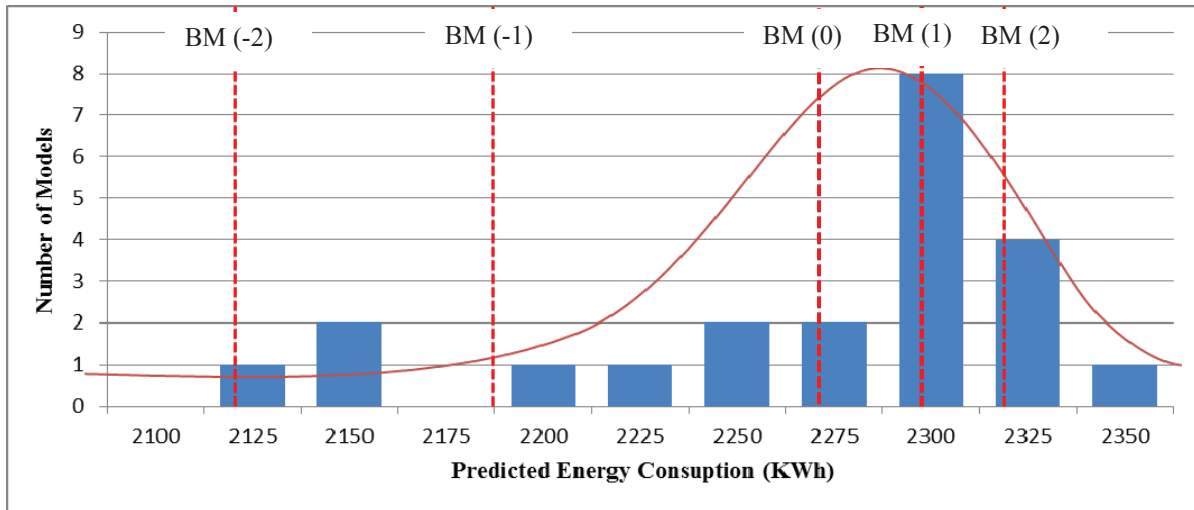
In order to create a more acceptable model, the seven inputs were selected to be varied over reasonable ranges. These inputs include: four thermostat set points (occupied cooling, occupied heating, unoccupied cooling, and unoccupied heating), cold deck reset temperature, EER of HVAC systems, and VAV minimum flow. Table 4-4 shows the ranges that these inputs varied within.

**Table 4-4: Variables and Ranges for Creating Multiple Base Cases**

	<b>Description</b>	<b>Ranges</b>
1	Set point - Occupied Cooling (F)	75-78
2	Set point - Occupied Heating (F)	69-72
3	Set point - Un-occupied Cooling (F)	75-82
4	Set point - Un-occupied Heating (F)	64-68
5	Cold Deck Reset temperature (F)	55-61
6	EER for Air Conditioners	11-15
7	VAV Minimum Flow %	25-50

These factors were selected because, based on the interview with the property manager and the researcher's professional judgments, they might involve a higher level of uncertainty. For example, relative to thermostat set points, the property manager indicated that set points have varied significantly in the past. Thus, the set points values were selected as the inputs to be varied for creating other acceptable base models. Based on the mechanical drawings of the building, the EER values for two RTU units should be 15 and 14. However, this building was built in 2000, and it is likely that HVAC systems do not currently perform as efficiently as what they were designed for. Therefore, the EER values for the two systems were varied in ranges of 12-15 and 11-14.

Several base models were created in addition to those built previously and their error indicators were calculated to ensure that they meet the acceptability conditions by the aforementioned guidelines. 22 models were within the acceptable tolerances. Figure 4-5 shows the distribution of the predicted yearly energy usages of the 22 base models:



**Figure 4-5: The Distribution of Predicted Energy Use (MWh) of 22 Base Models**

As the distribution of energy consumptions shows, there are some base models (towards the left side) that under-predicted the energy consumption, compared to 2,276.5 MWh consumption of the best base model, and there are others (towards the right side) that over-predicted the consumption. The best model with  $EER_{year}$  of 0%, which is presented in Table 4-5, is close to the mean of the above distribution.

This part of the case study attempts to examine the impacts of the different base models on the final savings distribution while evaluating the lighting control systems. Thus, the goal of the following analysis is to test whether or not the impacts of modeling new retrofit options using different base models are significant enough to encourage modelers to put extra time and effort into running additional simulations.

Accordingly, five base models (BM) were selected from 22 models to be used for evaluating the lighting control option and generating the savings distributions. The five base models, BM (-2), BM (-1), BM (0), BM (+1), and BM (+2), are shown in Figure 4-5 by dash lines. BM (-2) denotes the base model with lowest predicted energy use, BM (0) the medium, and BM (2) the highest energy use. Their related assumptions, savings, and error indicators are presented in Table 4-5:

**Table 4-5: Five base models assumptions, savings and error indicators**

	<b>BM (-2): Lowest energy use prediction</b>	<b>BM (-1): Lower energy use prediction</b>	<b>BM (0): Best Model</b>	<b>BM (+1): Higher energy use prediction</b>	<b>BM (+2): Highest energy use prediction</b>
<b>Yearly energy use prediction (MWh)</b>	2,130.90	2,181.60	2,276.50	2,291.50	2,315.60
<b>EER month</b>	-4.1% to +14.3%	-8.7% to +11.6%	-13.3% to +8.2%	-14.3% to +6.9%	-13.8% to +7.7%
<b>EER year</b>	6.24%	4.06%	0.00%	-0.62%	-1.70%
<b>CV (RMSE m)</b>	9.03%	8.09%	6.79%	6.84%	7.14%

Again, the calibration process and building the most accurate simulation model were not the main purposes of this case study. The goal here was to demonstrate the process of calibration and generation of distributions of energy consumption to ultimately present the uncertainty associated with energy performance. The model was made as accurate as possible to provide a reasonable estimate of the outcomes' variation, considering the available data, means, and research timeframe.

#### **4.2.4 Accounting for Risks**

According to a principal at CQI Associates, energy models do not replicate the real world situation, “because those models do not take into account the true investment and cost issues and as well as experience-related issues about them. We have never seen the savings that high [as predicted by the model].” There is a certain level of uncertainty associated with each technology which depends on the current level of knowledge of designers or contractors. How innovative is the technology? “What is the known technology and what is unknown? What is the proven and what is not proven? What are the standard/best practices versus more advanced practices?” (a personal communication, 03.24.11)

One goal of this part of the case study was to present a procedure for including the uncertainty associated with various factors associated with lighting control systems into the modeling process and accounting for those inherent experience-related risk issues in the modeling outcomes. This analysis attempts to explore how the risk and uncertainty may impact on financial outcomes and investment decisions. It is important to note that this study is mainly concerned with demonstrating the process and not the accuracy of final numeric results. The accuracy of outcomes depends on the quality of assumptions and information that was obtained through literature, researcher’s professional judgments, expert interview, and questionnaires.

There are several risks associated with the actual performance of lighting control systems. As mentioned previously, daylight sensors need to be well calibrated to perform as they are designed, otherwise there

might be no savings and low satisfaction by occupants. Occupancy sensors may not be as effective as they are expected to be, if not located properly to cover the area under their control. There is always a risk of poor quality of installation or workmanship—the contractors' risk.

Regarding the uncertainty associated with lighting systems performance, the sales manager at Lutron Electronics indicated that there will be no uncertainty as to the quality of the system or performance of the system related to meeting the intent of the specification. However, there might be some risk associated with the system programming in addressing what the end users really need and want. Here is the response from the Lutron Electronics sales manager:

Lutron along with other lighting control manufacturers will design and bid to the specification to develop the Bill Of Material. The details of system performance are then tied to the Sequence of Operation (SOO). In other words "What do you want the system to do, how do you want to interact with the system and how do you want it to perform per room, per floor, or per building level?" The SOO is a critical component to the success and overall "perceived" performance of the system. As a manufacturer and designer, if we are not given input up front, we are then forced to develop templates to allow us to program the system under a set of predetermined criteria. These templates and criteria may not address the needs, wants and performance characteristics that the end user expected. However, if this expectation is not documented or conveyed to the manufacturer then we will have to make assumptions.

#### **4.2.5 Five Cases for Lighting Control Systems Option – Determining Variance**

Therefore, in order to demonstrate a process of accounting for the potential risk associated with the performance of the lighting retrofit option in the modeling process, five different cases were developed. Seven factors/variables related to lighting controls performance were identified and their values were varied over defined ranges for creating the five lighting retrofit cases. Case 1 was the best case, case 3 was the most-likely, and case 5 was the worst case.

Defining a range for each variable would help to account for some of the risks associated with the option's performance. If a retrofit option is an innovative technology that the market does not have much experience with, the wider ranges might be defined for its uncertain variables. If it is a proven technology, like the lighting retrofit option in this case, the ranges could be narrower accordingly. Table 4-6 shows the variables and their values for each lighting control system case:



**Table 4-6 : Variables and Range for Creating Five Lighting Controls Cases**

<b>Variables</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>
Minimum Light Level – Daylight Sensors	5%	5%	10%	10%	20%
Occupancy Sensors (Schedule)	Low	Low-Medium	Medium	Medium-High	High
High End Tuning Strategy	21.0%	20.5%	20.0%	19.5%	19.0%
Personal Dimming Control	17.0%	16.0%	15.0%	14.0%	13.0%
Lighting Power Density (W/Sq.Ft)	1.1	1.3	1.5	1.5	1.6
Demand (KW) Prediction Adjustment Factor	0.8	0.86	0.92	0.96	1

The minimum lighting level or the minimum output fraction for continuous control type, which is the lowest lighting output that the lighting system can dim down to, is expressed as a fraction of maximum light output. This is the fractional light output that the system produces at a minimum input power. Lutron Electronics claims that their sensors could dim down to 1%, however, daylighting was modeled with systems with minimum lighting level of 5%, 10%, and 20% to account for the potential risks, mentioned above (eQuest does not have a daylight option for less than 5% minimum lighting level). Occupancy sensors are modeled with different occupancy schedules, low to high.

In the high end tuning strategy, typically the digital ballasts would be set to trim 20% on top of the lighting output. Therefore, a range of 19%-21% trimming was considered for this variable. Studies, mentioned in Section 4.1, showed a 15% lighting energy savings when personal dimming controls were employed. A saving range of 13%-17% was considered for personal dimming controls to account for uncertainty associated with its related savings.

Lighting power density is one of the factors that could have a significant impact on the outcomes of lighting control systems. Also, it could vary significantly based on the occupants' behavior. Since no tests were conducted in this case study to measure the actual lighting power density and the reflected ceiling plan were not available, a range of 1.1-1.6 (W/Sq.Ft) was considered to account for this variance.

Demand reduction is one of the important benefits of lighting control systems such as daylight sensors. The demand peak (KW) reduction of this option was estimated through eQuest. As described previously, the energy base models in this study were calibrated based on KWh consumptions, so that the predicted KWh matches the actual KWh. They were not calibrated based on their KW prediction.

The predicted KW of the best base model (BM0) was compared to the actual values. The  $EER_{year}$  was 13.61%. This indicates that the BM0 was over-predicting the annual demand peak by 13.61%. Therefore,

in order to account for this inaccuracy in energy models, a multiplier, in a range of 0.8-1, was considered to adjust the KW prediction in each case.

The five lighting retrofit cases, described in Table 4-6, were modeled using the five base models, explained in Table 4-5, through eQuest, which resulted in a total of 25 energy models/savings estimates. These 25 estimates are used to generate the distributions of energy savings and related financial performance indicators.

An Excel-based model, a Lighting Control Systems Analytics (LCSA), presented in APPENDIX A, was then developed for estimating the final lighting controls energy savings and performing economic analyses for each case. This is an analytic tool that could take the KWh and KW estimates from energy models as inputs, and perform a comprehensive analysis to estimate energy savings and financial performance indicators such as simple payback, simple ROI, NPV and IRR as outputs. As part of the model, a sub-analytic was also developed to include the health and productivity benefits associated with lighting control systems. The estimation and economic analysis parts of the LCSA are explained in detail in next sections.

The assumptions for creating the five lighting cases are primarily based on the researcher's professional judgment. They may not be the most accurate assumptions as no measurement tests or tenant interviews are performed in this case study. As mentioned previously, the goal of this part of the case study was not to generate the most accurate outcomes but to demonstrate a procedure to include risk and uncertainty in the energy modeling process of green retrofit technologies. The result of the analysis shows how various potential risk and uncertainty might impact the final financial outcomes, and therefore, the investment decisions.

#### **4.2.6 Energy Performance Indicators Distribution: Energy Consumption (KWh) and Demand Peak (KW) Savings**

In order to estimate the distributions of energy performance indicators, 1) the impacts of daylight harvesting, occupancy sensors, and different lighting power density on energy savings were first calculated by modeling the 25 cases (five cases by five base models) in eQuest. 2) The outputs, including KWh and KW estimates for both lighting and whole building, were taken to the LCSA. 3) The impacts of high-end trimming, personal dimming control, and demand peak adjustment factors were then estimated and incorporated through the LCSA. 4) The distributions of energy performance indicators, KWh savings

and KW savings, were generated based on the 25 saving estimates. Figure 4-6 and Figure 4-7 show the distributions of total MWh and KW savings:

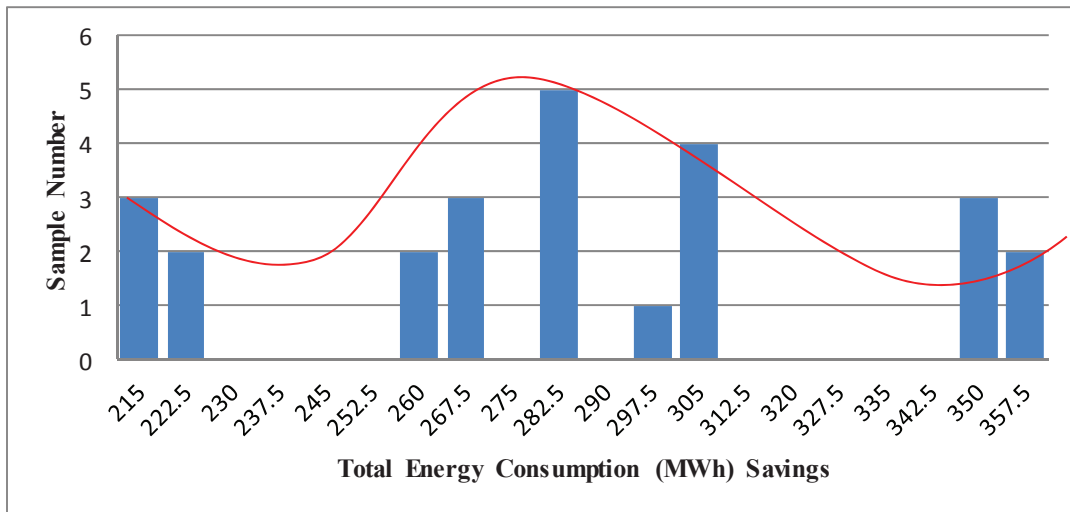


Figure 4-6: The Distribution of Annual Energy Consumption Savings (MWh)

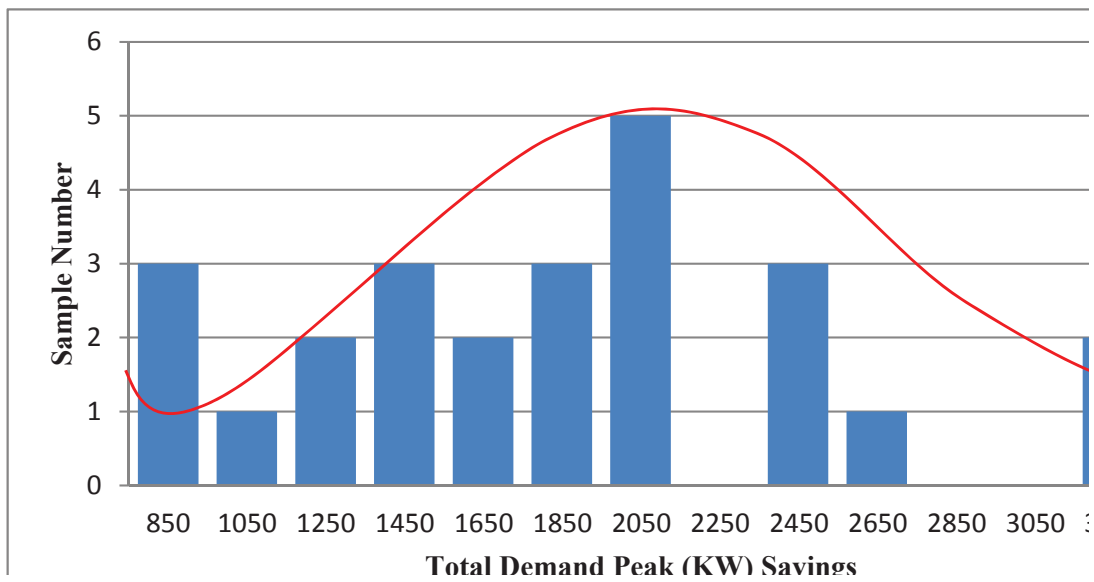


Figure 4-7: The Distribution of Annual Peak Demand Savings (KW)

### 4.3 **Step 2: Estimation of Whole-Building Performance and Cost-Based Economic Analyses**

The purpose of this step of the process was to predict the new building performance resulting from employing the lighting control systems option. This step is a translation step from building performance indicators, KWh and KW savings, to whole-building performance.

Two types of whole-building performance factors are identified in Chapter 3: green and non-green. Green building performance factors, which are the factors that might be influenced by the green retrofits, include development costs (capital costs, timing, incentives, tax savings grants and financing costs), resource use, occupant satisfaction, health and productivity, safety and security, contribution to green or energy certifications, achievable government incentives, reputation, marketability, public benefits, development and cash flow risks, etc. Non-green building performance factors, which are the critical factors in valuation of a property and not related to the retrofits, include location, access, age, size, security, market condition, etc.

In this step the impacts of lighting control systems on the green performance factors were analyzed. For the purpose of this research, it was assumed that all non-green building performance factors do not change after the green retrofit and therefore, all changes in the final financial outcomes are the results of the green retrofits. The green performance factors that were considered in this case study are categorized into the following three types:

- A. Energy-Related Factors: factors that have impact on energy savings, including capital costs, operation and maintenance costs, and utility incentives.
- B. Non-Energy Factors: the benefits that are not related to energy savings but could contribute to cost savings, including health and productivity.
- C. Non-Cost Savings Factors: the benefits that may not contribute to energy and cost savings, including improved occupant's comfort/satisfaction, improved safety and security<sup>28</sup>, contribution to energy or green certification, and improved building energy performance rating and Greenhouse Gas (GHG) emissions.

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<sup>28</sup> Improved safety and security is also claimed as a benefit of lighting controls by Lutron Electronics. Lighting controls can be connected to fire alarm and security systems to turn on lights in case of an emergency. Dimmers installed by hallways and stairs can illuminate a path of light, making it easier to navigate from one room to the other during the night (Lutron, 2011a).

Both simple and life cycle financial analyses were performed for each case over a 20-year life cycle and distributions for simple payback, simple ROI, NPV, and IRR were generated based on the 25 estimates. The financial analyses in this step for both energy and non-energy benefits are based on costs and cost savings. The results of these cost-based financial analyses were compared with the value-based financial analyses outcomes.

**A Comment on Non-Energy and Non-Cost Savings Factors:** As mentioned in Chapter 3, currently, establishing the precise quantitative relationship between performance indicators, health/productivity and market value seems to be almost impossible, due to limited data and difficulty in obtaining required information in a way that can be used directly in property level decision making. However, as Muldavin (2010) has also argued, in real estate, perfect science or exact knowledge about such factors is not required. The current studies with approximations about potential benefits are sufficient to give the decision-makers information and insight, but they need to be very carefully analyzed and applied in their decision-making process. In a property valuation process, the reaction of potential occupants to such information is particularly important.

In this case study, the most comparable studies and data for the relationship between lighting controls and benefits such as health, productivity, and satisfaction were identified and the assumptions for the five cases were made based on their results. More detail about including such benefits into the assessment process is presented in Section 4.3.3 and 4.3.4:

**A Comment on Financial Analyses:** As mentioned before, the true financial performance of a green retrofit option is beyond energy cost savings. Cost and non-costs benefits should be taken into account in the true financial assessment. Accordingly, in this case study, financial analyses, both simple and lifecycle, were performed in three levels to capture the financial performance of the green retrofit option:

1. Cost-based level-1: only energy related costs savings were considered.
2. Cost-based level-2: the non-energy cost savings were considered in addition to the items in level 1.
3. Value-based level: the value implications of the green retrofit option were considered in addition to items in levels 1 and 2. The financial implication of non-cost benefits, which is difficult to include in cost-based analyses, could also be captured at this level—steps 3 and 4 of the proposed framework which are discussed in Chapter 5.

Distributions for Simple Payback, simple ROI, and NPV analyses were generated for all three levels.

### 4.3.1 Energy Cost Savings Analysis

This section explains the assumptions and estimations of energy-related factors that were used in calculating energy cost savings. A distribution of energy cost savings is presented.

#### 4.3.1.1 Capital Costs

The entire capital costs data for lighting control systems, including equipment and installation (labor) costs, were obtained from Lutron Electronics. According to a sales manager of Lutron Electronics, “based on my experience, a fully implemented Quantum System runs \$2/Sq.Ft, which includes the software, graphic floor plan control, daylighting and occupancy sensing controls, wall stations and power controls (Energy Savr Nodes, dimming/switching panels, etc.). And an additional \$2/Sq.Ft to outfit all lighting fixtures; both fluorescent and LED with digitally addressable ballasts.” The estimates are the average for the entire gross square feet of the building.

Capital costs could vary significantly based on the building characteristics, number of existing lighting fixtures, users’ expectations, lighting contractors, etc. For the purpose of this analysis, five capital cost estimates were developed for the lighting retrofit cases 1-5 to account for the potential uncertainty associated with cost approximation of \$4/Sq.Ft, suggested by Lutron. Table 4-7 shows the assumptions and a total capital cost for each case:

**Table 4-7: Capital Costs**

<b>Descriptions</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>
All sensors, software, wall stations, etc./Sq.Ft	\$1.80	\$1.90	\$2.00	\$2.10	\$2.15
Digitally addressable ballasts for all fixtures /Sq.Ft	\$1.90	\$1.95	\$2.00	\$2.00	\$2.05
Total cost /SqFt (equipment and labor)	\$3.70	\$3.85	\$4.00	\$4.10	\$4.20
Total costs for entire building (equipment & labor)	<b>\$329,430</b>	<b>\$342,785</b>	<b>\$356,140</b>	<b>\$365,044</b>	<b>\$373,947</b>

#### 4.3.1.2 Utility Incentives

Pepco, the utility provider for TMC, provides incentives for lighting equipment replacements / retrofits and lighting control systems. Pepco pays all incentives four weeks after the project completion and verification. Table 4-8 shows Pepco’s incentives for related lighting controls:

**Table 4-8: Pepco Lighting Controls Incentives (Pepco, 2011a)**

<b>Lighting Control Systems</b>	<b>Incentives</b>
Occupancy controls - wall mount (near or replacing wall switch)	\$25 / Sensor
Occupancy controls – fixture mounted	\$25 / Sensor
Occupancy controls - remote / ceiling mounted	\$75 / Sensor
Occupancy controls – with step-dimming capability	\$40 / Ballast
Daylight controls – off / on	\$30 / Sensor
Daylight controls – with continuous or step-dimming capability	\$40 / Ballast

A lighting plan for TMC was not available and numbers of the existing lighting fixtures were not counted during site visits. Therefore, assumptions for the number of daylight sensors, occupancy sensors, and digitally addressable ballasts were made based on the following approximations suggested by two managers at Lutron Electronics:

According to a sales manager at Lutron Electronic, “the number of occupancy sensors depends on the floor plan layout. For budgeting purposes for occupancy sensors, I would use one sensor for every 1500 square feet. This is a conservative assumption. Daylighting sensor runs on a linear footage, one daylight sensor per every 30 feet. IEC says that in a lighting zone (approximately 16 feet off the window line) you are going to get direct solar penetration. With new technologies it could go into 25 feet.” According to the Center of Energy Excellence Manager at Lutron Electronics, “The number of ballasts will depend on the number of lamps and watts per square foot. A typical two lamp fixture will have one ballast per every 50 square feet and a typical three lamp fixture will have one ballast every 75 square feet.”

The incentives for the lighting control systems option were then estimated for the five cases based on assumed ranges for numbers of sensors and ballasts. Table 4-9 shows the assumptions for numbers of sensors and ballasts as well as the total incentives that could potentially be collected from Pepco:

**Table 4-9: Total Incentives for each Lighting Retrofit Case**

<b>Description</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case5</b>
No. of daylight sensor – a sensor for every 25-35 linear Ft.	71	78	83	89	99
No. of occupancy sensor – a sensors for every 1500-2000 Sq.Ft	45	48	51	56	59
No. of ballast – a ballast for every 40-75 Sq.Ft	1,187	1,272	1,484	1,781	2,226
Occupancy Controls - Remote Mounted - \$75 per Sensor	\$3,339	\$3,610	\$3,816	\$4,174	\$4,452
Daylight Controls –Continuous Capability - \$40 per ballast	\$47,485	\$50,877	\$59,357	\$71,228	\$89,035
<b>Total Pepco Incentive for the Lighting Control Solution</b>	<b>\$50,824</b>	<b>\$54,487</b>	<b>\$63,172</b>	<b>\$75,402</b>	<b>\$93,487</b>

Since the incentives are more likely to be paid in the same year that lighting retrofits occur, the total investment/development costs of the lighting retrofit option were estimated by subtracting the incentives from the total capital costs. Table 4-10 shows the net investment costs for the five cases.

**Table 4-10: Net Investment Costs**

	Case 1	Case 2	Case 3	Case 4	Case5
Net Investment/Development Costs	\$278,605	\$288,298	\$292,968	\$289,642	\$280,460

### 4.3.1.3 Operation Costs and Maintenance Cost Savings

**Operation Costs:** The primary operation cost related to lighting is the electricity charge for TMC. The electricity charges (\$) per KWh and KW were estimated for summer and winter based on the Pepco cost estimates for generation, transmission, distribution services, and other non-tariff surcharges presented in Pepco rate structure/schedule (Pepco). Table 4-11 shows the weighted averages of electricity charges for 2011 that were used in the financial analyses in this case study:

**Table 4-11: Weighted Average of Pepco Electricity Charges**

2011 Weighted Average Charge /KWh	\$0.12
2011 Weighted Average Charge /KW	\$2.81

The demand charge by Pepco is relatively low because according to a technical expert at ICF International “Pepco does not own generation, and as such the demand charges are much lower than for a vertically integrated utility that owns generation. The demand charges that would represent the development cost of generation are imbedded in the retail energy rates, not a component of demand charges”.

As mentioned previously, the NPV analyses were performed over a 20-year life cycle—2012 to 2031—in this study. For projecting the electricity cost until 2031, an escalation rate of 3.4% equal to inflation rate was considered based on the opinion of a technical expert at ICF International.

Energy escalation rate is one of the most uncertain factors in energy analysis that stakeholders do not have control over. Additional analysis was performed using Monte Carlo simulation method through @risk software to understand how escalation rate impact the LCC outcomes. A normal distribution with 90% confidence of range of 0 – 6.8% was determined for electricity escalation rate and distributions of NPVs and IRRs were generated. Distributions and statistical summary of NPVs and IRRs are presented in APPENDIX B.



**Maintenance Cost Savings:** Lutron Electronics claimed that lighting controls could result in maintenance and operation cost savings associated with ongoing facility management activities, such as re-lamping due to the longer life of bulbs when dimmed (Lutron, n.d.). According to the IESNA 9<sup>th</sup> edition Lighting Handbook, five incandescent bulbs last 20 times longer if dimmed by 50% (as indicated by Lutron, n.d.). According to a sales manager at Lutron, “using our digital ballasts, repurposing of the space would not require costly maintenance cost of re-wiring. Also, our systems have the ability to run reports on lamp / ballast failures, so that cuts down on the maintenance staff having unnecessary equipment around the building auditing lamp / ballast failures”.

For the purpose of NPV/LCC analysis, an annual maintenance cost savings of \$600-\$1000 were considered until the end of the first lighting controls useful life. The assumption was that the advantage of maintenance cost savings will be diminished as time passes.

#### 4.3.1.4 Total Cost Savings

Based on the annual kWh and KW savings, presented in Section 4.3.1.4, and electricity costs, presented in Section 4.3.1.3, the total cost savings were estimated for the 25 cases. Figure 4-8, Figure 4-9, and Figure 4-10 show the distribution of total costs savings, savings per Sq.Ft, and savings per employee of Davis Construction Company respectively:



Figure 4-8: The Distribution of Total Annual Energy Cost Savings



Figure 4-9: The Distribution of Annual Energy Cost Savings per Sq.Ft

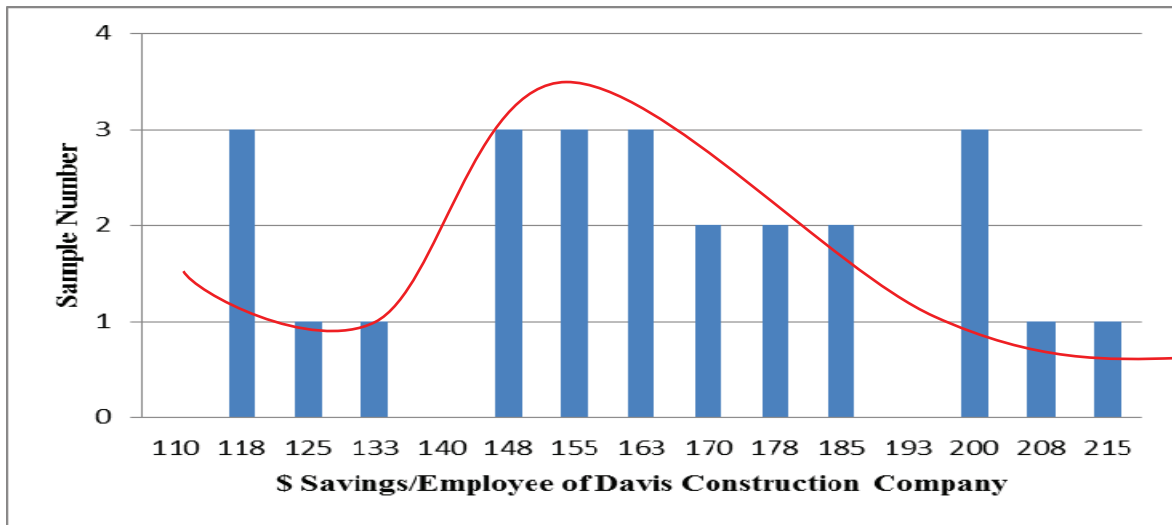


Figure 4-10: The Distribution of Annual Energy Cost Savings per Employee of Davis Construction Company

### 4.3.2 Cost-Based Financial Analysis Level 1 - Energy Savings

This is the first level of financial analysis, previously referred to as cost-based level-1, where only energy savings resulting from lighting control systems were taken into account.

### 4.3.2.1 Simple Payback and Simple ROI Distributions

Simple paybacks and ROIs were estimated using the total investment/development costs, presented in Table 4-3, and total cost savings presented in **Error! Reference source not found. Error! Reference source not found.** Figure 4-11 and Figure 4-12 show the distribution of simple paybacks and ROI.

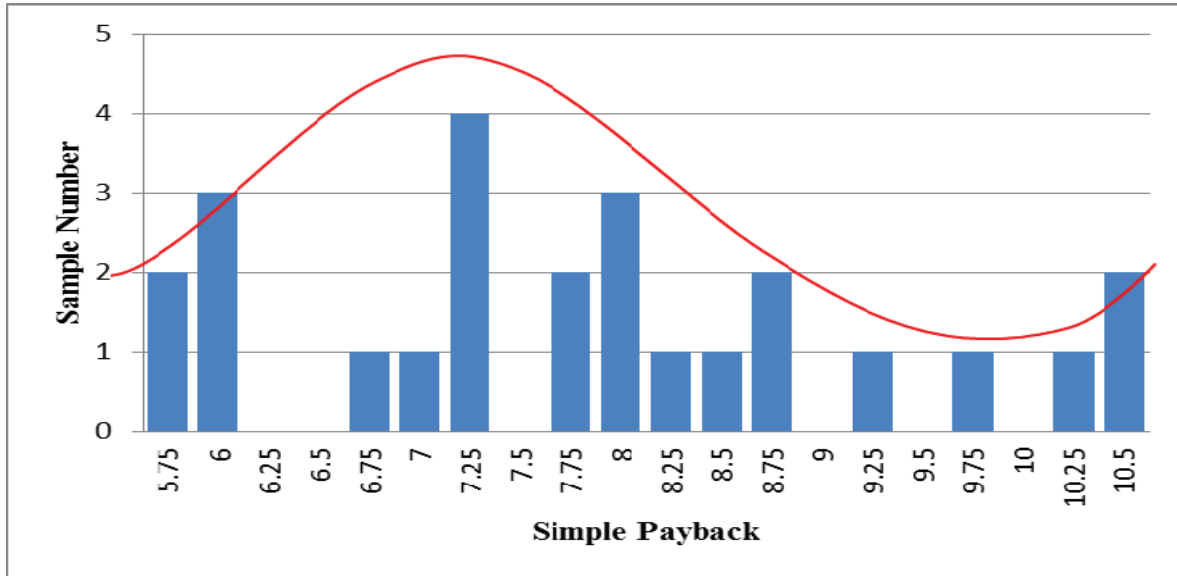


Figure 4-11: The Distribution of Simple Payback (Year) – Energy Savings

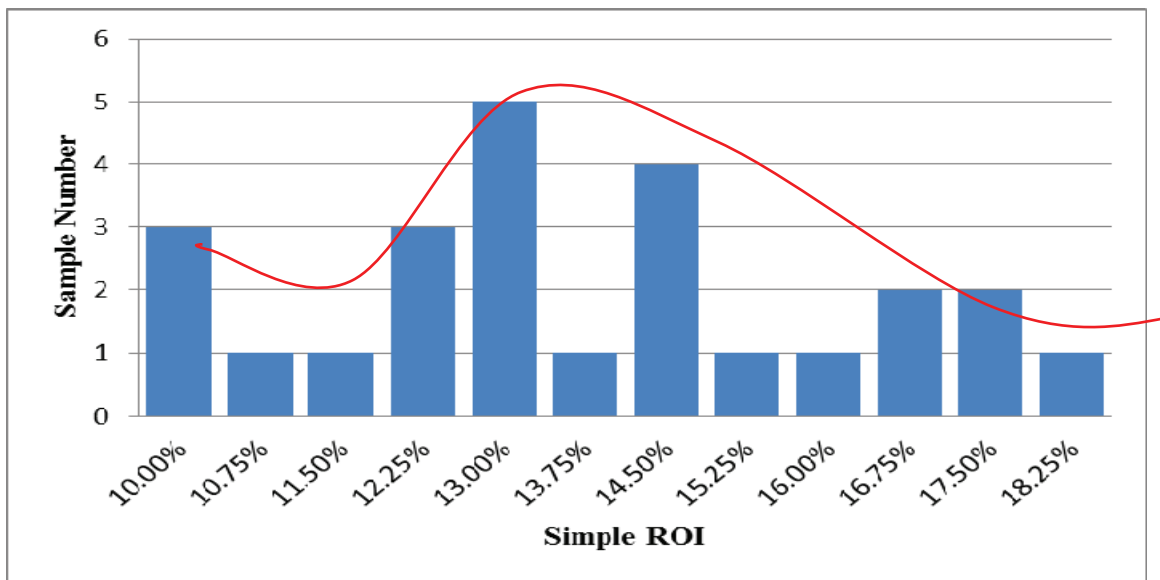


Figure 4-12: The Distribution of Simple ROI – Energy Savings

According to a sales manager at Lutron Electronic,

“...clients like to see a payback of around 5 years or less. It's a time threshold that I see most often. 2-3 year ROI gets funded right away, 3-5 year with the appropriate proposal typically gets put on a short list "as funding becomes available" and 5-8 year ROI gets put on the back burner unless we can promote "additional" value. IE maintenance cost, comfort, productivity, LEED registration, etc.”

Therefore, in this case with paybacks in a range of 5.5-10.5 years when only energy savings are considered, the decision is most likely no investment in lighting controls.

#### 4.3.2.2 Life Cycle Cost Analysis (LCCA) – NPV and IRR Distribution

Cash flows for a period of 20 years were developed. NPVs and IRRs were estimated over four time horizons of 5, 10, 15, and 20 years to show the financial performance of the lighting retrofit over various life cycles. The costs of lighting replacements at the end of their useful life cycle were included in the cash flows for two conditions. The two conditions are 1) When a lighting retrofit option is undertaken and new control systems are installed—the replacement costs can negatively impact the cash flow at the end of the new system’s useful life 2) When no lighting retrofit is undertaken and existing lighting fixtures will be replaced with similar models—the costs can positively impact the cash flow at the end of the remaining useful life of the existing lighting fixtures. This is because when the lighting retrofit will be undertaken now, the current fixture will not need to be replaced at the end of their useful life, and therefore, the replacement costs will be saved. Table 4-12 shows the certain assumptions that are made for performing the LCCA:

**Table 4-12 : Assumptions for LCCA**

	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>
Discount Rate for LCCA	7.0%	7.5%	8.0%	8.5%	9.0%
Reduction in maintenance cost for first X years (until the end of UL)	\$1,000	\$900	\$800	\$700	\$600
Remaining useful life (UL) of current lighting fixture	3	4	5	6	7
Total cost of upgrade current non-efficient fixture at the end of UL/Sq.Ft	\$0.80	\$0.90	\$1.00	\$1.10	\$1.20
Capital cost for replacing the current lighting fixture at the end of their UL	\$71,228	\$80,132	\$89,035	\$97,939	\$106,842
Useful life of new lighting control systems and fixtures from Lutron	15	14	13	12	11
Capital costs of upgrading new lighting systems after the first useful life (first 10-15 years)	\$160,263	\$169,167	\$178,070	\$186,974	\$191,425

Figure 4-13 through Figure 4-20 present the distributions of NPVs and IRRs over various periods of 5, 10, 15, and 20 years:

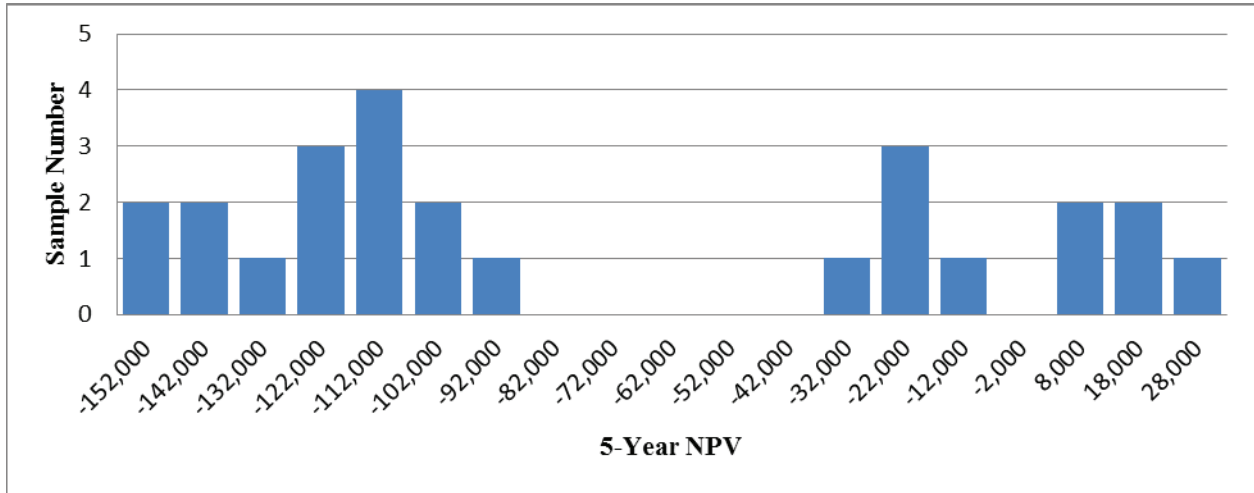


Figure 4-13: The Distribution of 5-Year NPV

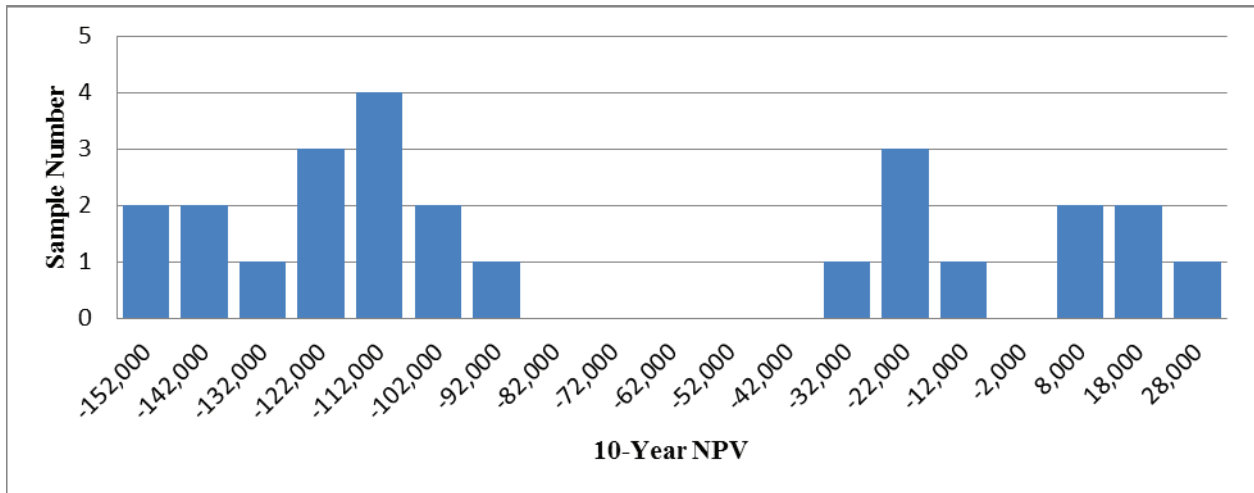


Figure 4-14: The Distribution of 10-Year NPV

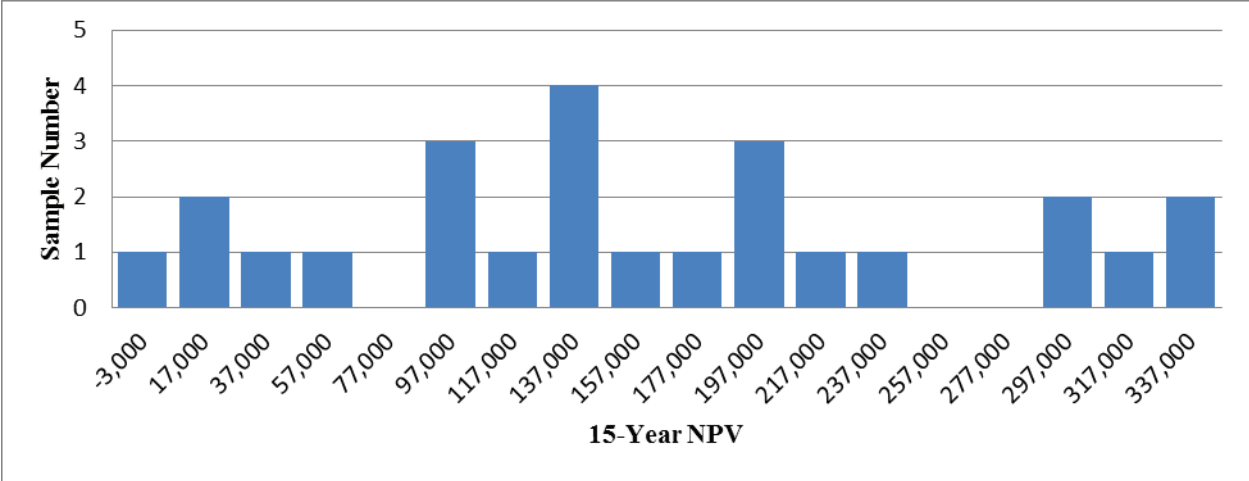


Figure 4-15: The Distribution of 15-Year NPV

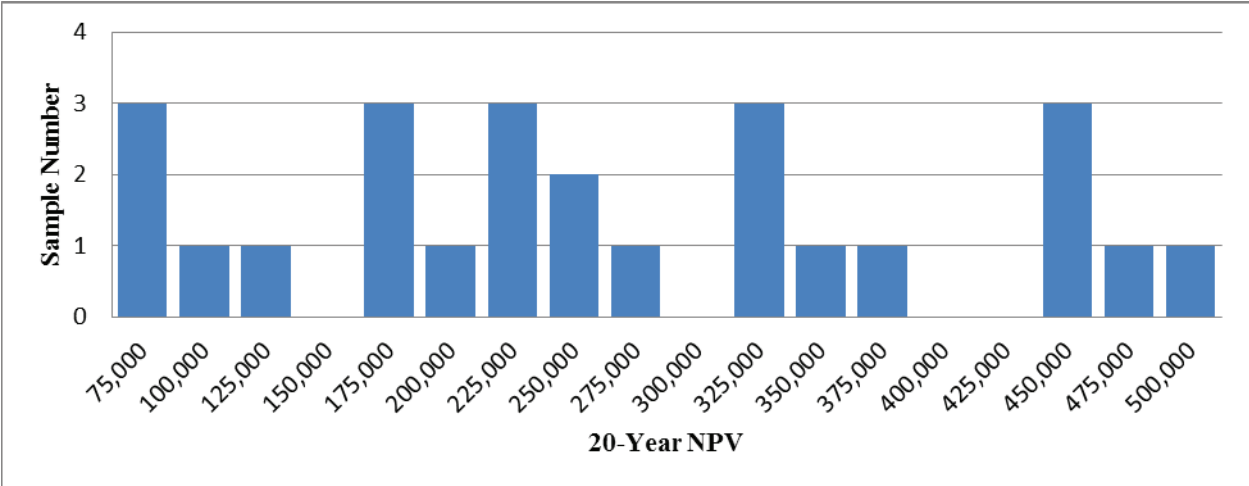


Figure 4-16: The Distribution of 20-Year NPV

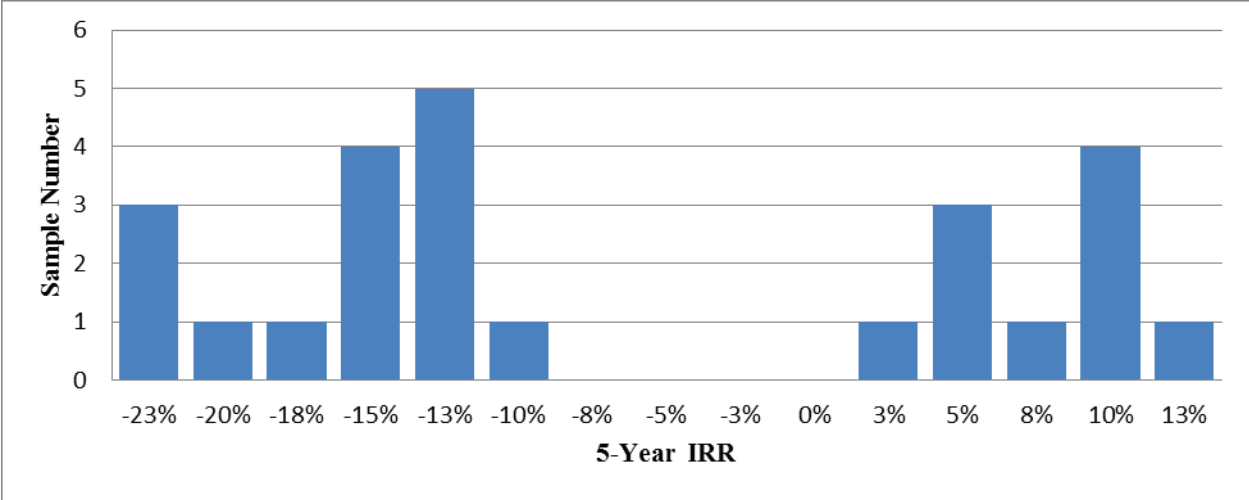


Figure 4-17: The Distribution of 5-Year IRR

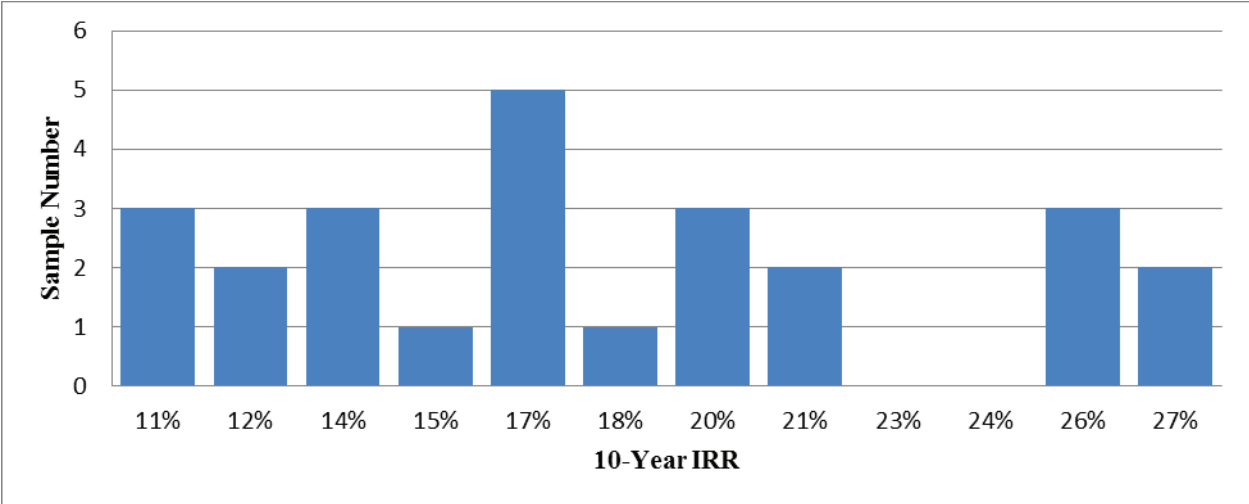
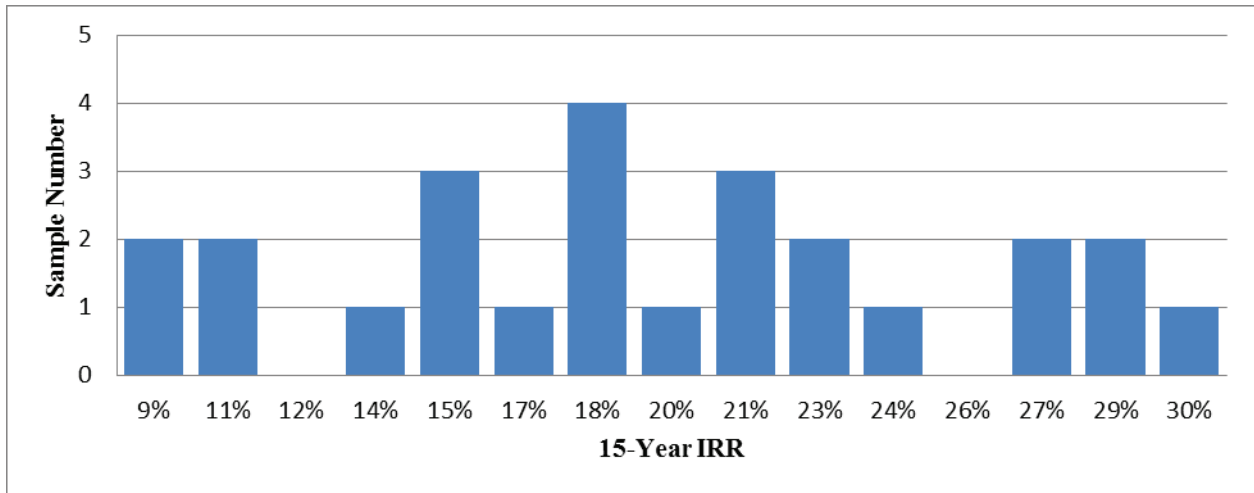
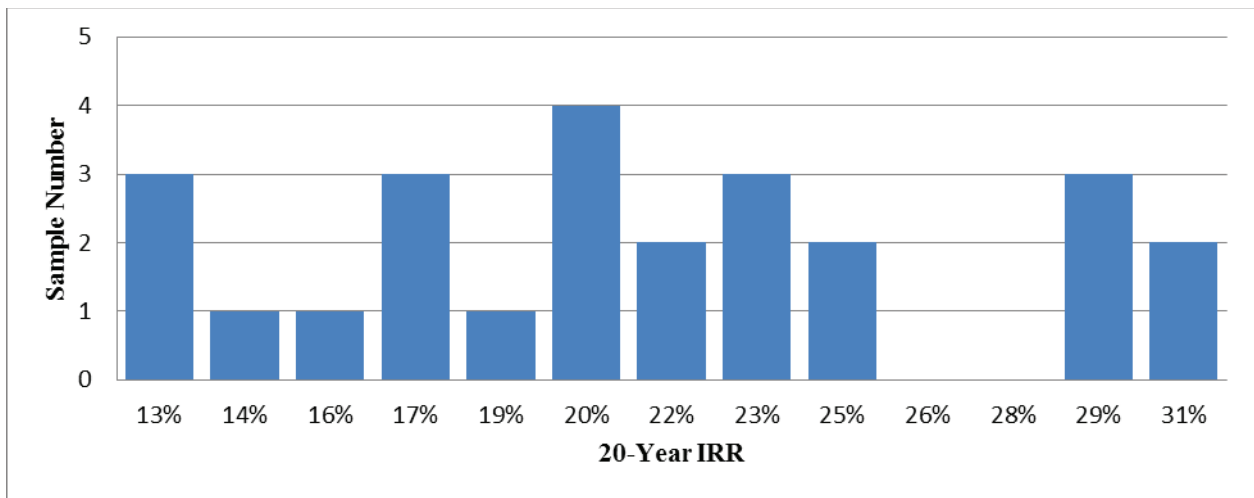


Figure 4-18: The Distribution of 10-Year IRR



**Figure 4-19: The Distribution of 15-Year IRR**



**Figure 4-20: The Distribution of 20-Year IRR**

As shown in Figure 4-11 and Figure 4-13, all simple payback estimates are greater than 5.5 years, but the 5-year NPV is greater than zero in five cases out of 25 cases. This means that if an investor with a 5-year return window makes his investment decision based on the results of simple payback analysis, then the decision would be no investment in the lighting control systems. However, based on the NPV analysis, an investor might consider investing in lighting controls, because NPV estimates are greater than zero in five cases. This is an indication of the limitation of Simple Payback analysis for assessing green investment opportunities. As discussed in detail in Chapter 2, Literature Review, Simple Payback analysis does not



include the potential long term benefits of green technologies and under-estimates the investment in green systems and strategies.

#### **4.3.2.3 Non-Energy/Social Benefits**

As mentioned previously, social/non-energy benefits of lighting controls refer to those benefits that are not related to energy cost savings but could contribute to the cost savings, such as health and productivity. Increased health and productivity would not only significantly contribute cost savings but also could impact the property value. More details about health and productivity impacts were discussed in Chapter 2, Literature Review.

In this case study, two approaches/steps were considered to include the benefits of health and productivity into the financial analyses: 1) a cost-based approach where the potential cost savings associated with health and productivity were estimated and 2) a value-based approach where the potential impacts of increased health and productivity on property value were estimated. The value-related impacts are addressed in in Chapter 5, where the DCF inputs were projected.

Scores of studies, including case studies, academic research, and lighting manufacturer’s brochures, show that lighting controls could improve both health and productivity—health to a lower degree and productivity to a higher degree. NSF/IUCRC Center for Building Performance and Diagnostics at Carnegie Mellon University is one of the organizations that have provided some approximations about the impacts of lighting controls systems on health and productivity based on the various case studies.

Among all the literature on the health and productivity impacts, studies by this center on health and productivity savings of lighting controls were more comparable with the lighting option analysis in this case study. Therefore, their suggested estimates were used as the primary source to generate a range for assumptions for health and productivity impacts and calculate their potential savings.

#### **4.3.2.4 Calculating Health and Productivity Cost Savings**

According to the Guidelines for High Performance Buildings by NSF/IUCRC Center for Building Performance and Diagnostics at Carnegie Mellon University<sup>29</sup>, replacement of outdated office lighting

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<sup>29</sup> The Center for Building Performance and Diagnostics (CBPD) conducts research, development, and demonstrations to increase the quality of and user satisfaction with commercial buildings and integrated building systems, while improving cost, time, and energy-efficiency. High-performance buildings must provide appropriate physical, environmental, and organizational settings to accommodate changing technologies and workplace activities. (<http://www.nsf.gov/pubs/2002/nsf01168/nsf01168u.htm>)

with quality lighting components featuring high-performance lamps, ballasts, fixtures and advanced controls would result in 27%-87% lighting energy savings and 0.7%-26% productivity gains with a median of 3.2%. In a controlled experiment, an improved lighting design would result in a 27% reduction in the incidence of headaches, which accounts for 0.7% of overall employee health insurance cost at approximately \$35 per employee annually (EBID, 2004).

Lutron Electronics has also claimed that lighting control could translate to 5% to 10% increased productivity (Lutron, 2011b). In a white paper for Lutron, Rowbottom (2009) has stated, “the exact impact [of lighting control on productivity] is hard to establish in a commercial environment. It’s reasonable to postulate that productivity improves at least 5% when workers can control their own visual environment, although productivity gains as small as 1% still make lighting control systems an excellent investment, with a payback period of seven months or less”.

For the purpose of this study, an average salary for the employees at TMC was assumed to be \$60,000 per year. The health and productivity savings were also estimated for employees of Davis Construction Company. As mentioned previously, the owner of TMC is also the president of Davis Construction Company which occupied 2/3 of the building. He is the final decision-maker regarding the retrofit investment. Since this research is primarily concerned with the financial analysis of green investment from the perspective of the property owner, the portion of the health and productivity savings that might impact the investment decisions (the savings related to the employees of Davis Construction Company) was estimated and included in the financial analyses. Table 4-13 shows the health and productivity assumptions and savings for the five lighting controls option:

**Table 4-13: Health and Productivity Assumptions and Savings**

<b>Description</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>	<b>Average</b>
<b>Productivity Assumptions and Savings</b>						
Increased Individual Productivity	4.0%	3.2%	2.0%	1.0%	0.5%	2.1%
Savings per Employee /Year	\$2,400	\$1,920	\$1,200	\$600	\$300	\$1,284
Savings for entire workers /Year	\$573,600	\$458,880	\$286,800	\$143,400	\$71,700	\$306,876
Savings for Davis’s Employee /year	\$382,400	\$305,920	\$191,200	\$95,600	\$47,800	\$204,584
<b>Health Assumptions and Savings</b>						
Savings per Employee /Year	\$35	\$25	\$15	\$10	\$5	\$18
Savings for entire workers /Year	\$8,365	\$5,975	\$3,585	\$2,390	\$1,195	\$4,302
Savings for Davis employee /year	\$5,577	\$3,983	\$2,390	\$1,593	\$797	\$2,868
<b>Total Savings for the Owner of TMC</b>	<b>\$387,977</b>	<b>\$309,903</b>	<b>\$193,590</b>	<b>\$97,193</b>	<b>\$48,597</b>	<b>\$207,452</b>

As shown in Table 4-13, the savings associated with improved employee productivity is very significant when compared to energy saving; even 0.5% improved productivity could result in \$71,700 additional total savings for this building. Figure 4-21, Figure 4-22, and Figure 4-23 show the distributions of total cost savings, savings per square foot, and savings per employee of Davis Construction Company when the health and productivity savings are included along with previously calculated energy savings:

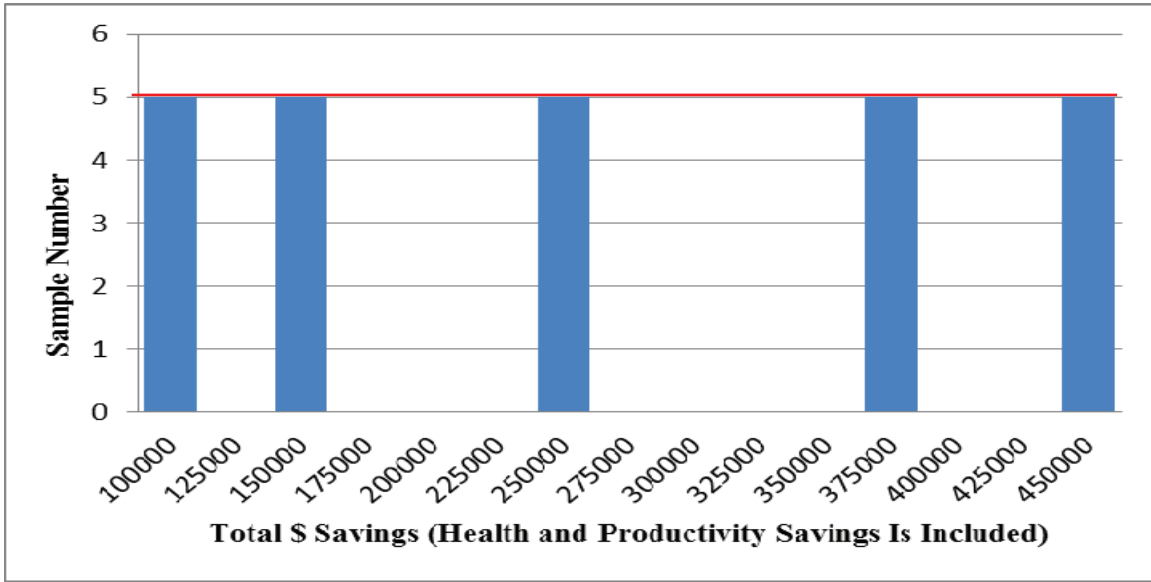


Figure 4-21: The Distribution of Total Cost Savings (Health & Productivity Savings Are Included)

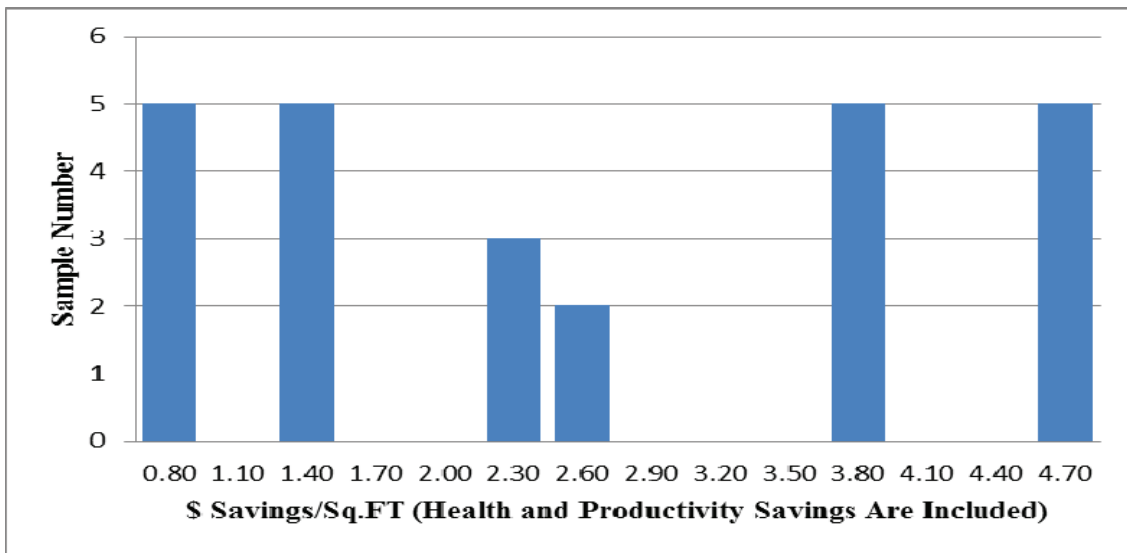
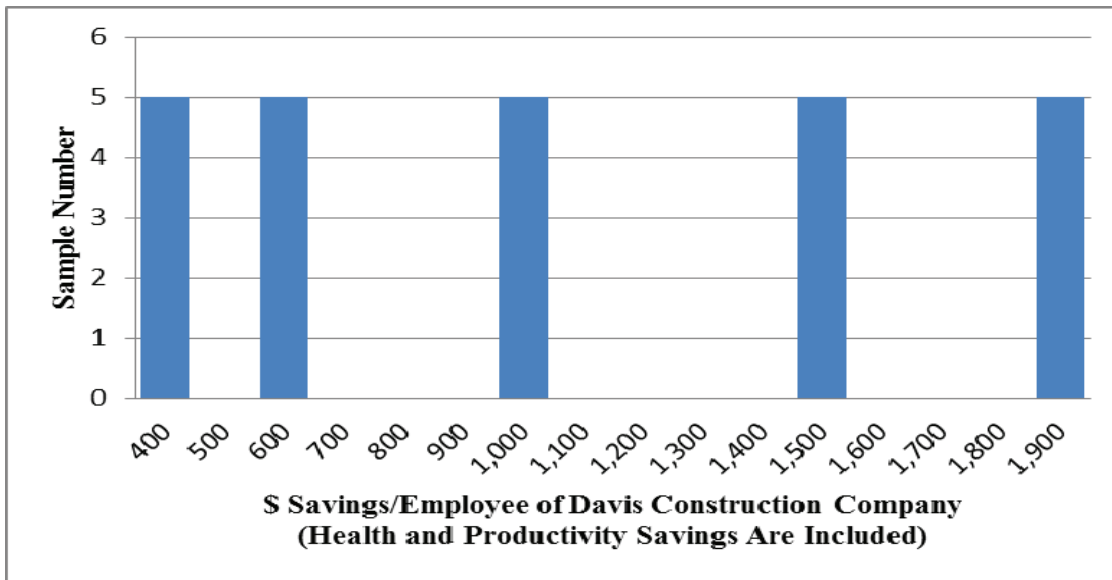


Figure 4-22: The Distribution of Cost Savings per Sq.Ft (Health & Productivity Savings Are Included)



**Figure 4-23: The Distribution of Total Cost Savings per Employee of Davis Construction Company (Health & Productivity Savings Are Included)**

As shown in the above figures, the impact of health and productivity are so significant that this changes the shape of the savings distributions to flat. This means that the saving estimates are not very sensitive to the various uncertainties associated with base models and lighting controls cases when the health and productivity savings are taken into account. This issue is discussed in more detail in Section 4.3.4.1.

The accuracy of saving estimates depends on the data suggested by NSF/IUCRC Center for Building performance and Diagnostics at Carnegie Mellon University. Again, the goal here was not to estimate the most accurate savings, the goal was to present a process of including non-energy savings the financial assessments and show how these might impact financial outcomes and ultimately investment decisions.

### **4.3.3 Cost-Based Financial Analyses Level 2 – Energy and Non-Energy Savings**

This is the second level of financial analysis, previously referred to as cost-based level-2, where non-energy savings resulting from lighting control systems are taken into account in addition to energy savings, calculated in Section 4.3.1.4.

#### **4.3.3.1 Simple Payback and Simple ROI Distribution**

Figure 4-24 and Figure 4-25 show the distributions of simple payback and simple ROI for the 25 cases:

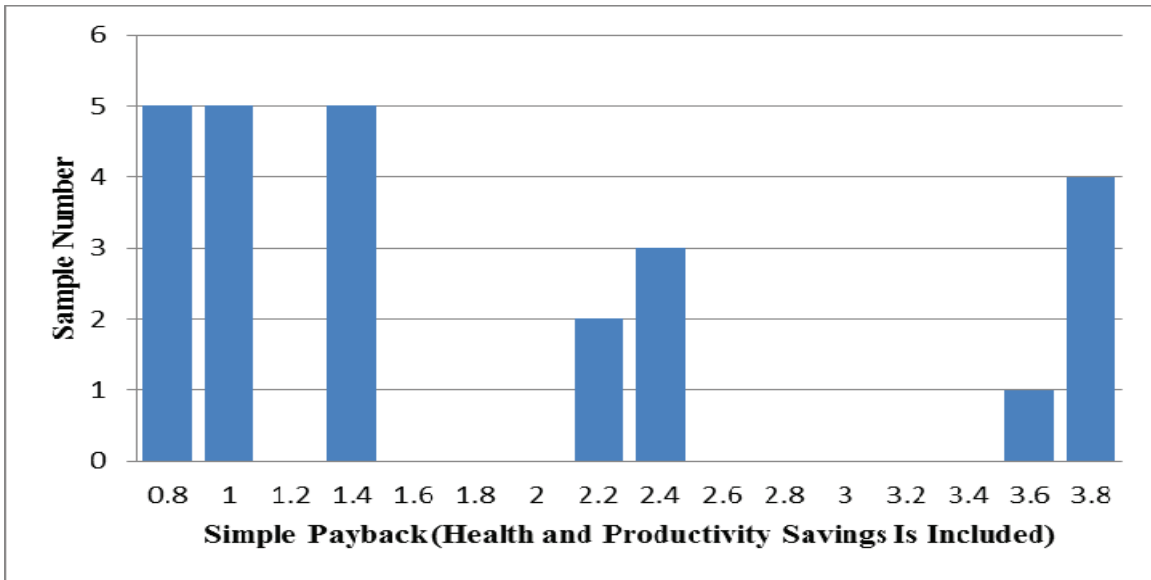


Figure 4-24: The Distribution of Simple Payback (Health and Productivity Savings Are Included)

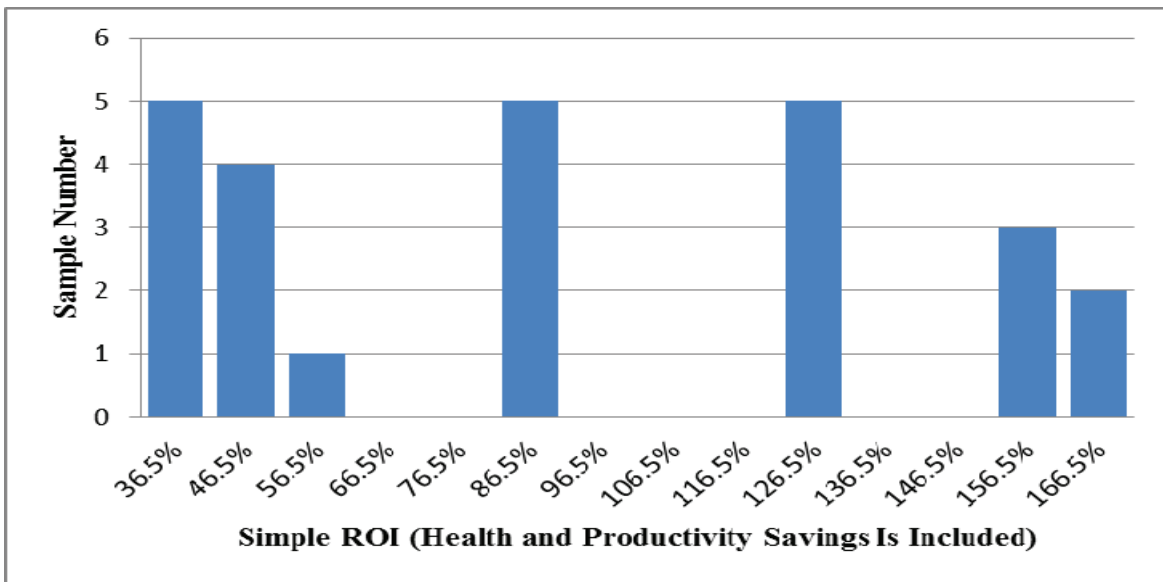


Figure 4-25: The Distribution of Simple ROI (Health and Productivity Savings Are Included)

As shown in Figure 4-24 and Figure 4-25, the inclusion of health and productivity savings, even the portion that might be of interest to the owner of TMC, has significantly reduced the payback period. The paybacks for 10 cases become less than one year, for 10 cases less than 2 year, and for remaining 5 cases

between 3-4 years. Therefore, when the owner is looking at a payback less than 3 years, he will most likely consider investing in this option as the average payback is 1.7 year.

This analysis shows how including non-energy benefits in the financial analysis process, even if it is a cost-based approach, can alter a green investment decision from no investment to a no-brainer investment.

#### 4.3.3.2 Life Cycle Cost Analysis (LCCA) - NPV Distribution

The significance of including health and productivity savings on NPVs are shown in the Figure 4-26 though Figure 4-29:

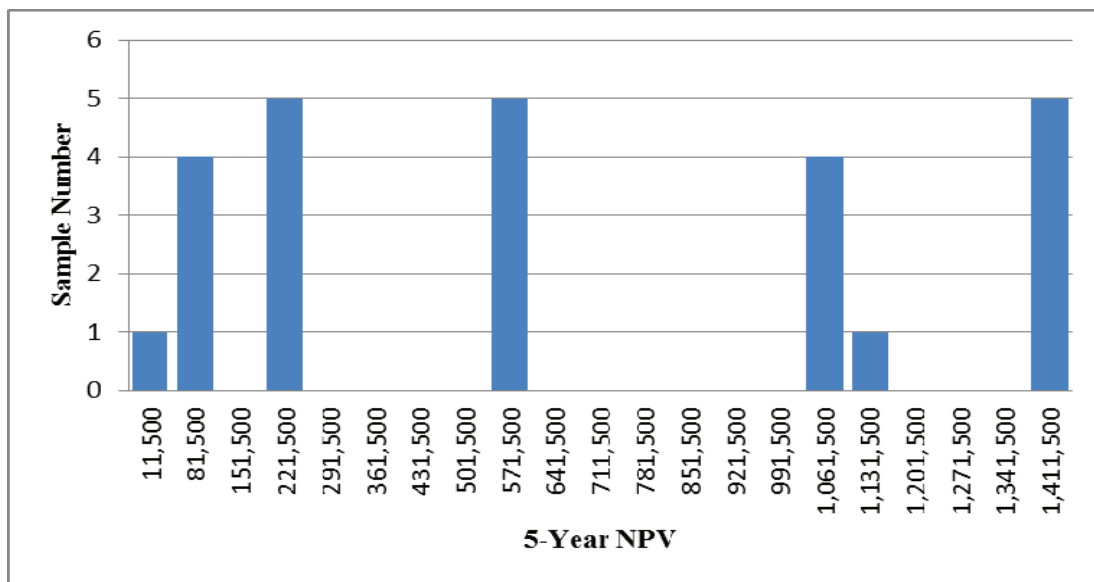


Figure 4-26: The Distribution of 5-Year NPV (Health and Productivity Savings Are Included)

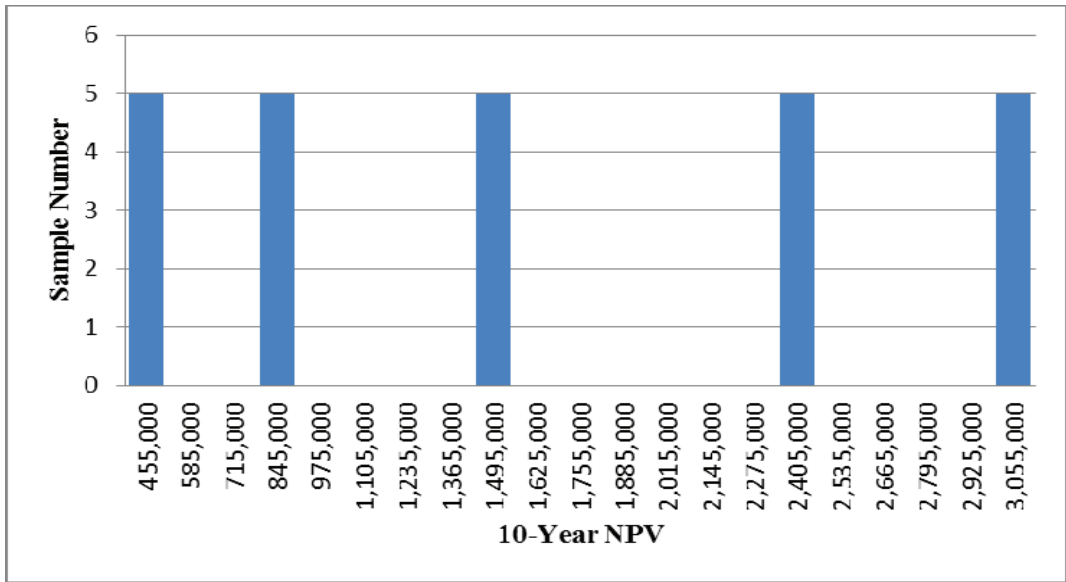


Figure 4-27: The Distribution of 10-Year NPV (Health and Productivity Savings Are Included)

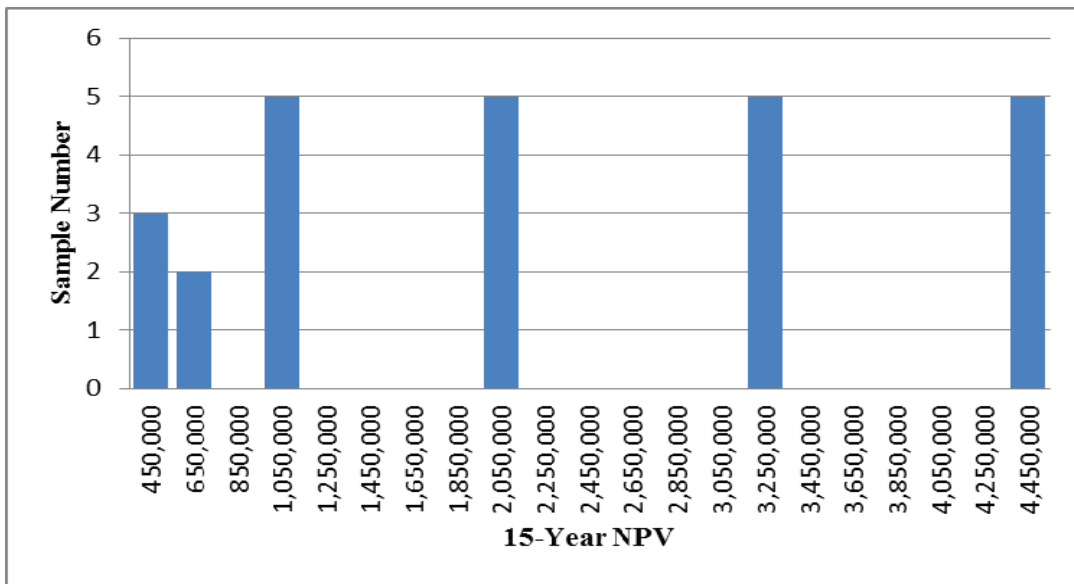


Figure 4-28: The Distribution of 15-Year NPV (Health and Productivity Savings Are Included)

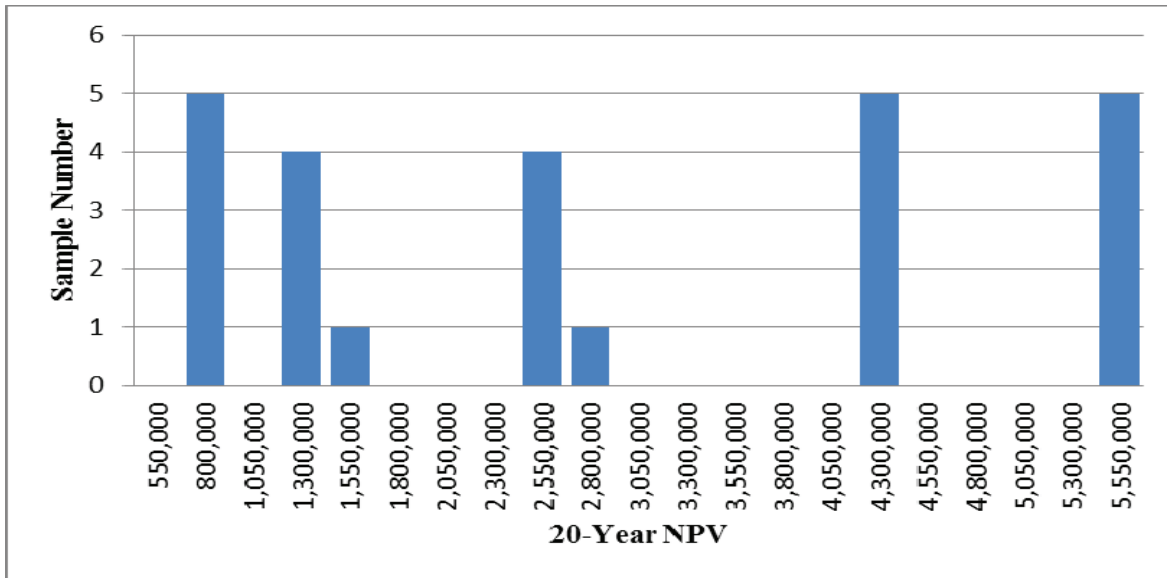


Figure 4-29: The Distribution of 20-Year NPV (Health and Productivity Savings Are Included)

#### 4.3.4 Non-Cost Savings Benefits

Non-cost benefits refer to the benefits that do not contribute to energy and cost savings, such as occupants’ comfort/satisfaction, and contribution to energy or green certification. These benefits may play a role in financial performance by impacting on property value which cannot be captured in the cost-based analyses in the previous step.

Scores of studies, stated in Chapter 2, demonstrate a positive relationship between such factors and the property value. However, the results of these studies are general and may not be appropriate for making investment decisions at the property level. Each property has unique characteristics in a particular market and this is the market that defines the value of a property.

As demonstrated in the proposed assessment framework in Chapter 3, the building performance information, both qualitative and quantitative, needs to be connected to the valuation model (eg. DCF model), so the value implications associated with green options could be captured and included in the financial assessment process. This is step 3 of the proposed assessment framework where whole-building performance factors need to be translated into financial model inputs.

For estimating the potential value-added by employing lighting controls in this case study, all potential benefits in the form of a combination of qualitative and quantitative information were summarized as part



of a survey introduction and were reported to real estate experts to collect their opinions on DCF inputs. Non-cost saving benefits of lighting controls could be captured in this step, referred to as a value-based analysis level.

The quantitative information is numerically predicated based on eQuest and the LCSA Excel-based model, and qualitative data is available in the literature, including energy cost savings, improved health and productivity, increased probability of achieving LEED certifications, and improved building energy performance rating and Greenhouse Gas (GHG) emissions. The qualitative information includes those benefits for which there were not sufficient resources in the literature to make numeric assumptions, including improved comfort, safety and security.

#### 4.3.4.1 The Contribution in Achieving LEED Certifications

Lutron Electronics has claimed that its lighting controls solution can contribute to 40 out of 110 possible points (36%) in the new LEED 2009 NC rating system, 39 of the 110 possible points in LEED EB, and 35 of the 110 possible points in LEED CI. The following is a summary of the credits that Lutron solutions could contribute in achieving LEED NC (Jouaneh, 2010):

**Table 4-14: The Contribution of Lutron Lighting Controls to LEED Certifications (adapted from Jouaneh, 2010, p. 6)**

<b>LEED 2009 NC</b>			
<b>Summary of credits that lighting controls could contribute in achieving</b>			
Credit	Description	Points that lighting controls help achieve	% of total possible points
SS	Sustainable Sites	1 out of 26	4%
EA	Energy and Atmosphere	24 out of 35	69%
MR	Material and Resources	2 out of 14	14%
IEQ	Indoor Environmental Quality	3 out of 15	20%
ID	Innovative Design	6 out of 6	100%
RP	Regional Priority	4 out of 4	100%

Five assumptions, in a range of 5-25, were made for the number of LEED points that could be achieved through employing the lighting control systems. Based on these assumptions and minimum number of points required for achieving each level of LEED certification, a probability for achieving each level was estimated for each case—a probability is equal to the number of points that were assumed to be achieved in each case divided by minimum points required for achieving a certain level of LEED certification. It was assumed that this building could meet all the pre-requisites defined by LEED. Table 4-15 shows the probabilities for achieving four levels of LEED certifications:

**Table 4-15: Probabilities for Achieving Four Levels of LEED Certifications**

	<b>Minimum Points</b>	<b>Case 1</b>	<b>Case2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>
<b>Number of points assumed to be achieved by the selected lighting options</b>	<b>25</b>	<b>20</b>	<b>15</b>	<b>10</b>	<b>5</b>	
<b>Certified</b>	<b>40</b>	50.00%	37.50%	25.00%	12.50%	25.0%
<b>Silver</b>	<b>50</b>	40.00%	30.00%	20.00%	10.00%	20.0%
<b>Gold</b>	<b>60</b>	33.33%	25.00%	16.67%	8.33%	16.7%
<b>Platinum</b>	<b>80</b>	25.00%	18.75%	12.50%	6.25%	12.5%

It should be noted that the 40 points that are suggested by Lutron Electronics are the ones that lighting controls could contribute in achieving a LEED certification and this certification may not be attained solely by employing lighting controls systems, for example, the 4 points of regional priority may not be achievable in many regions in the U.S. It would be very difficult or impossible to link, with certainty, a particular technology to the number of LEED points that could be achieved. Thus, a conservative range of 5-25 was selected for estimating the increased probabilities for achieving LEED Certification.

#### **4.3.4.2 Improved Building Energy Performance Rating and Greenhouse Gas (GHG) Emissions**

The Portfolio Manager tool, developed by the U.S. Environmental Protection Agency (EPA), was used to assess how employing lighting controls could impact the building energy performance rating and its GHG Emissions.

EPA’s Portfolio Manager is a web-based tool that helps to track and assess energy and water consumption within individual buildings as well as across the entire building portfolio. It evaluates the building’s energy performance on a scale of 1–100 relative to similar buildings nationwide<sup>30</sup> and determines the ENERGY STAR ratings of buildings. A rating of 50 indicates that the building, from an energy consumption standpoint, performs better than 50% of all similar buildings nationwide, while a rating of 75 indicates that the building performs better than 75% of all similar buildings nationwide. A building with rating of 75 or above is eligible for an ENERGY STAR label.

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<sup>30</sup> Statistically representative models are used to compare the subject building against similar buildings and characteristics from a national survey conducted by the Department of Energy’s Energy Information Administration. This national survey, known as the Commercial Building Energy Consumption Survey (CBECS), is conducted every four years, and gathers data on building characteristics and energy use from thousands of buildings across the United States.

Current electricity consumption (KWh) and costs from the electricity bills for 2009 were first entered into Portfolio Manager to determine the current performance rating and GHG emissions. Table 4-16, which is a part of a statement of energy performance generated through the Portfolio Manager, shows the current energy performance estimates and their comparison with national average and rating of 75. A complete statement is presented in APPENDIX C.

As shown in Table 4-16, the current Energy Performance Rating of TMC is 38 out of 100, and the energy consumption and GHG emissions in the building are about 15% above the national average and about 55% above the ENERGY STAR building requirements.

The energy performance was then evaluated for three energy savings scenarios: min, max, and average savings. The statements of energy performance for all scenarios are presented in APPENDIX B. As shown in Table 4-17, by employing the lighting controls option, the average energy consumption would become equal to the national average, and energy cost and GHG emissions would be slightly below the national average. With the retrofit, the Energy Performance Rating will increase from 38 to a range of 47-53, which means investing in lighting controls has the potential to provide 24%-41% of the energy savings this building needs to achieve an ENERGY STAR label.

**Table 4-16: Energy Performance Comparison**

Performance Metrics	Evaluation Periods		Comparisons		
	Current (Ending Date 11/30/2009)	Baseline (Ending Date 11/30/2009)	Rating of 75	Target	National Median
Energy Performance Rating	38	38	75	N/A	50
<b>Energy Intensity</b>					
Site (kBtu/ft <sup>2</sup> )	84	84	55	N/A	74
Source (kBtu/ft <sup>2</sup> )	282	282	183	N/A	248
<b>Energy Cost</b>					
\$/year	\$ 278,309.17	\$ 278,309.17	\$ 181,161.65	N/A	\$ 244,914.71
\$/ft <sup>2</sup> /year	\$ 3.04	\$ 3.04	\$ 1.98	N/A	\$ 2.68
<b>Greenhouse Gas Emissions</b>					
MtCO <sub>2</sub> e/year	1,092	1,092	711	N/A	961
kgCO <sub>2</sub> e/ft <sup>2</sup> /year	12	12	8	N/A	11

**Table 4-17: Impact of Lighting Controls on Energy Performance Rating and GHG Emissions**

Performance Metrics	Current	After Lighting Retrofit			National Average	ENERGY STAR label
		Min	Max	Average		
<b>Energy Performance Rating</b>	<b>38</b>	<b>47</b>	<b>53</b>	<b>50</b>	<b>50</b>	<b>75</b>
Site (kBtu/Ft <sup>2</sup> /yr)	84	72	77	74	74	55
Source (kBtu/Ft <sup>2</sup> /yr)	282	239	257	248	248	183
GHG Emissions (MtCo <sub>2</sub> e/yr)	1,092	922	990	956	961	711
Energy Cost (\$/year)	\$278,309	\$228,480	\$251,334	\$240,146	\$244,915	\$181,162
Energy Cost (\$/sqft/yr)	\$3.04	\$2.50	\$2.75	\$2.63	\$2.68	\$1.98

#### **4.3.4.3 Improved Occupants’ Comfort/Satisfaction and Safety/Security**

Several studies have confirmed direct relationships between lighting controls with lighting quality, visual comfort, and overall environmental satisfaction (Boyce et al, 2003). These studies show that the quality of light affects the visual environment of a commercial enterprise; that people are more comfortable if they can control their visual environment; and there is a direct relationship between comfort and productivity. Unfortunately, researchers have yet to put an exact number on the productivity gains; the Light Right Consortium came closest when they found that workers are 6% more comfortable when they have individual control over their lighting environment (as cited by Rowbottom, 2009), but this study is limited in scope and application.

Improved safety and security is claimed as a benefit of lighting controls by Lutron Electronics. Lighting controls can be connected to fire alarm and security systems to turn on lights in case of an emergency. Dimmers installed by hallways and stairs can illuminate a path of light, making it easier to navigate from one room to the other during the night (Lutron, 2011a)

In this study, because the quantitative data about improved comfort and safety was not sufficient in the literature, no numeric assumptions were made for these benefits of lighting controls. Such benefits were included in the introduction of surveys in the form of qualitative information.

#### **4.3.5 Discussion on Using Multiple Base Models for Simulating Retrofit Options**

The goal of using multiple base models for simulating the energy retrofit options was to examine the impacts of the inaccuracy of base models on simulation outcomes in order to understand how this approach could improve the final financial outcomes and investment decisions. *The hypothesis here is that considering the inaccuracy of a base model in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. This additional sub-analytic attempts to test this hypothesis towards the*

*broader goal of this research, which is assisting decision-makers to make more informed decisions about investing in green retrofits.*

In order to measure the impacts of simulation with multiple base models on financial outcomes, the low-end and high-end impacts were estimated by comparing the minimum and maximum of each financial outcome to related average value of the best model (BM0). The assumption was that the retrofit options would be modeled using the best model (BM0), if multiple base models would not be used. Table 4-18 shows the impacts, both absolute values and percentages, on different financial indicators:

**Table 4-18: Impacts of simulating by multiple base models on financial outcomes**

<b>Financial Indicator</b>	<b>(Min - BM0)</b>	<b>(Max - BM0)</b>	<b>Low-End Impact</b>	<b>High-End Impact</b>
Total \$ Savings	-\$744	\$3,563	-2%	13%
Simple Paybacks	-1.2	0.2	-12%	2%
Simple ROI	-0.3%	1.3%	-2%	13%
5-Year NPV	-\$3,596	\$16,625	-38%	136%
10-Year NPV	\$0	\$65,771	0%	253%
15-Year NPV	-\$9,181	\$39,206	-334%	2708%
20-Year NPV	-\$11,334	\$46,742	-10%	79%
5-Year IRR	-1%	4%	-17%	74%
10-Year IRR	-1%	2%	-3%	25%
15-Year IRR	-1%	3%	-4%	32%
20-Year IRR	-1%	2%	-2%	20%

Therefore, if the lighting controls option was only modeled using one calibrated base model:

- The total savings could have been underestimated by 13% (\$3,563) or overestimated by 2% (\$744).
- The Simple Payback could have been underestimated by 2% (0.2 year) or overestimated by 12% (1.2 year).
- The 5-year NPV could have been underestimated by 136% (\$16,625) or overestimated by 38% (\$3,596).
- The 5-year IRR could have been underestimated by 74% (4%) or overestimated by 1% (17%).

The results of the analysis show that including inaccuracy of base models could have the potential to impact the financial outcomes and influence the investment decisions. There were a few conditions in the NPV analyses, 10-year and 15-year NPV, where one case has a negative NPV with the best case (BM0) but positive NPVs with other base models. Thus, if an investor bases her/his decision on the result of

modeling with a single base model, she/he would not agree to invest in the lighting controls option. The 4% increase in a 5-year IRR or \$16,625 in a 5-year NPV could alter an investment decision from “no go” to “go”.

The financial outcomes, when health and productivity savings are included, show no or very little impacts for using multiple base models. Because health and productivity savings are very significant when compared to energy savings, changes in energy savings resulting from base models would not play a major role in the total savings.

It should be noted that many factors might play roles in the magnitude of impacts. Factors include level of calibration, type of retrofit options, investors return’ horizons, building characteristics, nature/level of analysis (is it at the planning or investment grade? Is it for an individual property or a portfolio?), etc.

The conclusion of this sub-analytic is that the inaccuracy of base models could potentially impact the investment decisions at the property level, when selecting the retrofit options. It could alter an investment decision from ‘no go’ to ‘go’; however, the result of this single analysis cannot be generalized. Therefore, depending on the level of analysis, modelers are encouraged to consider the inaccuracy of a base model in addition to the uncertainties associated with each retrofit option when making investment recommendations about green retrofits to decision-makers.

#### 4.4 **Summary**

A lighting control systems package is selected as the green retrofit option to be evaluated in the case study to numerically demonstrate the application of the proposed process. This option, lighting control systems, is a combination of four lighting control strategies including daylight harvesting, occupancy sensing, high-end trim, and personal dimming control.

The distributions of energy performance indicators, KWH and KW savings, resulting from lighting controls are estimated through eQuest and a LCSA Excel-based model. The required assumptions for energy modeling and LCCA of lighting controls are initially made based on the literature and researcher’s professional judgment, and then were verified through interviews with experts from the related industries.

When simulating a new retrofit option in an existing building, there are two factors that could influence the distribution/variance of savings associated with the retrofit option: 1) ranges of assumptions for new retrofit options 2) the inaccuracy of base models. The final simulation output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy

of base models, is often ignored. However, the analysis in this chapter shows that considering the inaccuracy of a base model scope in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. It could alter an investment decision from “no go” to “go”.

Seven energy model inputs were selected to be varied over reasonable ranges for creating multiple base models for evaluating the new lighting controls option. These factors were selected, because based on the interview with the property manager and researcher’s professional judgments, they might involve a higher level of uncertainty. Five acceptable base models were used for evaluating the lighting control option and generating the savings distributions.

Five different cases were developed by varying seven factors related to lighting controls performance in order to demonstrate a process of accounting for the potential risk associated with the performance of the lighting retrofit option in the modeling process. All distributions of energy performance indicators, whole building performance, and financial indicators were generated based on the 25 cases/samples (five lighting controls cases by five base models) through the LCSA model.

Sustainability benefits are beyond the energy cost savings. In this case study, the following types of green benefits resulting from employing lighting controls were considered in the assessment of green building performance factors—step 2 of the proposed process:

- A. Energy-Related Factors: factors that have impact on energy savings, including capital costs, operation and maintenance costs, and utility incentives.
- B. Non-Energy Factors: the benefits that are not related to energy savings but could contribute to cost savings, including health and productivity.
- C. Non-Cost Savings Factors: the benefits that may not contribute to energy and cost savings, including improved occupant’s comfort/satisfaction, improved safety and security, and contribution to energy or green certification.

Ranges and distributions were developed for all energy-related and non-energy factors, mentioned above, based on the energy modeling outcomes, literature review, and interviews with experts. However, the quantitative data for benefits such as improved comfort, safety and security were not sufficient in the literature to make numeric assumptions and estimate ranges or distributions for these benefits of lighting controls. Such benefits are included in the form of qualitative information and their financial implications would be captured in the value-based analysis level.

The true financial performance of green retrofit option is beyond energy cost savings. Cost and non-costs benefits should be taken into account in the true financial assessment. Accordingly, in this case study, financial analyses, both simple and lifecycle, were performed in three levels to capture the financial performance of the green retrofit option:

1. Cost-based level-1: only energy related costs savings were considered.
2. Cost-based level-2: the non-energy cost savings, including health and productivity, were considered in addition to the items in level 1.
3. Value-based level: the value implications of the green retrofit option, all of the above benefits, were considered in addition to items in levels 1 and 2. The financial implications of non-cost benefits, which are difficult to include in cost-based analyses, could also be captured at this level.

Two approaches/steps are proposed to include the benefits of health and productivity into the financial analyses: 1) a cost-based approach where the potential cost savings associated with health and productivity are considered, and 2) a value-based approach where the potential impacts of improved health and productivity on property value is considered. The value-related impacts are addressed in Chapter 5, where the DCF inputs are projected. The cost savings related to improved employees' health and productivity is significant. As shown in this chapter, the inclusion of health and productivity savings in the financial analysis, even if it is a cost-based approach, can alter a green investment decision from no investment to a no-brainer investment.

Accordingly, in this chapter, the ranges and distributions of performance indicators and whole building performance factors are created for those benefits where qualitative data was available. Those benefits, for which there was not sufficient quantitative data available, are included in the value-based analysis in the form of qualitative information. This chapter provides the required building performance information for the value-based analysis, as suggested in steps 1 and 2 of the proposed assessment framework. All the lighting controls green impacts, a combination of qualitative and quantitative information, as well as the characteristics and financial information of the selected building are summarized in a survey introduction and reported to the real estate experts to collect their opinions about the value implications—steps 3 and 4 which are presented in Chapter 5.



## **CHAPTER 5 CASE STUDY– MARKET RESEARCH AND VALUE-BASED ANALYSIS**

This chapter describes the second part of the case study which includes steps 3 and 4 of the proposed assessment framework. The focus here is on the value-based financial analysis which considers how the entire building performance, including both quantitative and qualitative information estimated in Chapter 4, could be translated into value variables—DCF inputs—to be included in the assessment process. This chapter also presents the estimated distributions of final financial outcomes including NPVs and IRRs, where the potential incremental revenue resulting from the green retrofit option is included.

### **5.1 Value-Based Financial Analysis**

As mentioned before, the true financial performance of green retrofit options is beyond the energy cost savings. Cost and non-cost saving benefits should be taken into account in the true financial assessment. Accordingly, in this case study, a value-based financial analysis is introduced to capture the potential financial implications of non-cost benefits in the context of value and risk. Such benefits cannot be measured in the cost-based analysis.

As fully discussed in Chapter 2, several case studies and casual-comparable studies suggest that green buildings generally have higher property value when compared to conventional non-green buildings. These studies argue that investing in green attributes/certifications could potentially increase value variables such as rent and occupancy rates. The incremental value is primarily the result of the higher demand from space users, investors, and regulators in the market.

The non-cost saving benefits of green investment, such as improved health and productivity, higher user satisfaction/comfort, contribution to green certification, lower carbon emission, etc., could potentially result in higher demand, and therefore, increase the property revenue and value. Thus, a value-based analysis is necessary to capture the non-cost saving benefits of green investment and include them in the financial assessment.

Without analyzing the value and considering the potential impacts on revenue and risk, financial analysis of green investment is not complete as many benefits are ignored. The market analysis shows that demand for sustainable features and green buildings is increasing, and as a result the value and risk implications of

green investment are becoming more tangible. *Accordingly, as time passes, the value analysis level becomes the more critical part of the financial assessment of green options in real estate investment.*

Regarding the valuation of sustainability in real estate, it should be noted that sustainability factors that might impact demand need to be considered with other non-sustainable factors such as like location, general market supply and demand factors, comparable building attributes, pricing, etc. It is extremely difficult to determine the incremental value associated with sustainability in general and even more difficult to assess the incremental value for a particular sustainable option. Real estate professionals are still not able to accurately determine an incremental value for investment in lobby versus landscaping or design. They rely on their market experience and judgment of what users may require based on qualitative and quantitative analysis. Accordingly, it should be possible to start integrating sustainability as a building component, such as lobby or property landscape, into valuation and the decision-making process without having a specific number for every incremental financial input or specific ROI for every sustainable option investment.

As fully discussed in Chapters 2 and 3, among other property valuation approaches, the Discounted Cash Flow (DCF) approach is well-suited to deal with various factors involved in real estate valuation, and incorporate the potential costs, benefits, and risks associated with green investment in generating revenue. The following sections describe how the distributions of the DCF inputs are determined in this case study based on the building performance distributions generated in steps 1 and 2.

## **5.2 Step 3: Estimation of Distributions of the DCF Inputs**

This step includes simultaneous translation of all collected qualitative and quantitative information concerning the building performance to financial language, which is done by an appraiser, underwriter, or due diligence person (valuer), who selects the final DCF inputs (qualitative filter's judgment). Thus, the process of selecting the DCF inputs is a qualitative process.

Valuers often conduct a detailed market analysis and collect as much information as they can. They then integrate and analyze the data, both qualitative and quantitative, to qualitatively predict the DCF inputs. A thorough market research investigation could be done through 1) a detailed analysis of comparable buildings and market evidence; 2) a detailed analysis of historic market trends and forecasts of demand, rents, occupancy rates, and other key variables; and 3) independent surveys among brokers, tenants, property owners, investors, and other stakeholders in the sub-market.

In this case study, the required information for determining the triangular distribution (best, worst, and, most-likely cases) of the DCF inputs were collected through the following four sources:

1. Surveys/interviews with key real estate market stakeholders including the major tenant/property owner, the property manager of TMC, market researchers, brokers, and appraisers who were familiar with the Rockville market. The information obtained through these experts provided insight into the importance of green benefits to potential tenants and investors as well as current and expected value implications of green buildings/labels in the Rockville market—qualitative information.
2. A sub-market report on Rockville by TRANSWESTERN, which includes many statistics from the CoStar<sup>31</sup> database concerning market demand, tenants, vacancy, absorption, leasing activities, rental rate, and sales. It also includes some forecasts about future market demand, rents, absorption, and vacancy rates—quantitative information.
3. Comparable buildings, three LEED and three non-LEED buildings, which were identified through CoStar and GBIG databases. These comparable buildings provide some insights concerning the average rents and tenant mix in the sub-market—quantitative information.
4. Current causal-comparative studies, which have suggested estimates about the impacts of green attributes/labels on property value, rents, and occupancy rates—quantitative information.

The qualitative and quantitative data from the above sources are integrated and used as a foundation upon which certain assumptions were developed for the triangular distributions of the key DCF inputs—three-point estimates.

It should be noted that the goal here is to demonstrate a market research procedure for selecting the DCF inputs and express the importance of considering the concept of value when evaluating green retrofit options. The goal is not to arrive at the most accurate outcomes but to demonstrate a process. As more market evidence for green buildings becomes available and better tools and processes are developed for

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<sup>31</sup> CoStar is commercial real estate's leading provider of information, analytic and marketing services. Founded in 1987, CoStar conducts expansive, ongoing research to produce and maintain the largest and most comprehensive database of commercial real estate information. Our suite of online services enables clients to analyze, interpret and gain unmatched insight on commercial property values, market conditions and current availabilities ([www.costar.com/about](http://www.costar.com/about)).

utilizing evidence and assessing sustainability in a subject property, the accuracy of the distributions for the DCF inputs will be improved.

## **5.2.1 Market Analysis**

The qualitative and quantitative information collected as part of the market analysis are presented in Sections 5.2.1.1 to 5.2.1.4:

### **5.2.1.1 Interviews with the Key Stakeholders—Qualitative Information**

Phone interviews were conducted with the following real estate stakeholders in the Rockville market:

- President of Davis Construction Company—Primary tenant and the owner of TMC
- Senior Property Manager at Cushman & Wakefield—The property manager of TMC
- Senior Vice President at TRANSWESTERN—Office brokerage in MD
- Senior Appraiser at Cushman & Wakefield
- President of PGH Consulting, LLC—Appraiser in MD
- Director of Research at Cushman & Wakefield
- Senior Director of the Brokerage Group at Cushman & Wakefield
- Senior Managing Director & Principal at Cassidy Turley

The primary aim of these surveys was to gain insight into the market demand and tenants' behavior as they relate to green benefits. For example, how important are green or energy efficiency benefits to the types of tenants expected to be leasing space in Rockville?

#### **5.2.1.1.1 Survey Introduction and Questions**

Respondents were provided with a 3-5 page survey introduction. It includes

1. A summary of case study and survey objectives;
2. Property characteristics such as location, access, age, size, current tenant information;
3. Current financial information such as current rental rates, rental growth, occupancy rates, and lease roll over rates;

4. A summary of green retrofit impacts resulting from employing lighting controls—all building performance information from steps 1 and 2, both quantitative ranges and qualitative. The impacts include:
  - Energy cost savings and financial outcomes—quantitative ranges
  - Health and productivity savings & financial outcomes—quantitative ranges
  - Contribution to the building energy performance rating—quantitative ranges
  - Increased probability of achieving LEED certifications—quantitative ranges
  - Improved occupants' comfort—qualitative information
  - Improved Safety & Security—qualitative information
  - Potential enterprise-level sustainability benefits—qualitative information
5. Information about 6 comparable buildings, three LEED and three non-LEED buildings, in Rockville

Different versions of the survey introduction were developed for different respondents; two of them are included in APPENDIX D. Respondents were asked to review the survey introduction and respond to questions during the interview. They were asked different questions based on their expertise. A list of market questions is presented in APPENDIX E.

#### **5.2.1.1.2 Key Findings of the Surveys**

A complete summary of each interview can be found in APPENDIX F. The key points from the interviews related to the purpose of the market research are presented below:

- Davis Construction is headquartered in TMC and occupied 65% of the building. Sustainability and energy efficiency are important to Davis Construction from a marketing and business advantage standpoint. Davis Construction is building several green buildings for their clients and it is important for them to show their clients that they are responsive to these issues. As a tenant, Davis is willing to pay more for a green space. As the owner, the president of Davis indicated that they are willing to accept higher costs and longer paybacks for green products when it is time for replacement /renovation of old systems.
- The utility costs in TMC are relatively high, because the building is all electric. Perhaps, the most appealing benefits of green retrofits to the current tenants is the potential utility cost decrease. This could play a role in their decisions concerning renewing their leases; otherwise other sustainability benefits are not a concern.

- Variables associated with value are most likely to first affect the tenant retention—renewal probability.
- The mix of potential tenants in this market is primarily government tenants, government contractors, health service offices, FIRE (Finance, Insurance, and real estate) sectors, and typical private sector service companies. There are few large corporate tenants.
- Most typical tenants in the Rockville market are not concerned with being in a green building. When told of the potential benefits of green features the typical tenant appears to be interested but very few seem to really care. They are primarily looking to the best/cheapest deal and may not be willing to pay more for green benefits.
- The main driver for government leases is total cost, but proximity to the Metro is also very important. GSA requires that government tenants must be in buildings with an Energy Star rating of 75 or above and LEED-Silver or higher. Government contractors might also see some benefits for leasing green buildings.
- There is clearly no evidence in the Rockville market that suggests a premium for rental rates, occupancy rates, and cap rates of green buildings when compare to conventional buildings. Green buildings need to be competitive like any other building in the market. Until the value implications manifest themselves in the market, appraisers do not include any incremental value into their valuation calculations.
- The LEED or ENERGY STAR labels do not play a major role in driving the rental rates in the comparable buildings. These labels might be important from a marketing standpoint as having certification may result in a more competitive building with higher absorption rates. These buildings may demand higher rents but it is typically because they are newer or were recently renovated. Green issues/labels are secondary to the general location, quality and amenities for a given building.
- Real Estate Investment Trusts (REITs) are the dominant investors in this sub-market. Sustainability seems to be important for institutional investors, but the more local entrepreneurs are less inclined to invest in it because of the perceived higher cost.
- Investors do not believe that they will get a worthwhile rate of return by investing in LEED certifications; they are just making their building more competitive.
- As time passes and more green buildings become available, the older buildings with less green features will become less competitive. The new buildings will need to have LEED

certification and green standards because it is expected that this is what tenants will be looking for in the near future. There will be a rent premium for certified buildings in this market. It is reasonable to expect that green technologies will eventually increase value.

- In the DC area, there is a \$5 per Sq.Ft. incremental rent and 100 basis points<sup>32</sup> (1%) vacancy difference between existing green/LEED-EB buildings and non-green buildings.
- Current asking rents for a sampling of LEED properties in Rockville range from \$35-\$49 while average class A asking rents in Rockville were \$36.53 in the 3<sup>rd</sup> quarter 2011. LEED is only one of many factors driving the higher asking rents. For instance, 2000 Tower Oaks has relatively high asking rent (\$45-\$49), but it is also a new building (completed in 2008) with high-tech green features and top-of-the-line amenities.
- DCF inputs predictions for the current building in Rockville sub-market:
  - **Rental rate:** lower to mid 30's. The current rent is within a good market range.
  - **Rental growth:** currently 3% is good.
  - **Tenant improvement:** for new lease: \$25 to \$30 \$/Sq.Ft. To renew a lease: \$5 to \$10 \$/Sq.Ft.
  - **Occupancy rate:** 5-6% vacancy rate.
  - **Capitalization rate:** 7%-7.75%
  - **Renewal probability:** 70%

In summary, the mix of major tenants in the submarket (governments, health services, FIRE sectors) along with growing requirements and demands by government tenants, and growing demand by health care industries, suggest that there is a significant potential market and tenant demand for sustainability in the subject building. However, interviews with experts suggest that there is no evidence for a premium for rental rates, occupancy rates, and cap rates of green buildings at this time. This could be a reflection of various factors including lease structure, current market conditions, or tight tenant budgets.

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<sup>32</sup> A basis point is a unit of measure used in finance to describe the percentage change in the value or rate of a financial instrument. One basis point is equivalent to 0.01% (1/100th of a percent) or 0.0001 in decimal form. In most cases, it refers to changes in interest rates and bond yields.

### 5.2.1.2 Rockville Market Statistics

TRANSWESTERN, one of the largest real estate brokerage firms in the US, has developed a sub-market report for Rockville using the statistics offered through the Co-Star database. It also includes forecasts about future demand, rents, absorption, and vacancy rates. Below are key relevant points from this report:

- Rockville is home to the County Courthouse, which generates significant demand in the sub-market. Attorneys account for a large percentage of the tenant base, as well as other firms that conduct business with various county government offices and agencies. A large number of the major tenants identified by Co-star are health service related, including the National Institute of Allergy/Diseases, National Institute on Alcohol Abuse & Alcoholism, and Department of Health & Human Services. There are a few prestigious and top fortune 500 companies among the major tenants including Booz Allen Hamilton and SIAC.
- Office market conditions in Rockville continued to gradually improve during the 3<sup>rd</sup> quarter of 2011, as net absorption was positive and vacancy inched down. YTD net absorption through the 3<sup>rd</sup> quarter of 2011 totaled 112,000 SF, as compared to 103,000 SF during all of 2010.
- The vacancy rate remains elevated and exerted downward pressure on rents during the past nine months. The overall vacancy rate for Class A space declined to 15.5% during the 3<sup>rd</sup> quarter of 2011, from 15.8% at mid-year.
- Rents decreased 1.5% in the last nine months as compared to 8.6% during all of 2010. The average effective rent decreased to \$22.95/SF (full service) during the 3<sup>rd</sup> quarter of 2011, from \$23.30/SF at year-end 2010. The top asking rent in this sub-market is \$47.00/SF (full service) at 2000 Tower Oaks Boulevard.
- Leasing activity was steady in Rockville as tenants leased approximately 960,000 SF during the first three quarters of 2011.
- There have been no new office deliveries in the Rockville sub-market since 2009. Buildings that have been delivered since the start of 2005 in Rockville continue to lease moderately well, at 75% occupied.
- Office market conditions in Rockville are expected to continue to gradually improve during the 3<sup>rd</sup> quarter of 2011, as net absorption was positive and vacancy inched down. However, the vacancy rate remains elevated and exerted downward pressure on rents during the past nine months. Demand is also expected to gradually increase during the remainder of the year



and into 2012, as the metro area experiences a steady recovery. Rents should begin to edge up in the near-term, as demand strengthens and tenants compete for the limited number of large blocks of available space. The growth of the medical research and biotech industries should help sustain the recovery in this sub-market in the long-run.

### **5.2.1.3 Current Evidence on Impact of Green on Property Value:**

Three recent studies, which compared the rents and value of a series of green buildings with similar non-green buildings, show that a group of LEED and ENERGY STAR buildings have higher rents and value.

- Eichholtz, Kok, and Quigley (2009) have found that rents/sq. ft. and sales prices were roughly 3% and 16% respectively higher for their green group. They also believe that the lower energy consumption could play a role in driving the rental rate and property value. A 10 percent decrease in energy consumption leads to an increase in effective rent of about 20 basis points and an increase in value of about two percent, over and above the rent and value premium for a labeled building.
- Miller, Jay, and Florance (2008) have estimated that the LEED group of buildings has about 50% higher rents and 10% higher property value and the ENERGY STAR group has 9% higher rent and 5% higher property value when compared to the non-green group.
- Fuerst and McAllister (2008) have found 10% and 19% higher average rent for LEED and ENERGY STAR groups respectively. In their 2009 study, they found a rental premium of approximately 6% for LEED certification and 5% for Energy Star. For sales prices, they have estimated price premiums of 31% for Energy Star and 35% for LEED certified buildings. Fuerst and McAllister (2009) have also found 8% and 5% higher occupancy rates for LEED and ENERGY STAR buildings, respectively.

Relative to types of tenants of current green spaces in the US, Eichholtz, P., Kok, N., & Quigley, J. (2009b) have found that by far the largest occupier of green space, both in total and as a proportion of the total space use is legal services (p. 23) and the Department of Health and Human Science is ranked 8<sup>th</sup> among the major tenants occupying green spaces (p. 21) A CoStar study also has ranked legal firms, insurance, financial institution, real estate and medical offices 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 5<sup>th</sup>, and 9<sup>th</sup> respectively in signing green leases between 2006-2008 (cited by Muldavin, 2010, p. 91). Thus, legal service firms, health and human services, insurance, financial, real estate, and medical offices could be among the most likely tenants for green buildings.

#### **5.2.1.4 Comparable buildings in Rockville, MD**

Six buildings, three LEED and three non-LEED, in Rockville, MD are identified through GBIG and COSTAR databases and their key characteristics are presented in this section. Some of these buildings are close to TMC; some of them are just a few blocks away. These buildings are not meant to be the best comparable buildings, but they can provide some insights about the average rents and tenant mix in the sub-market.

It should be noted that the experts did not believe that the LEED and ENERGY STAR labels or green attributes would play a major role in driving the rental rate or occupancy for these comparable buildings in the Rockville market.

#### **LEED buildings from GBIG**

1. Twinbrook Place: 7-story Class A office property within 0.3 miles from TMC, 140,000 sqft, LEED Gold in 2010, built in 2009, rent: \$37.5/sqft for 20000 sqft, and 120 months lease
2. Element: 4-story Class A office building in the same parkway within 0.2 mile from TMC, 90,000 sqft, LEED Gold, built in 1960s and renewed in 2009, LEED Gold in 2010, fully leased by the GSA for the FDA
3. 801 Anderson Ave: 3-story office building within 0.5 mile from TMC, built in 1963 renovated in 1999, LEED Gold EBOM in 2009, Mix of tenants: government, acquisition date: December 2007

#### **Non-LEED buildings from COSTAR**

4. Washington Science Center: 4-story office building within 1.4 miles from TMC, 110,000 sqft, built in 1974 and renovated in 2006, within walking distance of a Metro station, energy efficiency rating of 75, parking ratio of 3.2/1000 sqft, renovation includes new exterior skins, core elements, energy efficient systems, etc., rent \$32.5/sqft for 10 years lease
5. 6000 Executive Blvd.: 6-story office building within 1.7 miles from TMC, 125,000 sqft, built in 1972 and renovated in 2007, within walking distance of a Metro station, parking ratio of 3.1/1000 sqft, rent \$30/sqft for 5-10 years lease
6. Blackwell One: 5-story office building within 6 miles from TMC, 120,000 sqft, built in 2000, Energy Star labeled in 2009, parking ratio of 3.8/1000 sqft, rent \$32.5/sqft for 3-10 years lease

**Highlights:**

- A LEED building built in 2009 close to TMC (0.3 miles) is asking for 23% higher rent than TMC.
- A LEED building built in the 1960s and renovated in 2009 a few blocks from TMC (0.2 miles) is fully leased by Government tenants—high demand by government tenants
- Government tenants occupy a LEED building within walking distance of TMC (0.5 miles)—potential government tenants.
- A building built in 1974 & renovated in 2006, but with some energy efficient systems, is asking for about 6% higher rent than TMC.
- A building built in 1972 & renovated in 2007 is asking for about 2% lower rent than TMC.
- A building built in 2000, the same year as TMC, but with an Energy Star label, is asking for about 6% higher rent than TMC.

**5.2.2 Determining the Triangular Distributions of the Key DCF Inputs**

The DCF inputs that are likely to be impacted by green investment include rental rate, rental growth, occupancy rate, renewal probability, capitalization and discount rate, down time between tenants, utility expense, leasing expense, and tenant improvement. The incremental impacts of these variables depend on many factors including the unique characteristics of a property, market conditions, type of tenants, and the nature of green improvement/investment.

If there is a clear indication for higher demand by investors and tenants for green buildings or attributes when compared to conventional buildings, there might be premiums for some of the key value variables, if not for all of them. For example, the rental rates or rental growth rates might not change significantly after a green retrofit, but the renewal probability, absorption rate, and occupancy rate may increase and result in increased value. The reduced future market risk of green buildings could also be expressed in the lower capitalization rate in the DCF analysis, which results in higher value. In Chapter 5, additional sensitivity analysis is performed to test the impacts of integrating revenue in financial analysis when the rental rate and growth do not change after green investment.

For demonstrating the value-based financial analysis in this case study, six key variables were selected and certain assumptions were made for their triangular distributions—three-point estimates—based on all of the information presented in the previous sections: interview with experts, market statistics, current literature, and comparable buildings in Rockville. The six most significant variables include rental rate, annual rental growth, occupancy rate, renewal probability, capitalization rate, and utility expenses.

The generated triangular distribution of each DCF input demonstrates the uncertainty associated with achieving the predicted input. As fully discussed in Section 2.3.4.1, triangular distribution is accepted by valuation experts such as French (2007) as a simple, understandable and appropriate approach to express the valuation uncertainty in a uniform and useful manner.

When selecting DCF inputs, the assumption is that all non-sustainable factors such as market condition influencing the financial performance do not change after retrofit and changes in DCF inputs and financial outcomes are solely due to the green retrofits. This allows focusing on the green impacts when selecting the DCF inputs rather than the simultaneous consideration of all related sustainable and non-sustainable factors and information.

The utility expenses in this case study were calculated based on the energy savings estimates from Chapter 4. Three-point estimates, worst case, most likely case, and best case, were assumed for the rest of the variables. The assumption for the worst cases is that the green retrofits will not influence the value variables as suggested by some of the experts. Therefore, the current financial data for TMC were considered for the worst cases, which are the base cases in the value-based analysis. These three-point estimates will be included as inputs to the financial model in LCSA to estimate the final financial performance indicators.

### **5.2.2.1 Data Analysis**

The demand for green does not currently seem to be high in the Rockville market, which could be due to many factors such as lease structures and market condition. However, there is the potential for strong demand in the near future, in part because the potential tenants in this sub-market (government, legal, insurance, financial, real estate, health and human science sectors) are the most likely occupiers of green space, based on interviews, Rockville sub-market report, and the CoStar statistics presented in section 3.

The current utility expenses of the building are much higher than average since the building is all electric. According to the property manager, for current tenants, utility cost reduction is the most important benefit of green improvements that might impact their decisions about staying in the building. On the other hand, a study by Eichholtz, Kok, and Quigley (2009) has shown that a 10 percent decrease in energy consumption leads to an increase in effective rent of about 20 basis points and an increase in value of about two percent, over and above the rent and value premium for a labeled building. The lighting controls option used in this research is estimated to reduce the utility cost by 14% on average in TMC and might result in a higher rental rate and renewal probability.

Current asking rents for a sampling of LEED properties in Rockville are in the range of \$35-\$49 while average class A asking rents were \$36.53 in the 3<sup>rd</sup> quarter of 2011. The lighting controls option could potentially increase the probability of achieving LEED certification by 50% for certified, 40% silver, 33.5% gold, and 25.5% platinum on average.

Assumptions for three-point estimates of selected DCF inputs are presented below and summarize in Table 1:

**Rental rate:** given the \$32.46 average rents of TMC, it is reasonable to assume that the rent will increase to \$34 and \$37 for most likely and best cases respectively.

**Annual rental growth:** Although rental rate is suggested as one of the factors that could be affected by green investment, there is little evidence supporting this impact. The 3% growth rate considered in current budgeting sounds very reasonable for this sub-market. Thus, the rental rate is assumed to remain the same, 3%, for the most likely case and to be 4% for the best case.

**Occupancy rate:** the current occupancy rate of TMC is 96.6%, which is a relatively high occupancy rate considering the 15% vacancy rate in the 3<sup>rd</sup> quarter of 2011 for the entire Rockville sub-market. There is only one vacant unit in the first floor of TMC. Thus, the occupancy rate of 100% is assumed for both most likely and best cases.

**Renewal probability:** As indicated by most of the experts, the renewal probability might be affected most by green investment. The average renewal probability in the sub-market is 70%. Thus, 80% and 90% rates are assumed for the most likely and best cases respectively.

**Capitalization rate:** A range of 7% to 7.75% is suggested by one of the experts. Thus, 7.75%, 7.5%, and 7% rates are assumed for the base case, most likely case, and worst case respectively.

**Table 5-1: DCF Assumptions**

<b>DCF Assumptions</b>	<b>Base Case</b>	<b>Most-Likely Case</b>	<b>Best Case</b>
<b>Rental Rate</b>	\$32.46	\$34	\$37
<b>Annual Rental Growth</b>	3%	3%	4%
<b>Occupancy Rate</b>	96.6%	100%	100%
<b>Renewal Probability</b>	70%	80%	90%
<b>Capitalization Rate</b>	7.75%	7.5%	7%

### 5.3 **Step 4: Estimation of Distributions for the Financial Indicators**

The LCCA models, which were developed previously in the LCSA for cost-based analysis, were expanded to include the DCF assumptions for value-based financial analyses. The three-point estimates for DCF inputs including rental rate, annual rental growth, occupancy rate, and renewal probability were used to project the future revenue stream. The new value-based model in this case study expanded LCCA model by integrating a DCF methodology to include the impacts of green investment on property revenue. The development of this model is a first step toward turning the traditional LCCA to a more robust tool for sustainable option investment decision-making.

Incremental revenue was estimated for most-likely and best cases. The base case represents the current financial performance of the building, and therefore, the incremental revenue is zero. Given the goal of the case study and limited data for a reliable property valuation, the property value was not calculated as part of the financial analysis, and therefore, the assumptions for the capitalization rate were not included in the model.

It should be noted that a complete value-based analysis includes consideration of both revenue and cash flow/investment risk. In fact, cash flow risk could play a major role in financial performance of sustainable options in real estate investment as risk reduction is one of most important benefits of sustainability in real estate investment. Real estate people tend to mitigate risk and uncertainty as much as they can through various mechanisms such as insurance, surety, contracts, better planning, integrated design, or commissioning. The market perception of unmitigated risk and uncertainty is reflected in the discount rate and cap rate. A full DCF analysis is typically conducted over a 10 years life cycle. The 11<sup>th</sup> year NOI is capitalized using the cap rate to estimate the property sale price and the net sale/residual value is estimated by deducting various costs such as cost of debt from the property sale price. The net sale along with the NOIs for the 10 years are discounted to estimate the present value using the discount rate. The discount rate indicates the level of compensation/return investors is willing to receive to make the investment, given the investment risk. The discount rate is the main variable for incorporating risk into the DCF analysis; the cap rate only accounts for the risks associated with residual value.

However, the value-based financial analysis in this case study is conducted over a 20-year life cycle to be consistent and comparable with the cost-based analyses in Chapter 4 and primarily focuses on including revenue into cash flow stream. It does not estimate any residual property value, nor includes the cap rate in the analysis. Thus, risk would not be fully addressed in the value-based model in this case study. Similar to the cost-based analysis, the discount rate in a range of 7%-9% was used for estimating the financial indicators. The risk-related benefits of green investment in real estate could be captured in a

more complete property valuation analysis—DCF modeling with residual value analysis—which is not the main purpose of this case study.

The financial outcomes including NPVs and IRRs were estimated for three cases, base case, most-likely case, and best case, for the periods of 5, 10, 15, and 20 years. These new financial outcomes include the potential incremental revenue resulting from the green retrofit option—lighting controls. The distribution for each financial outcome was generated from the 75 estimates, three DCF cases from the 25 lighting controls savings cases.

The financial outcomes were estimated for two scenarios: 1) TMC is an owner-occupied building and Davis Construction is the owner-occupant who has occupied 2/3 of the building 2) TMC is an owner-investor type building and Davis Construction is the major tenant but not the owner of building. Each scenario requires a different approach in the financial analysis due to the change in investor type.

Based on distributions calculated in Chapter 4, investment in the lighting controls package requires an initial capital investment in the range of \$278,605 - \$280,460 and will result in an annual energy savings of \$26,975 - \$49,829 (211.56 - 353.13 MWh savings and 666.24 - 3,141.05 KW savings). Therefore, with the capital investment of \$278,605 - \$280,460, the financial outcomes distributions, presented in Sections 5.3.1 and 5.3.2, could be achieved.

### **5.3.1 Financial Outcomes Distributions—TMC is an Owner-Occupied Building**

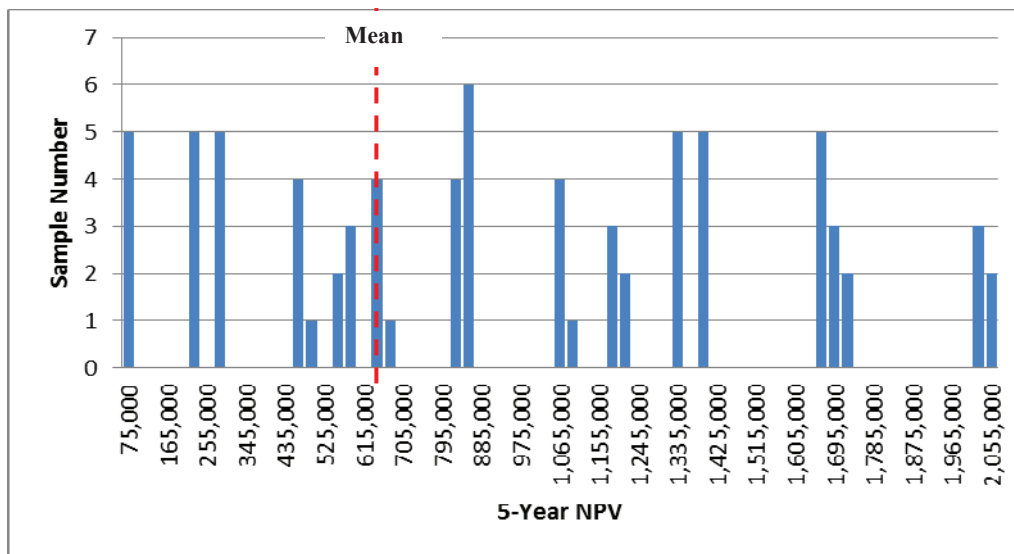
As mentioned previously, Davis Construction is the owner-occupant of TMC and occupies 2/3 of the building. The other 1/3 is rented by private companies. Information about current tenants is presented in the survey introduction in APPENDIX C APPENDIX D. Thus, through retrofit, Davis Construction Company will reap the benefits of health and productivity savings as well as 1/3 of increased revenue.

Accordingly, in this scenario, only 1/3 of increased revenue is included in the financial analysis. As mentioned previously, only employees of Davis Construction were considered in estimation of health and productivity savings. Table 5-2 summarizes ranges and averages of final NPVs and IRRs:

**Table 5-2: Summary of Financial Outcomes Ranges and Averages- the Owner-Occupied Scenario**

Metric	Minimum	Maximum	Average	Standard Deviation
<b>5-Year NPV</b>	\$11,477	\$2,037,498	\$939,961	\$580,776
<b>10-Year NPV</b>	\$326,571	\$4,606,455	\$2,254,461	\$1,197,522
<b>15-Year NPV</b>	\$439,944	\$6,782,365	\$3,203,637	\$1,746,352
<b>20-Year NPV</b>	\$587,383	\$8,817,314	\$4,133,661	\$2,283,435
<b>5-Year IRR</b>	11%	273%	133%	72%
<b>10-Year IRR</b>	32%	275%	140%	67%
<b>15-Year IRR</b>	34%	275%	140%	67%
<b>20-Year IRR</b>	34%	275%	141%	67%

Figure 5-1 to Figure 5-6 show distributions of NPVs and IRRs:



**Figure 5-1: The Distribution of 5-Year NPV- the Owner-Occupied Scenario**



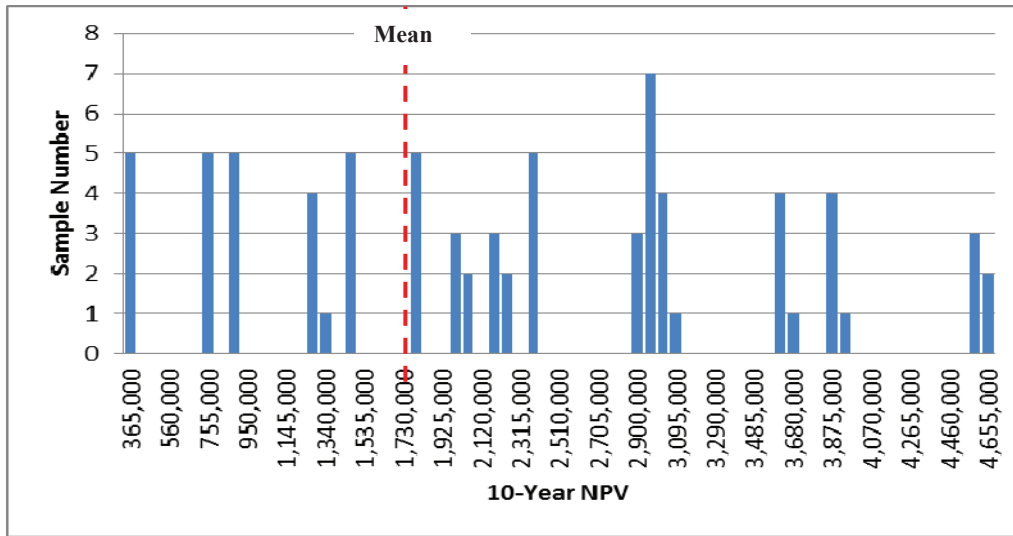


Figure 5-2: The Distribution of 10-Year NPV- the Owner-Occupied Scenario

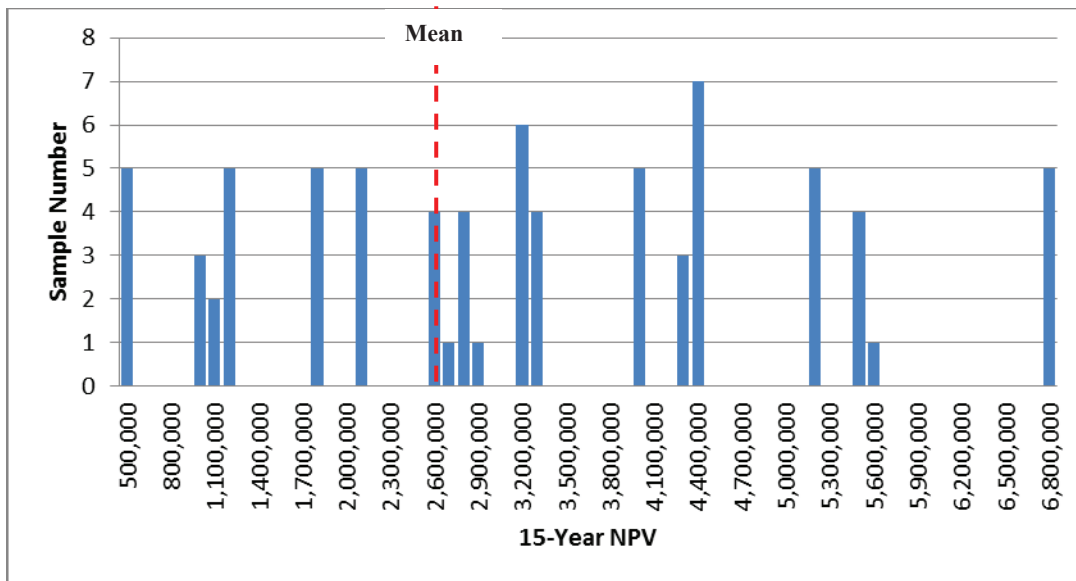


Figure 5-3: The Distribution of 15-Year NPV- the Owner-Occupied Scenario

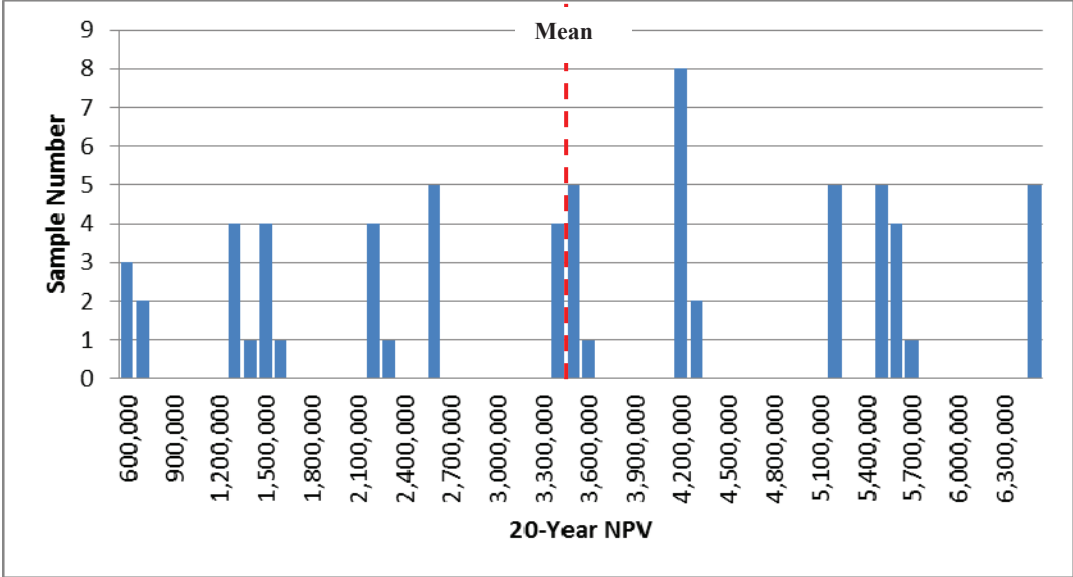


Figure 5-4: The Distribution of 20-Year NPV- the Owner-Occupied Scenario

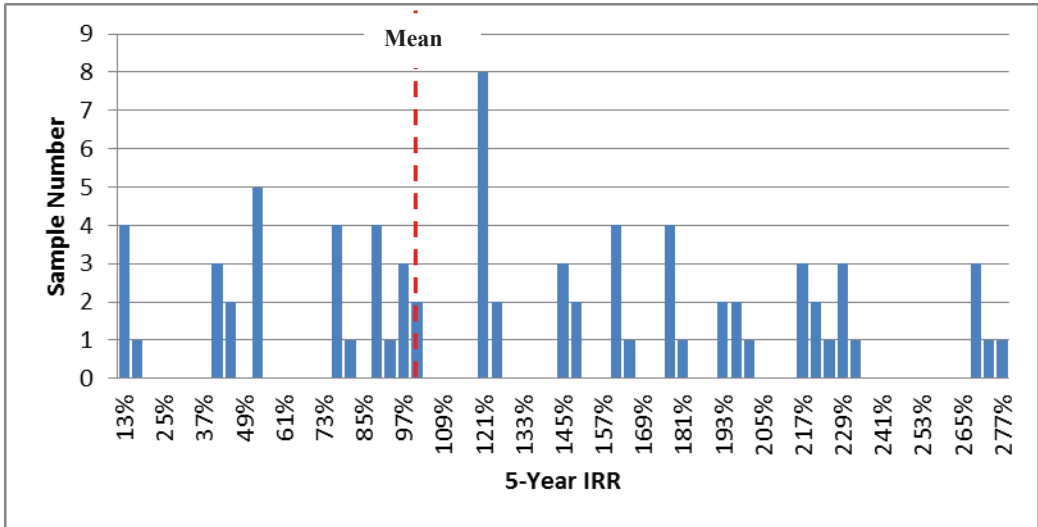


Figure 5-5: The Distribution of 5-Year IRR- the Owner-Occupied Scenario

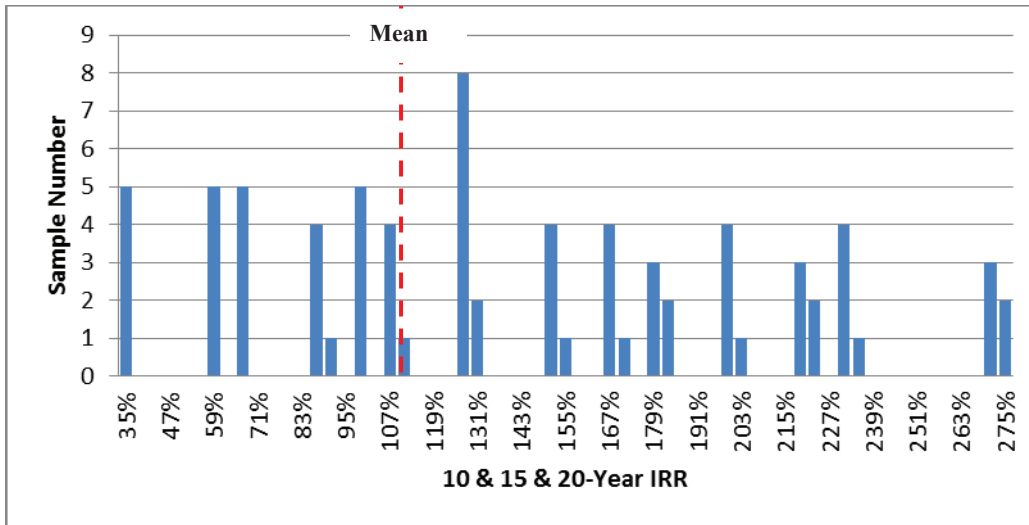


Figure 5-6: The Distribution of 10 & 15 & 20-Year IRR- the Owner-Occupied Scenario

### 5.3.1.1 Impact of the Value-Based Analysis Approach on Financial Outcomes

An average for each financial outcome is estimated for each case separately and the impacts of including revenue in the financial analysis are then calculated by comparing the financial outcomes of most-likely and best cases with the outcomes of the base case. The financial outcomes averages and impacts are presented in Table 5-3:

Table 5-3: Impacts of Value on Financial Outcomes Average– the Owner-Occupied Scenario

Metric	Base Case	Most-Likely Case	Best Case	% Increase in Most-Likely Case	% Increase in Best Case
5-Year NPV Average	\$645,177	\$900,060	\$1,274,647	40%	98%
10-Year NPV Average	\$1,573,418	\$2,123,322	\$3,066,642	35%	95%
15-Year NPV Average	\$2,200,478	\$2,949,425	\$4,461,010	34%	103%
20-Year NPV Average	\$2,803,076	\$3,741,509	\$5,856,399	33%	109%
5-Year IRR Average	96%	130%	172%	35%	80%
10-Year IRR Average	107%	137%	177%	28%	66%
15-Year IRR Average	107%	137%	177%	28%	66%
20-Year IRR Average	107%	137%	177%	28%	66%

Figure 5-7 and Figure 5-8 graphically show how a value-base financial analysis, including revenue in financial analysis, will impact the final financial outcomes.

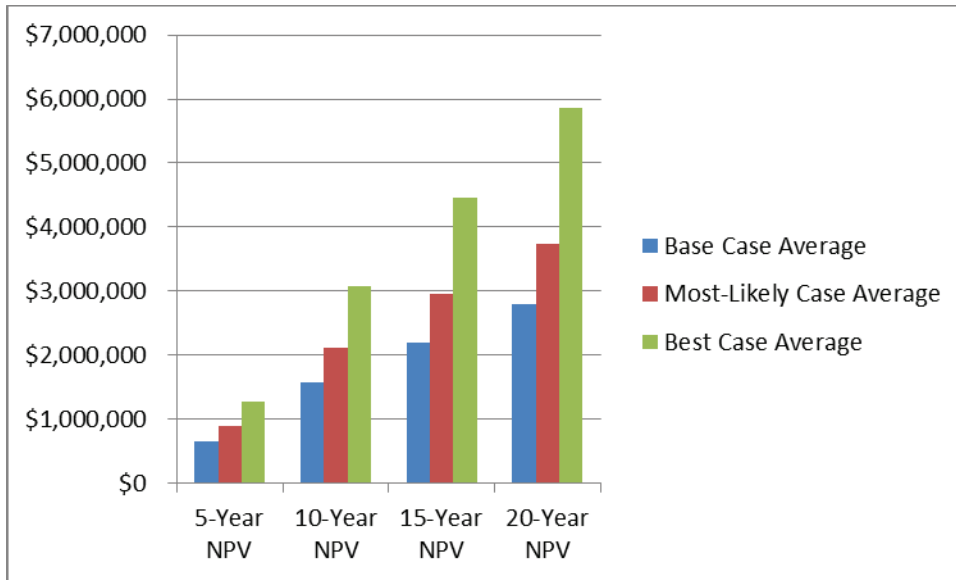


Figure 5-7: Impacts of Revenue on Final NPVs - the Owner-Occupied Scenario

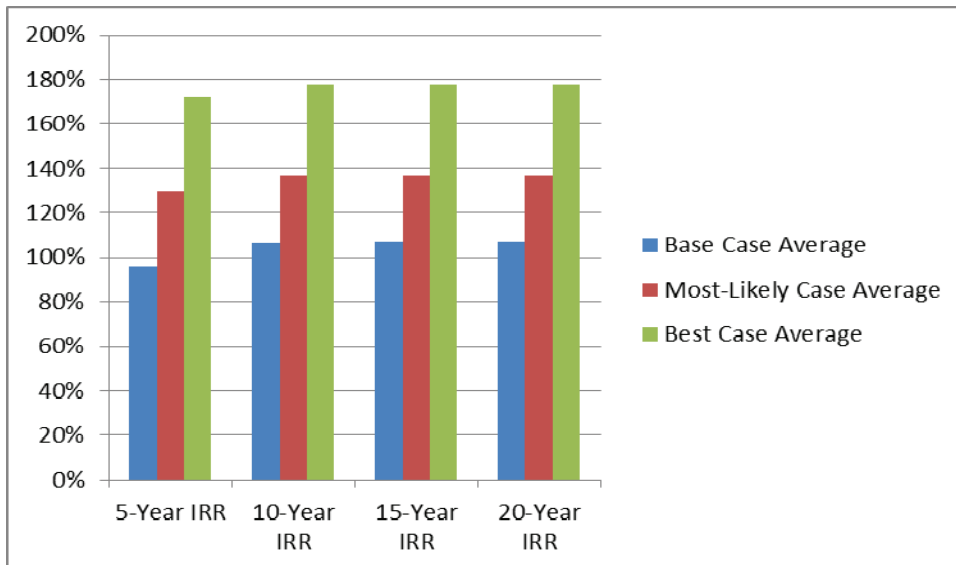


Figure 5-8: Impacts of Revenue on Final IRRs - the Owner-Occupied Scenario

### 5.3.2 Financial Outcomes Distributions—TMC is an Owner-Investor Building

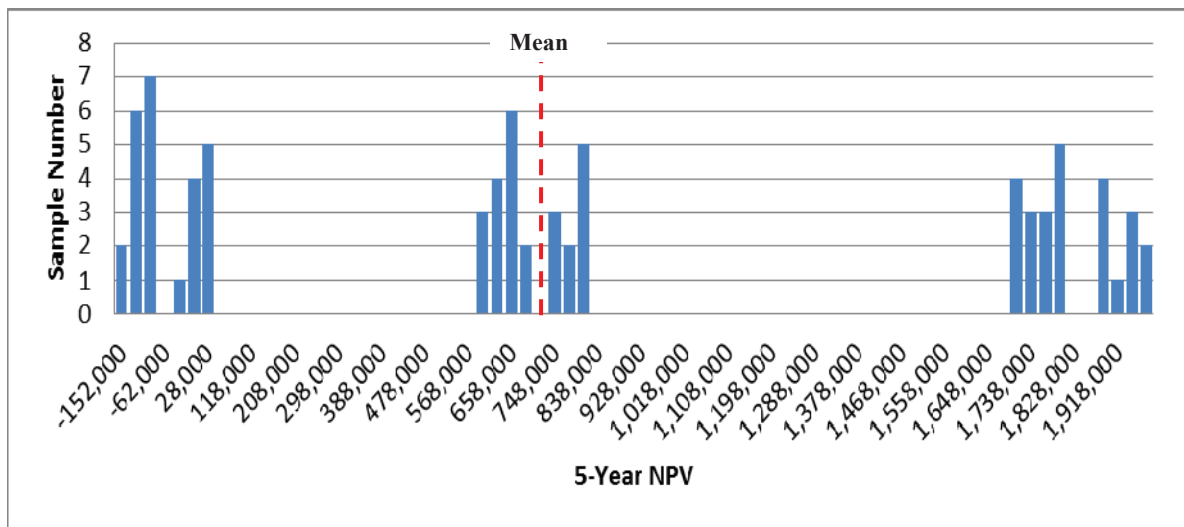
In this scenario, the assumption was made that TMC is an owner-investor building and Davis Construction is a typical tenant who occupies 2/3 of the building. Thus, the owner-landlord will reap

the full potential incremental revenue resulting from green retrofits. Health and productivity savings are not included as those benefits are primarily pertaining to occupants (employers) of a green space, or more importantly, may already be monetized in rent, occupancy, etc. Table 5-4 summarizes ranges and averages of final NPVs and IRRs, where the entire potential incremental revenue is included in the most-likely and best cases:

**Table 5-4: Summary of Financial Outcomes Ranges and Averages- the Owner-Investor Scenario**

Metric	Minimum	Maximum	Average	Standard Deviation
<b>5-Year NPV</b>	(\$152,667)	\$1,954,922	\$805,804	\$784,556
<b>10-Year NPV</b>	(\$28,430)	\$4,922,096	\$2,145,309	\$1,870,871
<b>15-Year NPV</b>	(\$3,390)	\$7,649,988	\$3,159,718	\$2,852,618
<b>20-Year NPV</b>	\$53,661	\$10,505,816	\$4,241,011	\$3,883,914
<b>5-Year IRR</b>	-23%	253%	108%	97%
<b>10-Year IRR</b>	9%	255%	120%	88%
<b>15-Year IRR</b>	9%	255%	120%	88%
<b>20-Year IRR</b>	12%	255%	121%	87%

Figure 5-9 to Figure 5-14 show distributions of NPVs and IRRs, which were generated based on the 75 estimates for the financial outcomes:



**Figure 5-9: The Distribution of 5-Year NPV- the Owner-Investor Scenario**

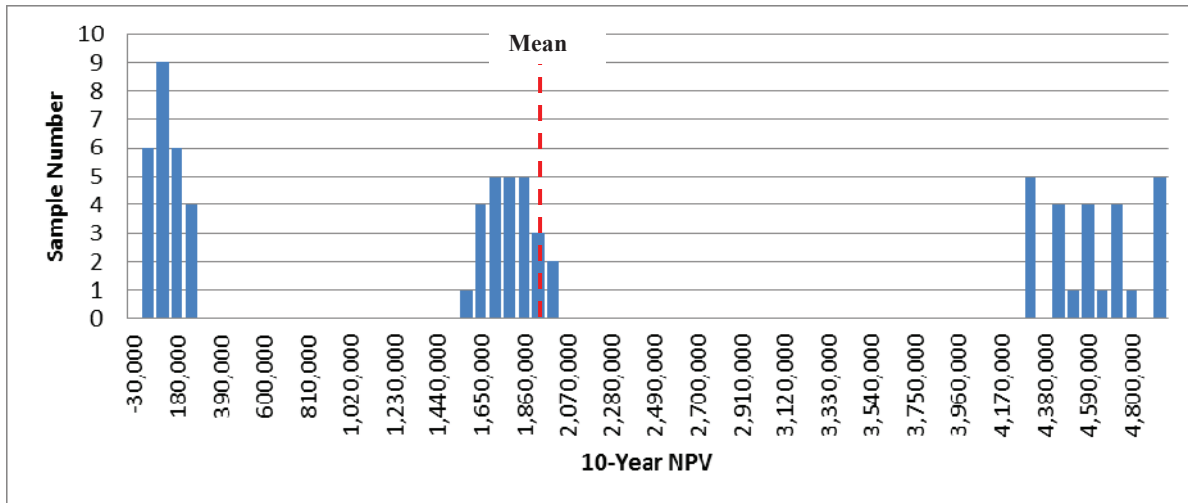


Figure 5-10: The Distribution of 10-Year NPV- the Owner-Investor Scenario

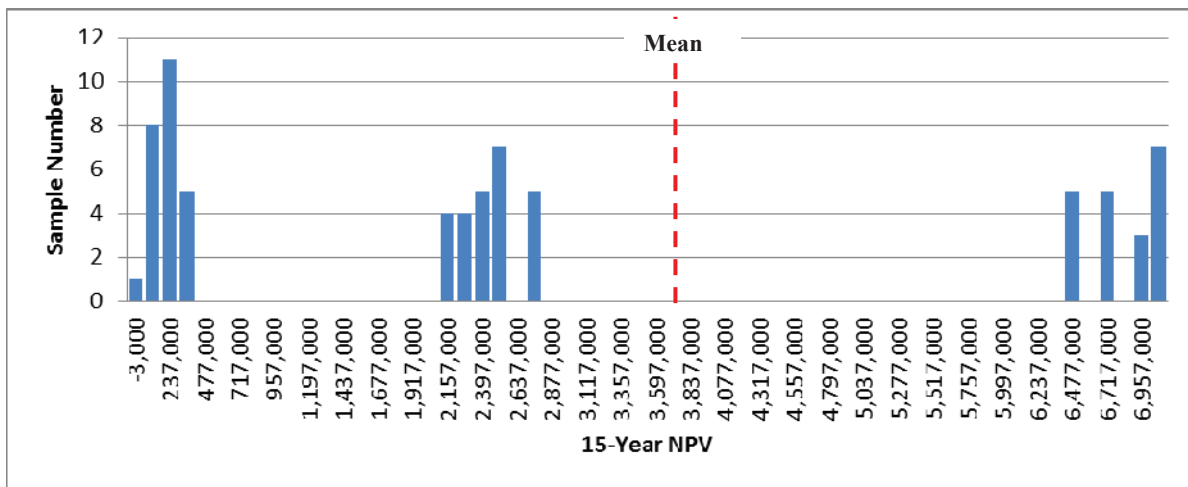


Figure 5-11: The Distribution of 15-Year NPV- the Owner-Investor Scenario

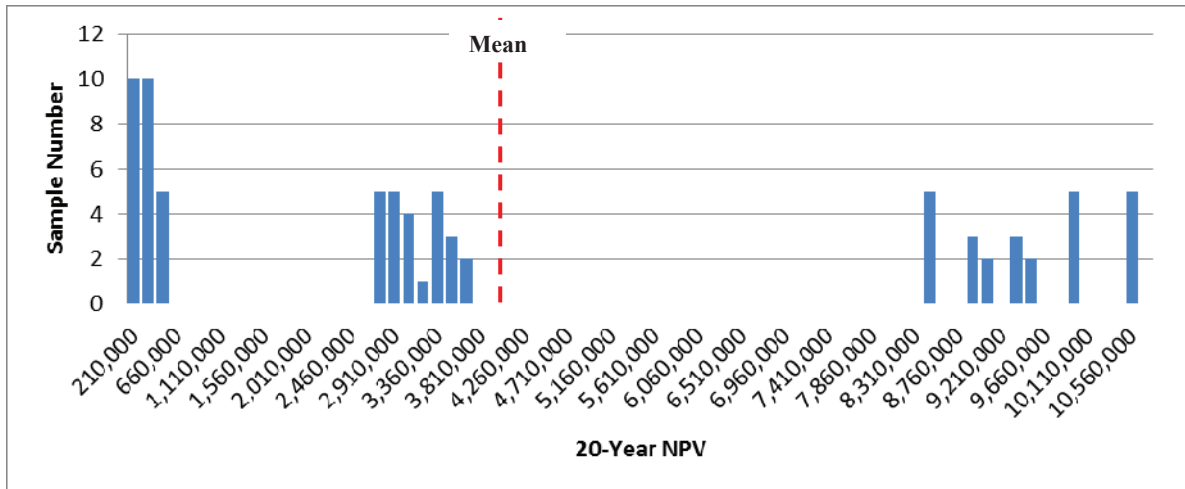


Figure 5-12: The Distribution of 20-Year NPV- the Owner-Investor Scenario

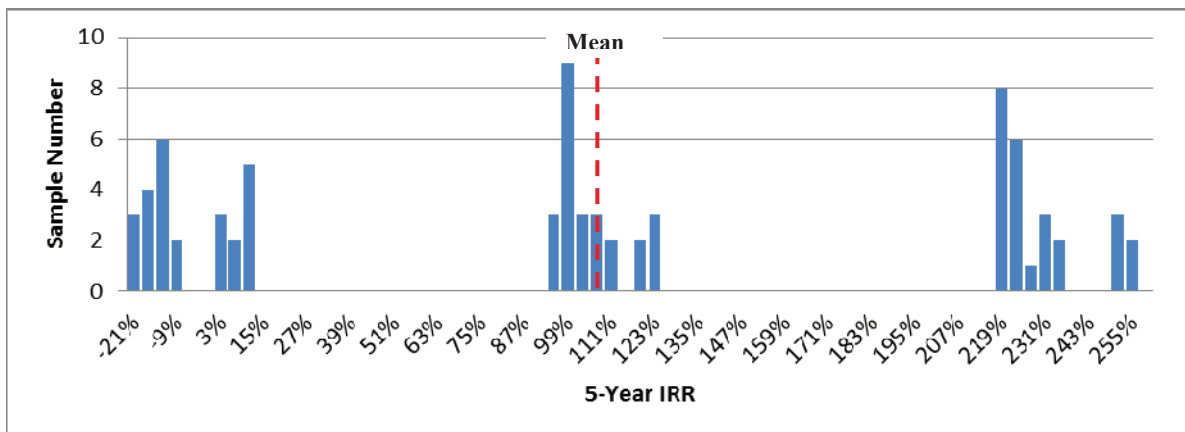
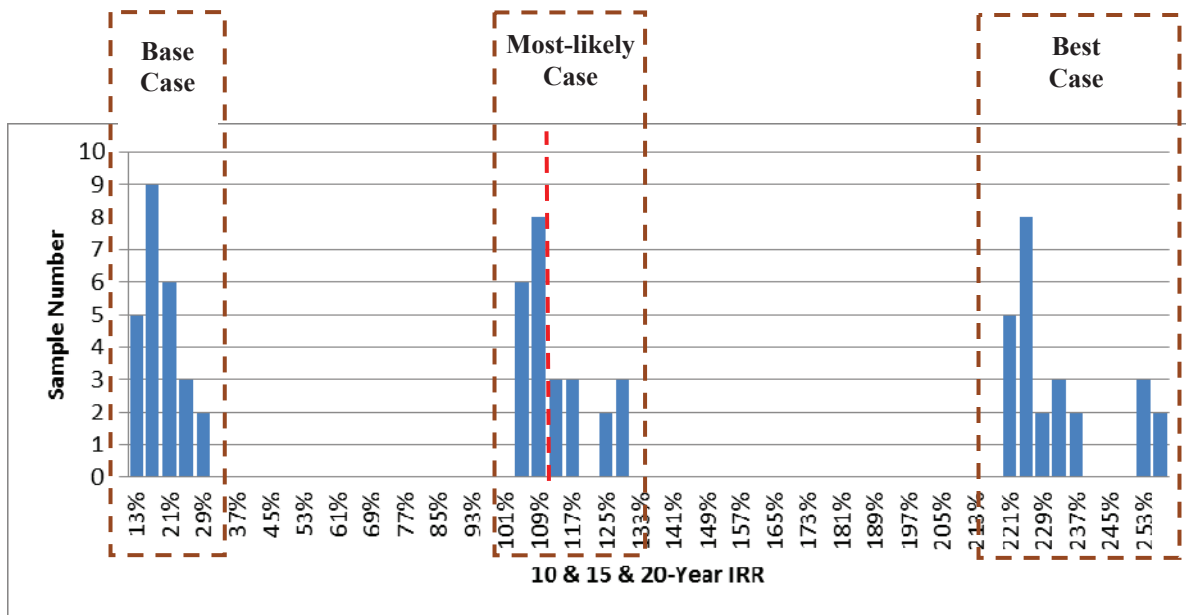


Figure 5-13: The Distribution of 5-Year IRR- the Owner-Investor Scenario



**Figure 5-14: The Distribution of 10 & 15 & 20-Year IRR- the Owner-Investor Scenario**

The significance of revenue impacts on financial outcomes can be seen in the form of distributions in Figure 5-9 to Figure 5-14 . As highlighted in Figure 5-14, values are grouped by base case, most-likely case, and best case. As mentioned previously, these distributions are generated from the 75 financial outcomes estimates, three revenue cases by 25 lighting controls savings estimates. The impact of including incremental revenue in the most-likely and best cases is so significant that it creates three distinctive parts in the distributions. From left to right, the three parts represent the distributions of base case, most-likely case, and best case for each financial outcome, respectively.

Additional distributions for average NPVs were generated using the Monte Carlo simulation technique through @Risk software. A triangle distribution was selected for each DCF inputs as stated in Table 5-1 and the model was run 50000 times to create a continuous distribution for each average NPV. Figure 5-15 to Figure 5-18 show the distributions and summary of statistics for 5-year to 20-year average NPV.

The statistics (min, max, mean, and standard deviation) presented in Table 5-4 are more accurate when compared to those estimated through the Monte Carlo simulations. The accuracy of distribution and statistics in Monte Carlo Simulation greatly depends on the number of iterations in the simulation. The larger number of iterations would result in the more accurate distribution and statistics. The purpose of these additional simulations was just to show how the distributions appear graphically when a larger number of outcomes was estimated and included in the distributions.



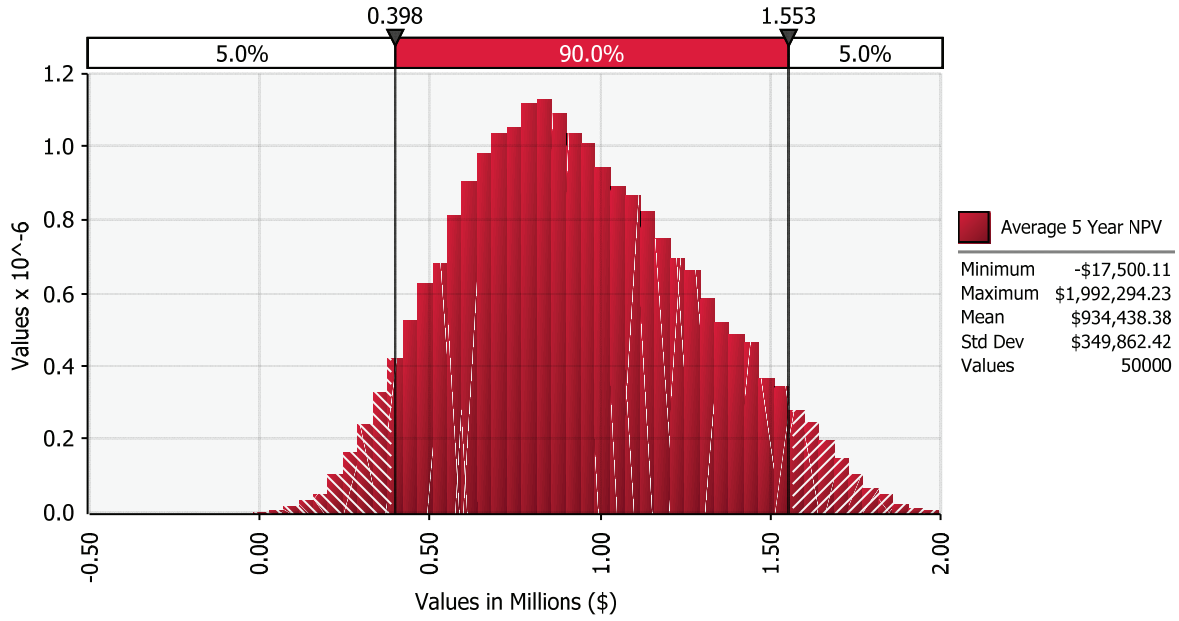


Figure 5-15: The Distribution of Average 5-Year NPV- the Owner-Investor Scenario

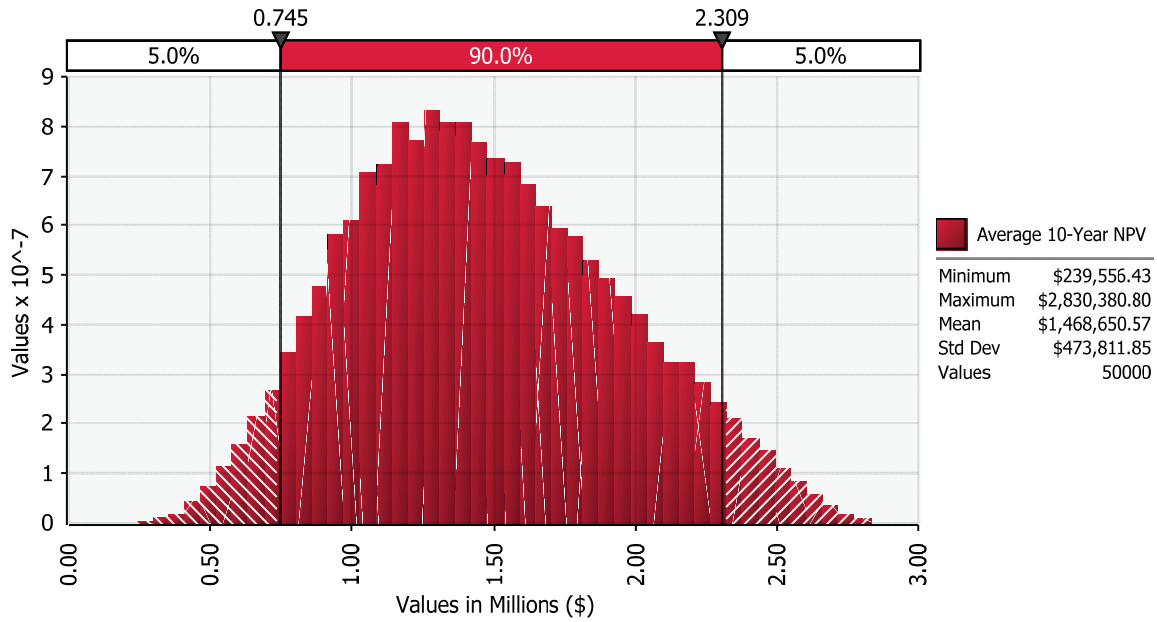


Figure 5-16: The Distribution of Average 10-Year NPV- the Owner-Investor Scenario

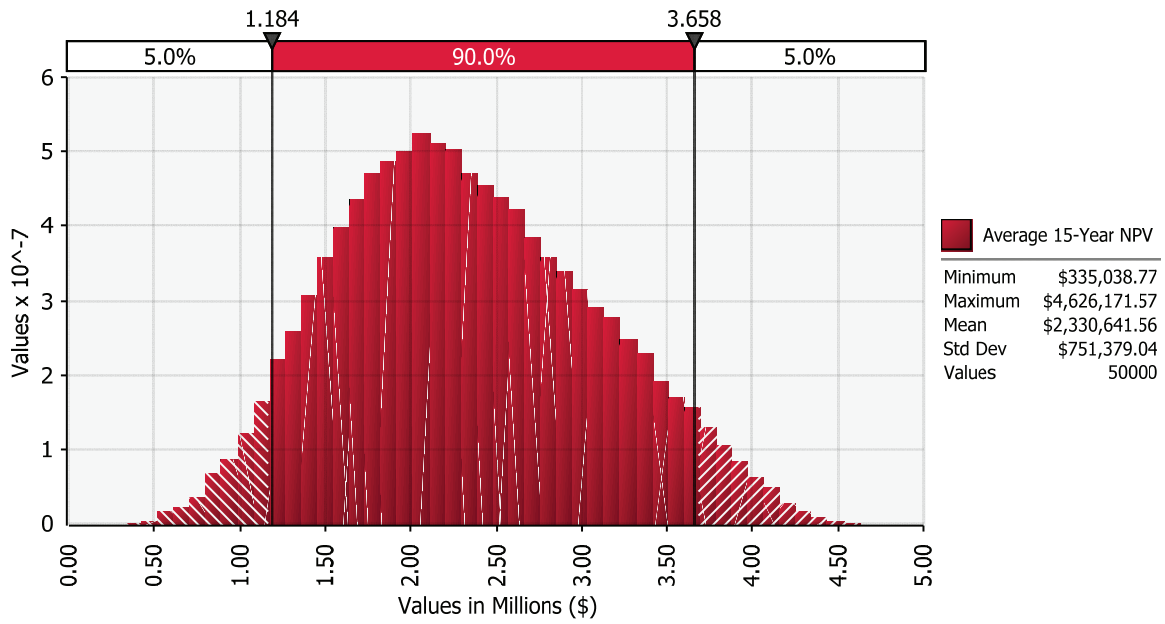


Figure 5-17: The Distribution of Average 15-Year NPV- the Owner-Investor Scenario

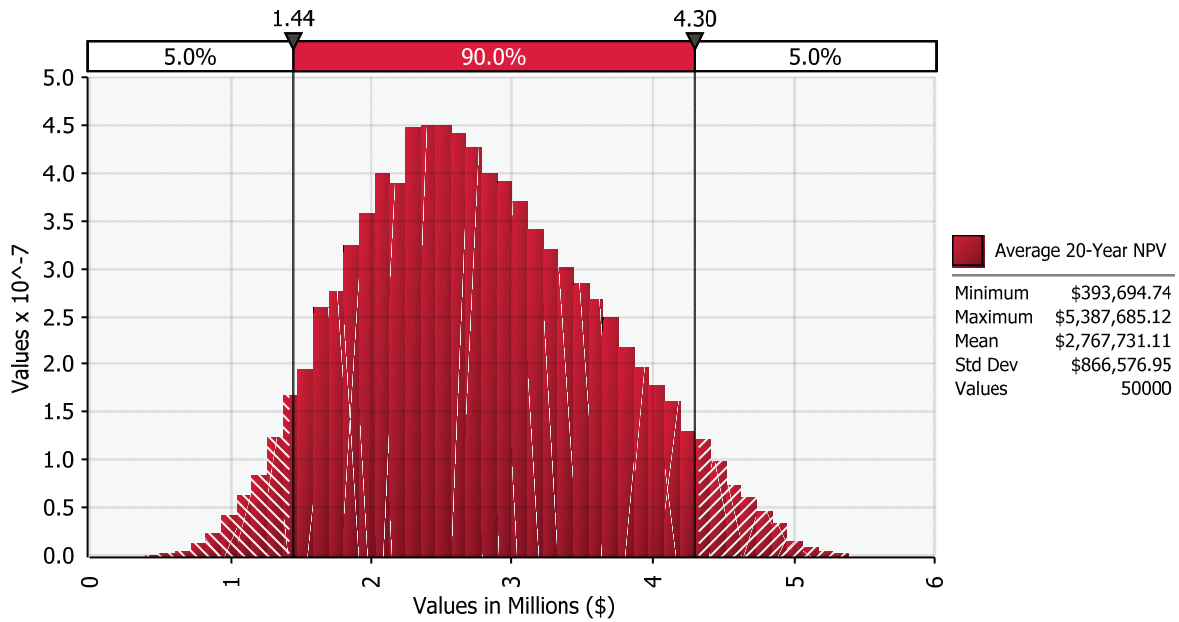


Figure 5-18: The Distribution of Average 20-Year NPV- the Owner-Investor Scenario

### 5.3.2.1 Interpretation of Distributions of Final Outputs

As discussed in Chapter 2, probability distributions provide information about the probability of achieving the estimated outcomes. Based on the empirical rule, as shown in Figure 5-19, if a distribution is approximately normal then the probability is about 68.26 percent of the estimates will lie within one standard deviation of the mean (mathematically,  $\mu \pm \sigma$ , where  $\mu$  is the arithmetic mean), about 95.44 percent will be within two standard deviations ( $\mu \pm 2\sigma$ ), and about 99.74 percent will lie within three standard deviations ( $\mu \pm 3\sigma$ ) (Ott & Longnecker, 2001, p. 158).

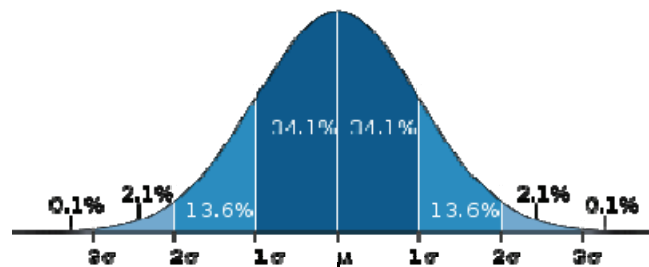


Figure 5-19: Probabilities in a Normal Distribution

The distributions of average NPVs in this scenario are approximately normal, and therefore, the following information could be understood from the distribution of average 5-year NVP:

- There is less than one percent chance that the average 5-year NVP is negative.
- There is a 68.2 percent chance that the average 5-year NVP falls between \$0.58M and \$1.28M.
- There is a 95.4 percent chance that the average 5-year NVP falls between \$0.23M and \$1.63M.
- There is a 99.7 percent chance that the average 5-year NVP falls between -\$0.12M and \$1.98M.
- There is a 90 percent chance that the average 5-year NVP falls between \$0.4M and \$1.55M.
- The minimum expected average 5-year NVP at the confidence level of 90 percent is \$0.4M.
- There is an 84.1 percent chance that the average 5-year NVP is not less than \$0.58M.

The above information provides investment decision-makers with more insight into risk associated with achieving the expected financial outcomes. Thus, decision-makers would be able to make more informed decisions concerning investing in green retrofit options. Figure 5-20 compares the outcomes that are generated as a result of including ranges of inputs in the process with those that would have been calculated if single-point estimates were utilized as inputs:

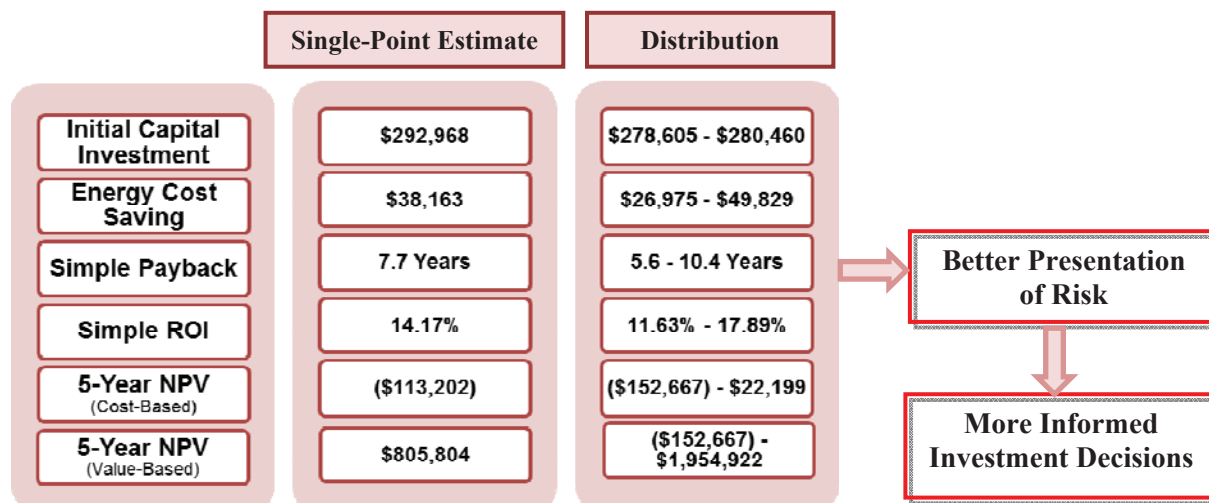


Figure 5-20: Comparison of Process Outputs – Single-Point Estimates VS. Distributions

### 5.3.2.2 Impact of the Value-Based Analysis Approach on Financial Outcomes

An average for each financial outcome was estimated for each case separately and the impact of including revenue in the financial analysis are then calculated by comparing the financial outcomes of most-likely and best cases with outcomes of the base case. The financial outcomes averages and impacts are presented in Table 5-5:

Table 5-5: Impacts of Value on Financial Outcomes Average– the Owner-Investor Scenario

Metric	Base Case	Most-Likely Case	Best Case	% Increase in Most-Likely Case	% Increase in Best Case
5-Year NPV Average	(\$78,550)	\$686,101	\$1,809,861	973%	2404%
10-Year NPV Average	\$97,429	\$1,754,268	\$4,584,230	1701%	4605%
15-Year NPV Average	\$150,239	\$2,397,081	\$6,931,835	1496%	4514%
20-Year NPV Average	\$249,254	\$3,064,555	\$9,409,224	1129%	3675%
5-Year IRR Average	-8%	104%	228%	1454%	3065%
10-Year IRR Average	17%	111%	230%	558%	1261%
15-Year IRR Average	18%	111%	230%	506%	1152%
20-Year IRR Average	20%	111%	230%	451%	1039%

Figure 5-21 and Figure 5-22 graphically show how including revenue in financial analysis can impact the final financial outcomes.

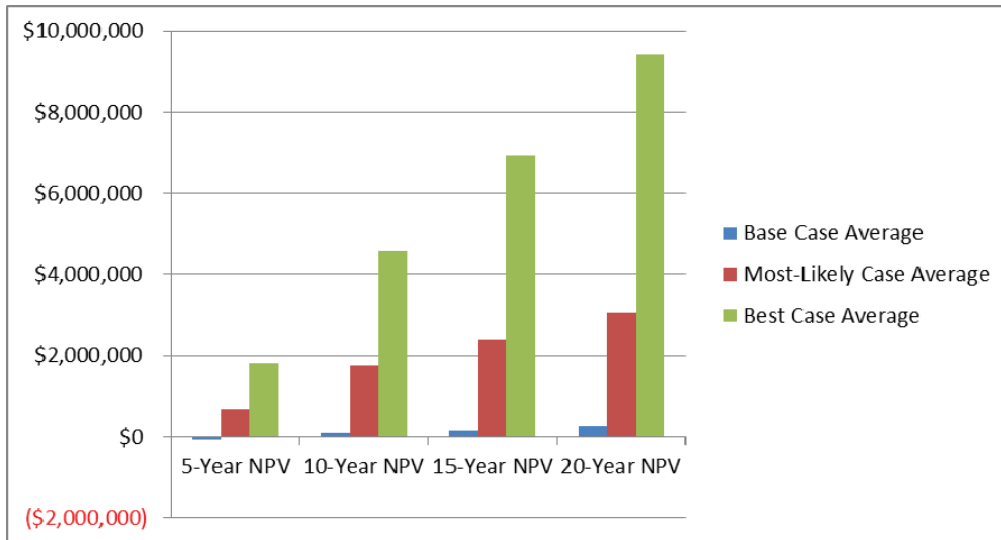


Figure 5-21: Impacts of Revenue on Final NPVs– the Owner-Investor Scenario

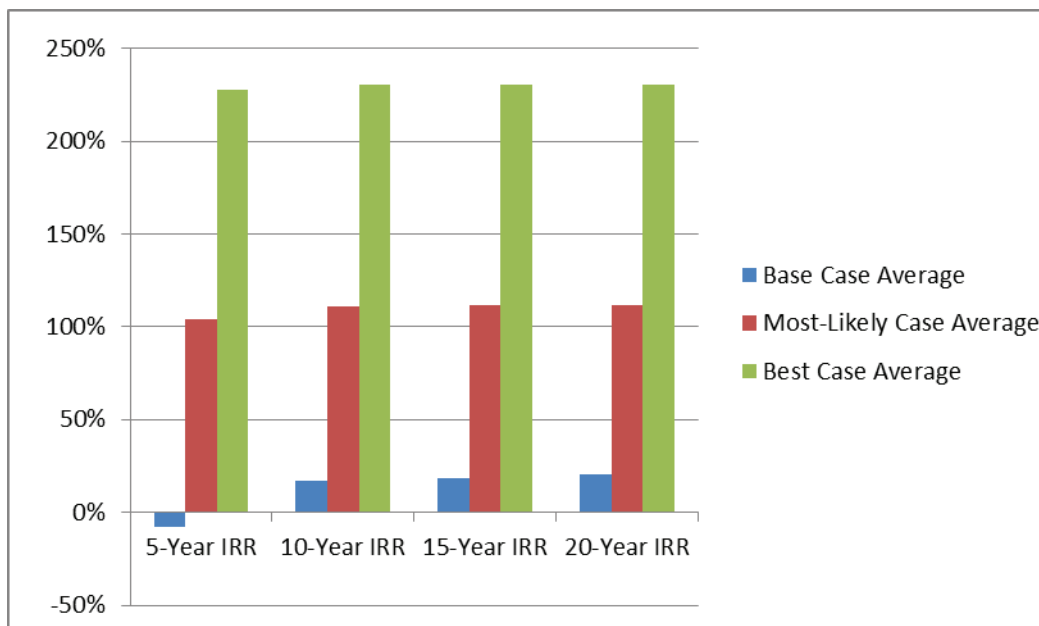


Figure 5-22: Impacts of Revenue on Final IRRs– the Owner-Investor Scenario

### 5.3.3 Sensitivity Analysis - Impacts of Various DCF Inputs on Financial Outcomes

There is an argument among real estate experts that rental rate is the last value variable that might change as a result of green investment. The respondents in the market survey step indicated that tenant retention

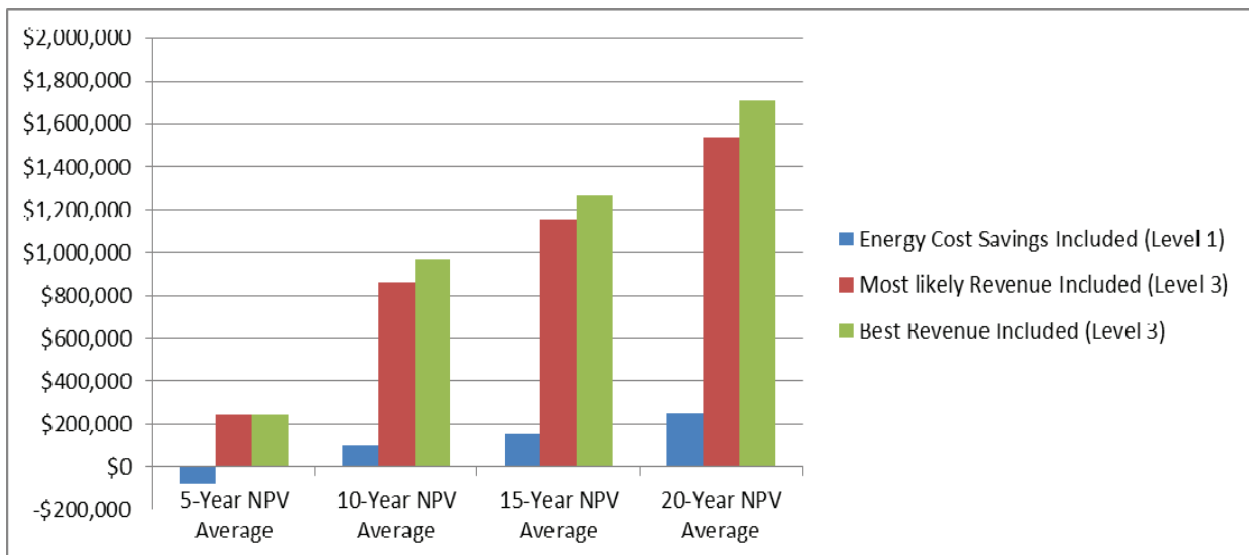
(renewal probability) is most likely to be impacted. Thus, in this section two additional scenarios are run to test the impacts of various variables on the financial outcomes and emphasize the importance of considering revenue when evaluating the financial performance of green options.

### 5.3.3.1 Rental Rate and Annual Rental Growth do not change

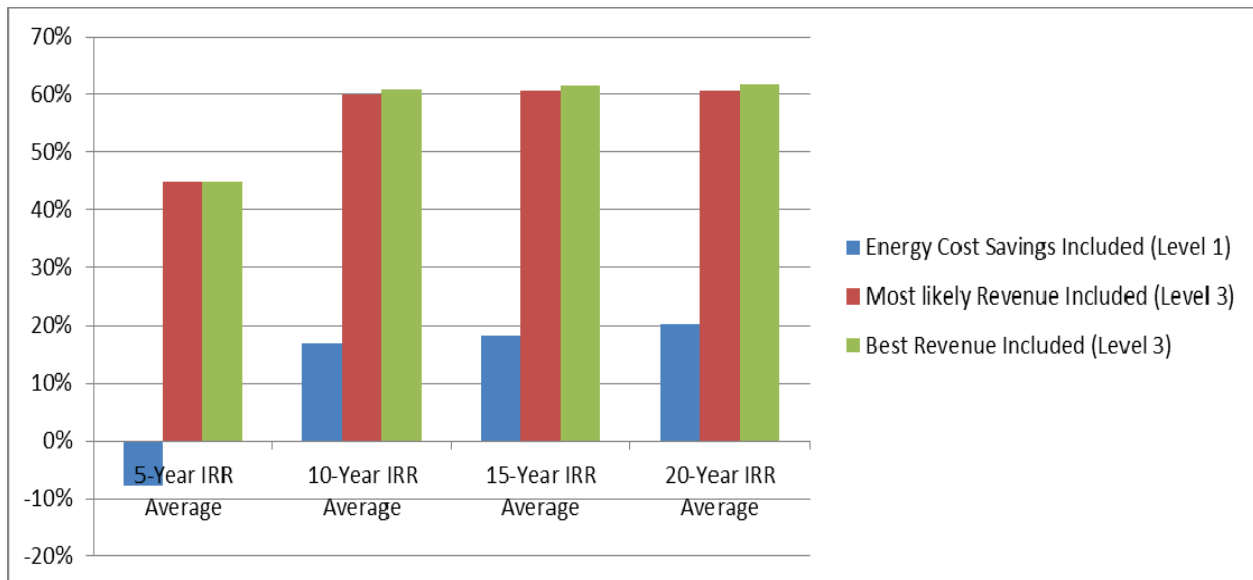
**In this scenario, the assumption is made that the rental rate and annual rental growth remain constant and only occupancy rate and renewal probability will increase. The results are presented in Figure 5-23**

**Figure 5-23 and Figure 5-24. As shown in Figure 5-23**

Figure 5-23, the average of 5-NPV is increased by 406% from -\$78,550 to \$240,669 when revenue is included, and therefore, the investment decision might be altered from ‘no go’ to ‘go’. Table 5-6 shows that even if the green investment does not increase the rent-related inputs, the impact of considering revenue in the financial outcomes is still very significant and may result in altering the investment decisions.



**Figure 5-23: Impact of Including Revenue on NPVs When the Rent-Related Inputs Do Not Change– the Owner-Investor Scenario**



**Figure 5-24: Impact of Including Revenue on IRRs When the Rent-Related Inputs Do Not Change– the Owner-Investor Scenario**

As shown in Figure 5-24, the average of 5-IRR is increased by 685%, from -8% to 45% when revenue is included, and therefore, the investment decision might be altered from ‘no go’ to ‘go’.

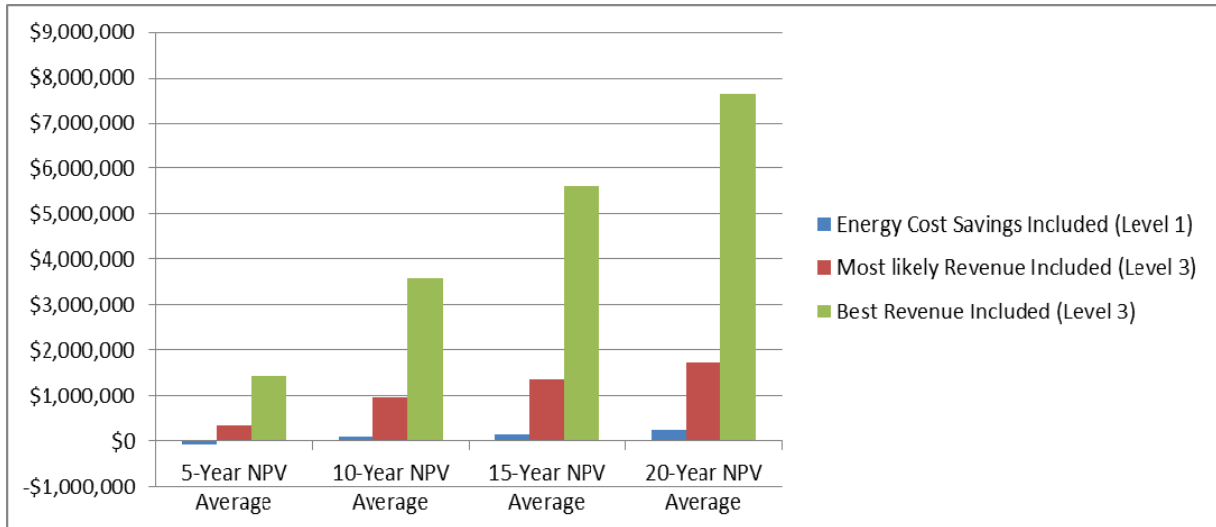
**Table 5-6: Financial Outcomes When the Rent-Related Inputs Do Not Change - Owner-Investor Scenario**

Metric (Average)	Energy Cost Savings Included (Level 1)	Most likely Revenue Included (Level 3)	Best Revenue Included (Level 3)	% Increase in Most-Likely Case	% Increase in Best Case
5-Year NPV	-\$78,550	\$240,669	\$240,669	406%	406%
10-Year NPV	\$97,429	\$858,169	\$969,593	781%	895%
15-Year NPV	\$150,239	\$1,152,645	\$1,263,227	667%	741%
20-Year NPV	\$249,254	\$1,530,104	\$1,711,289	514%	587%
5-Year IRR	-8%	45%	45%	685%	685%
10-Year IRR	17%	60%	61%	254%	260%
15-Year IRR	18%	61%	62%	230%	235%
20-Year IRR	20%	61%	62%	200%	205%

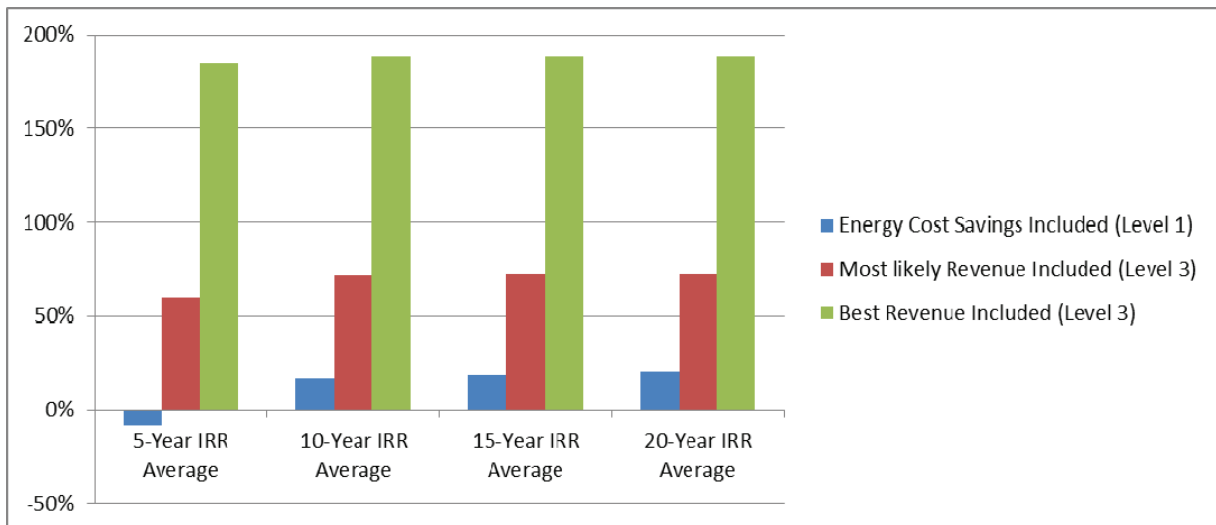
Therefore, considering value in the financial analysis might significantly impact the financial performance even though the rent-related inputs do not change. The results of this value analysis confirm that green investment decision could be significantly impacted by tenant retention. Investors still need to consider a value-based analysis even if there is no market evidence suggesting higher rents.

### 5.3.3.2 Occupancy rate and renewal probability do not change

In this scenario, the assumption is made that the occupancy rate and renewal probability remain constant and only rental rate and annual rental growth will increase with previous three-point assumptions. The results, as presented in Figure 5-25, Figure 5-26, and Table 5-7, show that financial performance is more sensitive to rent-related inputs.



**Figure 5-25: Impact of Including Revenue on NPVs When the Occupancy and Renewal Probability Do Not Change– the Owner-Investor Scenario**



**Figure 5-26: Impact of Including Revenue on IRRs When the Occupancy and Renewal Probability Do Not Change– the Owner-Investor Scenario**



**Table 5-7: Financial Outcomes When the Occupancy and Renewal Probability Do Not Change - the Owner-Investor Scenario**

<b>Metric (Average)</b>	<b>Energy Cost Savings Included (Level 1)</b>	<b>Most likely Revenue Included (Level 3)</b>	<b>Best Revenue Included (Level 3)</b>	<b>% Increase in Most-Likely Case</b>	<b>% Increase in Best Case</b>
<b>5-Year NPV</b>	-\$78,550	\$351,738	\$1,437,290	548%	1930%
<b>10-Year NPV</b>	\$97,429	\$970,189	\$3,577,324	896%	3572%
<b>15-Year NPV</b>	\$150,239	\$1,352,364	\$5,607,284	800%	3632%
<b>20-Year NPV</b>	\$249,254	\$1,731,535	\$7,638,406	595%	2965%
<b>5-Year IRR</b>	-8%	60%	184%	886%	2501%
<b>10-Year IRR</b>	17%	72%	188%	325%	1013%
<b>15-Year IRR</b>	18%	72%	188%	294%	924%
<b>20-Year IRR</b>	20%	73%	188%	259%	831%

## 5.4 Summary

Without analyzing the value and considering the potential impacts on revenue and risk, the financial analysis of green investment is not complete as many potential benefits are ignored. The market demand analysis shows that demand for sustainability and green buildings is increasing, and as a result the value and risk implications of green investment are becoming more tangible. Accordingly, as time passes, the value analysis level becomes a more critical part of the financial assessment of green investment.

Market analysis is a critical part of property valuation practice. Valuers (appraisers, underwriters, or due diligence persons) consider all building performance factors and conduct a detailed market analysis. They then integrate and analyze the data, both qualitative and quantitative, to qualitatively predict the DCF inputs. A thorough market research investigation could be done through 1) a detailed analysis of comparable buildings and market evidence; 2) a detailed analysis of historic market trend and forecasts of demand, rents, and other key variables; and 3) independent surveys among brokers, tenants, property owners, investors, and other stakeholders in the sub-market.

In order to determine the incremental value associated with green investment, a thorough market analysis is required to understand the market response to projected sustainability outcomes. What matters most is how the space users and investors in the particular sub-market react to benefits of sustainability, green, or energy efficiency investment. If there is a clear indication for higher demand for green buildings or attributes when compared to conventional buildings, there might be premiums for some of the key value variables, if not for all of them. The incremental impacts depend on many factors including the unique characteristics of a property, market conditions, type of tenants, and the nature of green improvement/investment.

In order to determine the incremental DCF inputs and demonstrate a value based financial analysis in this case study, the qualitative and quantitative data from four sources were analyzed and used as a foundation for forecasting triangular distributions of the selected five key DCF inputs—three-point estimates. The three-point estimates represent the uncertainty associated with the selected DCF inputs. Five selected key variables include: rental rate, annual rental growth, occupancy rate, renewal probability, and cap rate.

Four sources include 1) Surveys/interviews with key real estate market stakeholders including the major tenant/property owner of TMC, the property manager of TMC, market researchers, brokers, and appraisers who were familiar with the Rockville market. 2) A sub-market report on Rockville by TRANSWESTERN, which includes many statistics from the CoStar database for market demand, tenants, vacancy, absorption, leasing activities, rental rate, and sales. 3) Comparable buildings, three LEED and three non-LEED buildings, which are identified through CoStar and GBIG databases. 4) Current causal-comparative studies, which have suggested estimates about the impacts of green attributes/labels on property value, rents, and occupancy rates.

Three scenarios are developed for including the incremental revenue in the financial analysis, base case, most-likely case, and best case. The assumption for the base case is that there would not be any change in the value variables, and therefore, the incremental revenue is zero. The base case estimates represent the financial outcomes from the cost-based financial analysis.

The value-based financial analysis in this case study is conducted over a 20-year life cycle and primarily focuses on including revenue in the cash flow stream. It does not estimate any residual property value, nor does it include the cap rate in the analysis. Thus, risk would not be fully addressed in the value-based model in this case study. The risk-related benefits of green investment in real estate could be better captured in a more complete property valuation analysis—DCF modeling with residual value analysis—which is not the main purpose of this case study.

Another analysis layer was added to the previous LCCA model in LCSA to include the DCF assumptions for value-based financial analyses. The new value-based model in this case study is an expanded LCCA model that integrates a DCF methodology in its function to include the impacts of green investment on property revenue.

Incremental revenue is estimated for most-likely and best cases and included in new financial models through LCSA (Excel-based tool) for value-based financial analyses. The final financial outcomes including NPVs and IRRs are estimated for the periods of 5, 10, 15, and 20 years. The distribution for

each financial outcome was generated by 75 estimates, three DCF cases by 25 lighting controls savings cases. The estimated distributions explain the risk associated with achieving the financial outcomes.

The financial outcomes are estimated for two scenarios: 1) TMC is an owner-occupied building and Davis Construction is the owner who occupies 2/3 of the building 2) TMC is an owner-investor type building and Davis Construction is the major tenant but not the owner of building. In the owner-occupied scenario, Davis Construction will reap the improved employee's health and productivity benefits. Thus, the health and productivity savings related to Davis Construction' employees and 1/3 of incremental revenue are included in the financial analysis in addition to energy cost savings. In the owner-investor scenario, the entire incremental revenue is included in the financial analysis in addition to energy cost savings. Health and productivity savings are not included here but are for the owner-occupied scenario.

The financial outcomes in most-likely and best cases, where incremental revenue are included, are significantly higher than the outcomes of the base case, where only energy cost savings are considered. Even the 2-year NPVs are greater than zero when incremental revenue is included, which means investors that have a two year window would invest in the lighting controls system.

The results of the sensitivity analysis show that the rental rate has the most significant impact on deriving the financial performance. However, even if the green investment does result in increasing the rent-related inputs, the impact of other value variables such as renewal probability (tenant retention) or occupancy rate in the financial outcomes is significant enough to alter the investment decisions. Most respondents in the survey believed that tenant retention is more likely the first variable to be impacted by investing in green options. Therefore, considering value in the financial analysis might significantly impact the financial performance even though the rent-related inputs do not change.

## **CHAPTER 6 CONCLUSION AND DISCUSSION**

This chapter summarizes the case study methodologies, steps, and findings in the context of the proposed assessment framework to demonstrate how the framework is applied for deriving the financial performance of the selected green retrofit option in the case study. It discusses how the research goals and objective are addressed throughout the dissertation. This chapter also compares the numeric findings of the case study, outcomes of three levels of financial analyses, to explain the significance of the new approach regarding green investment decision making.

### **6.1 Research Summary**

Over the past five years, demand for sustainability and green investment has been increasing in the real estate industry. Investment decision-makers, including property investors and owner-occupants, are in need of more comprehensive, reliable and understandable information about costs and benefits of sustainable building features to be able to make more informed investment decisions.

Sustainability offers more than cost savings to real estate. The true financial performance of a sustainable property is beyond the energy and operating cost savings. Non-energy benefits such as improved health and productivity could play a role in deriving a true understanding for the financial performance. Sustainability investment could contribute to higher revenue and lower risk, and therefore, a higher property value.

The market trend toward achieving LEED certifications and green investment, both for new and existing buildings, suggest that demand for green attributes will continue to increase. Today, most space users, owners, and investors are aware of the potential benefits; however, the magnitude of their investment is less than what would be expected. This could be due to many technological and market barriers—the author believes that the main challenge related to green and energy efficiency investment is the market barriers associated with valuation and finance.

One of the major problems concerning sustainability and green investment is the inability of current techniques to fully assess the financial performance of sustainable options for the purpose of investment decision making at the property level. Current tools and techniques used for assessing sustainability at the property level, including building simulation programs, green certifications, or building performance-based assessments, are typically developed by design professionals and methods that are different from those used by investment decision-makers. These tools on their own do not provide the understandable,

comprehensive, nor reliable set of information in the context that enable investors to assess the true financial performance and make informed investment decisions. Most sustainable cost-benefit analyses tend to stop at the building performance level and focus on cost savings in their financial assessment. They fail to include non-cost benefits in their financial analyses and do not tie building performance factors to financial performance inputs that are important to property professionals. Investors use their own methods and processes to recognize the value and risk associated with investment options when making investment decisions.

No single tool is sufficient to fully assess the true financial performance of sustainable options. The technical tools (use by design professionals for evaluating building performance indicators) as well as valuation and statistical techniques (traditionally used by investors for assessing investment options) need to be integrated to create a new procedure for estimating the financial performance of sustainable options in the way that investors can rely and apply in their investment decision-making process. Non-energy benefits as well as potential value implications of sustainable options need to be taken into account in order to arrive at more comprehensive financial outcomes.

As the demand for sustainable features and energy efficiency increases (similar to what we have seen over the past decade) and sustainability becomes higher priority in real estate investment decision-making, the value implications of sustainability investment would become a more important part of the financial assessment process. In the future, without considering incremental value as well as risk and uncertainty, the financial analysis of sustainable options investment will not be complete and might result in bad investment decisions.

The need for more holistic financial assessment of sustainable property investment and deficiencies of current assessment tools in providing comprehensive, understandable, and reliable information for the purpose of major investment decision-making suggest the following principles for the development of new tools:

- More focus should be placed on the specific sustainable features and strategies employed in a sustainable property and their relation to value creation and risk mitigation, when evaluating the financial performance of a sustainable property rather than simply focusing on sustainable certifications or ratings.
- More focus should be placed on a thorough and reliable estimation of the actual building performance indicators and their relationship with financial performance. Current technical tools, which are primarily developed by design professionals, are well suited to deal with complexity

and interaction of building performance if used properly. Their results need to be adjusted intelligently and translated to the appropriate terms in order to be included in the financial models.

- More sophisticated financial techniques, rather than simple cost-based analyses, capable of addressing the full costs, benefits and risks of a sustainable property investment, should be utilized for estimating the financial performance indicators.
- Various ‘uncertainty factors’, both at the building performance and financial assessment levels, should be derived and integrated into the assessment process. More systematic and structured processes and tools are required to assess and present the risk and uncertainty to assist decision-makers to better mitigate or price them. More sophisticated statistical techniques could also be utilized for incorporating uncertainty and communicating more reliable estimates of financial performance.

Through this research, by integrating the simulation tools (used by design professionals for evaluating building performance) and financial techniques (traditionally used by property professionals for evaluating a typical property investment decision) in a single platform, a new framework is developed to assess the financial performance of a set of sustainable options while explicitly considering risk and uncertainty inherent in the evaluation process. It offers a more complete approach that goes beyond the current cost-benefit assessment to capture the financial performance of sustainable options, both cost and non-cost benefits, more completely and presents a better picture of value and risk. The process provides decision-makers with a much more comprehensive view of investment outcomes, as opposed to traditional single-point estimates of conservative simple PB or ROI, and would enable them to make more informed investment decisions when evaluating greening the existing properties.

In the development of the proposed framework, this study looked at three different domains simultaneously to bring them all together into a single model to evaluate the possible sustainable options and determine their distributions of financial performance indicators in a way that can be utilized by users for making high-quality investment decisions about greening their buildings. The three domains are: 1) sustainable options and their performance projections (energy-related systems investment); 2) the sustainable property valuation process and incorporating sustainability into the financial model (DCF model); and 3) incorporating and communicating the uncertainty in energy simulation as well as the property valuation process by utilizing the probability-based model.

A case study was then conducted to thoroughly demonstrate the numeric application of the proposed framework in the context of a non-green office building. The case study presents how to connect the technical outcomes to financial inputs, present the information, and estimate the financial performance of a green retrofit option, where incremental value and uncertainty have been factored in. It clearly demonstrates how to model and include various uncertainties associated with green systems evaluation, both at the building performance and financial performance levels, in the process.

The methodology in this research was a combination of both quantitative and qualitative approaches through integration of a case study and survey tactics. An integrated approach was required in this research because the case study includes energy simulation, building performance assessment, real estate market research, and a value-based analysis. The parts related to energy simulation and cost-based analysis required a quantitative assessment approach. However, for the parts related to market analysis and determining the value variables, a qualitative approach was needed for collecting the required information.

This dissertation is presented in six chapters:

Chapter 2 reviews the current literature concerning 1) definitions, trends, costs, benefits, and risks related to sustainable property investment, 2) sustainable property performance and assessment tools, 3) risk and uncertainty analysis methods, and 4) sustainable property valuation and financial methods. It describes the existing tools and techniques, both technical and financial, that are used for evaluating sustainable properties and explains why none of them on their own are sufficient for evaluating the financial performance for the purpose of major investment decision making. It also presents the current studies in the area of financial implications of sustainable property investment and introduces the key researchers working in this area. This chapter discusses the gaps in the literature that this research attempts to fill. It outlines the theories and fundamentals upon which the new financial assessment approach is developed.

Chapter 3 reviews the research goals and methodology in detail. It sets forth the rationales and foundations for the development of a new systematic framework to include risk and uncertainty for assessing the financial performance of sustainable options investment in the context of value. This chapter focuses on mapping the assessment process, and explains the characteristics, challenges, approaches, and methods employed in the framework. The framework includes four major steps that decision-makers need to follow to better understand the financial performance of sustainable options while considering risk and uncertainty. The steps include: 1) identification of energy systems and estimating a probability distribution; 2) determination of a probability distribution for each building performance factor; 3)

determination of a probability distribution for each DCF input; and 4) calculation of a probability distribution for final financial performance indicators.

Chapter 3 also describes the case study approach that is utilized in this research to test and demonstrate the applicability of the proposed framework in a real world situation. A lighting control systems package is selected as the green retrofit option to be evaluated in the context of an existing non-green office building in Rockville, MD to explain the estimation methods, data collection, and development of distributions in each step of the framework.

Chapter 4 presents the first part of the case study which fully explains steps 1 and 2 of the proposed framework. It describes the development of ranges and distributions of energy performance indicators, step 1, and whole-building performance factors, step 2, resulting from employing the lighting controls option. This chapter introduces the lighting controls system package and discusses the potential costs, benefits, and risks associated with this retrofit option. It includes 1) the development and calibration an energy model through eQuest for estimating the distributions of energy performance indicators associated with the lighting controls, 2) the development of an Excel-based model, LCSA, for calculating the whole-building performance and cost-based financial analysis of the lighting controls system package.

In this case study, financial analyses, both simple and lifecycle, are performed in three levels to capture the financial performance of the green retrofit option more completely: 1) Cost-based level-1: only energy related costs savings were considered; 2) Cost-based level-2: the non-energy cost savings, including health and productivity, were considered in addition to the items in level 1, 3) Value-based level: the value implications of the green retrofit option were considered in addition to items in level 2. The financial implications of non-cost benefits, which are difficult to include in cost-based analyses, could be captured at this level. Chapter 4 focuses on the cost-based financial analyses, levels 1 and 2, and presents distributions for simple payback, simple ROI, NPV, and IRR.

Chapter 5 presents the second part of the case study which fully explains steps 3 and 4 of the proposed framework. It focuses on the third level of financial analysis, which is a value-based financial analysis and explains how the entire building performance information, quantitative and qualitative, estimated in Chapter 4 could be translated into value variables—DCF inputs—to be included in the assessment process. This chapter describes how the DCF methodology could be integrated in a typical LCCA to include the potential incremental revenue resulting from the green retrofit option. It also presents the distributions of final financial outcomes including NPVs and IRRs.



The next section summarizes the findings of each step of the case study, presented in chapter 4 and 5, in the context of the proposed assessment framework to emphasize its application in the case study and its applicability and practicality in real situations.

## 6.2 **The Application of the Value-Based Assessment Framework**

In the case study, the proposed assessment framework was applied to assess the financial performance of a lighting controls package in a non-green office building (TMC) in Rockville, MD. Similar to the framework, the case study also includes four major steps, presented in chapter 4 and 5. Below is a summary of the outcomes of each step:

**Step 1: Estimation of energy performance indicators distribution:** The base model of TMC was set up in e-Quest and the lighting controls system package was then modeled using five different acceptable base models. The required assumptions for energy modeling were made based on drawings, interviews with property managers and the tenants of TMC, as well as the researcher's professional judgment.

The following distributions were then generated based on 25 estimates, five lighting controls cases by five base models:

- The Distribution of Energy Consumption Savings (MWh)
- The Distribution of Peak Demand Savings (KW)

**Step 2: Estimation of whole building performance distributions and cost-based financial analysis:**

The energy performance estimates in step 1 were taken to a LCSA Excel-based model to estimate the distributions of whole building performance, both energy-related and non-energy factors. Required assumptions for LCCA were made based on the literature review and interviews with professionals from Lutron Electronics.

- The Distribution of Total Energy Cost Savings
- The Distribution of Simple Payback – Energy Savings
- The Distribution of Simple ROI – Energy Savings
- Distributions of 5, 10, 15, and 20 years NPVs – Energy Savings
- Distributions of 5, 10, 15, and 20 years IRRs – Energy Savings
- The Distribution of Total Cost Savings – Health and Productivity Savings Are Included
- The Distribution of Simple Payback – Health and Productivity Savings Are Included
- The Distribution of Simple ROI – Health and Productivity Savings Are Included

- Distributions of 5, 10, 15, and 20 years NPVs – Health and Productivity Savings Are Included
- Distributions of 5, 10, 15, and 20 years IRRs – Health and Productivity Savings Are Included
- Ranges of Probabilities for Achieving Four Levels of LEED Certifications
- Ranges of Energy Performance Rating and GHG Emissions

The quantitative data for benefits such as improved comfort, safety and security was not sufficient in the literature to make numeric assumptions and estimate ranges or distributions for these benefits of lighting controls. Such benefits were included in the form of qualitative information, so their potential impacts on financial performance could be considered in the value-based analysis.

**Step 3: Market research and estimation of triangular distributions for key financial model inputs:**

A market analysis was conducted through 1) interviews with several real estate stakeholders in Rockville, MD; 2) a sub-market report on Rockville real estate market; 3) analyzing comparable buildings found through the CoStar and GBIG databases; and 4) current literature on the impacts of green attributes/certifications on property value. The qualitative and quantitative data from these sources were integrated and used as a foundation upon which certain assumptions were developed for triangular distributions of the key DCF inputs—three-point estimates. Three-point estimates key were selected for the following DCF inputs:

- Rental rate
- Annual rental growth
- Occupancy rate
- Renewal probability
- Capitalization rate

**Step 4: Value-based financial analysis and estimation of financial performance indicator**

**distributions:** Incremental revenues were estimated based on the three-point estimate of DCF inputs determined in step 3 and were included in new financial models through LCSA to estimate the financial outcomes. The financial outcomes were estimated for two scenarios: 1) TMC is an owner-occupied building and Davis Construction is the owner who has occupied 2/3 of the building 2) TMC is an owner-investor type building and Davis Construction is the major tenant but not the owner of the building; because each scenario requires a different approach for including revenue as well as health and productivity savings. The following distributions were generated by 75 estimates, three DCF cases by 25 lighting controls savings cases:

- Distributions of 5, 10, 15, and 20 years NPVs – Owner-Occupied Scenario
- Distributions of 5, 10, 15, and 20 years IRRs – Owner-Occupied Scenario
- Distributions of 5, 10, 15, and 20 years NPVs – Owner-Investor Scenario
- Distributions of 5, 10, 15, and 20 years IRRs – Owner-Investor Scenario

The following distributions were generated by running Monte Carlo simulation using @Risk software:

- Distributions of average 5, 10, 15, and 20 years NPVs – Owner-Investor Scenario

Figure 6-2 shows a schematic diagram of the proposed assessment framework, as shown previously in Chapter 3, and Figure 6-2 shows the assessment framework but filled with the distributions generated in the case study. It demonstrates the application of the framework in the case study.

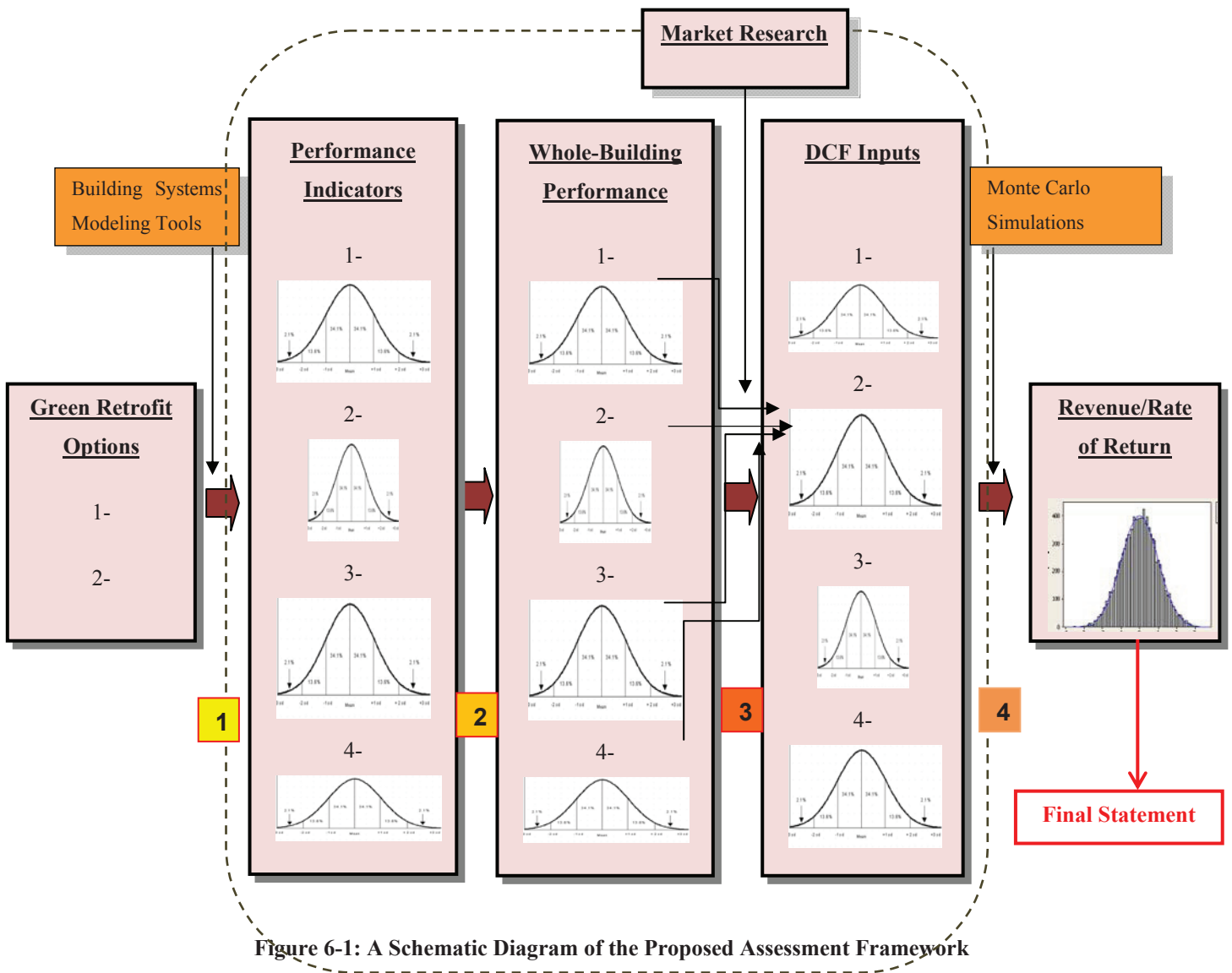


Figure 6-1: A Schematic Diagram of the Proposed Assessment Framework

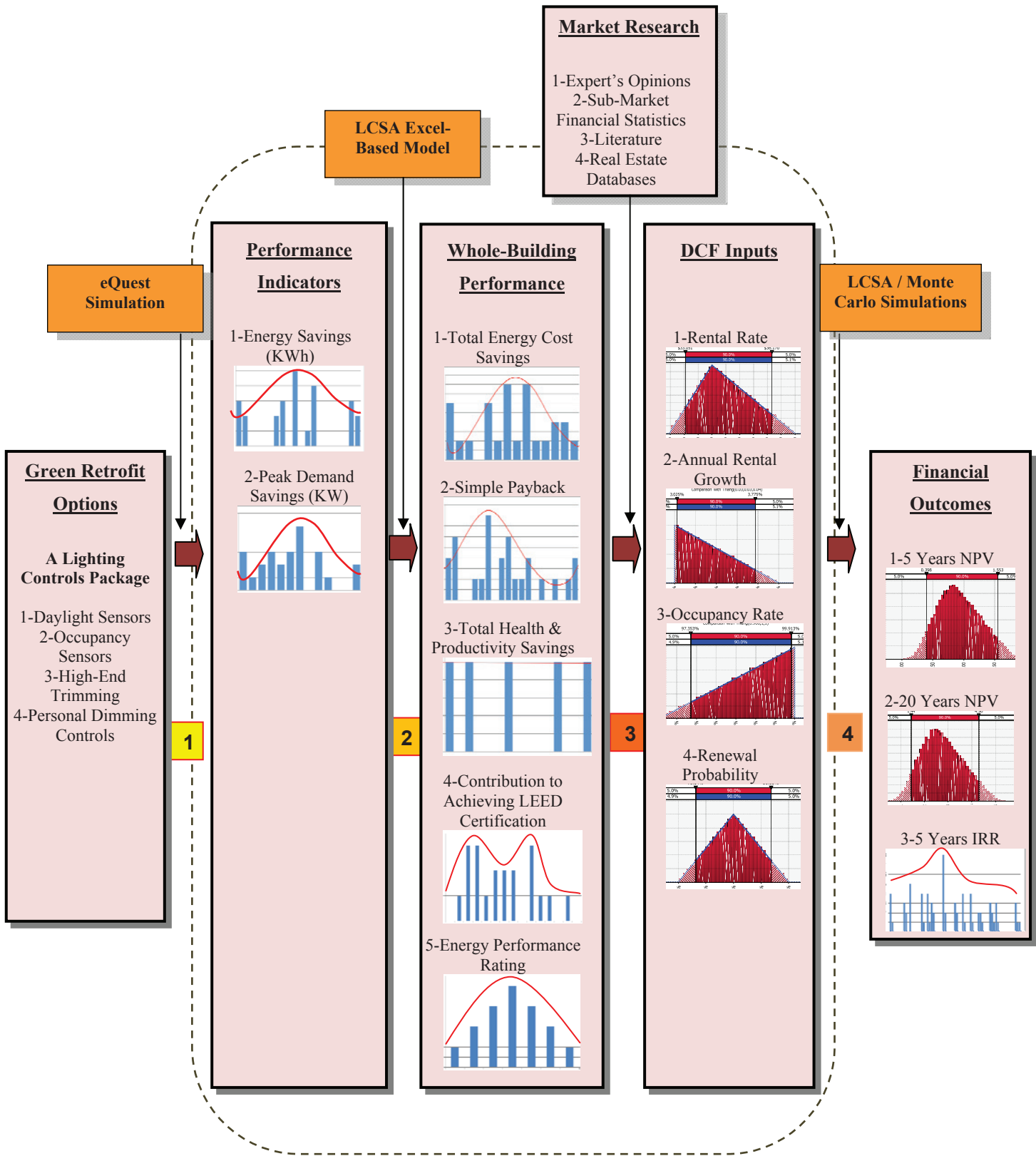


Figure 6-2: Application of the proposed framework in the case study

Thus, the proposed framework can be applied in real situations for a more comprehensive assessment of the financial performance of green retrofit options in existing income-producing properties. It presents a practical approach that can be utilized by decision-makers to enhance the quality of their decisions about investing in green options.

### **6.2.1 Integrating Uncertainties into the Framework**

There are certain levels of uncertainty associated with the assessment of sustainable options, both at the building performance and the financial performance levels, which would impact the risk of achieving the predicted final financial performance. The framework suggests utilizing ranges and probability distributions instead of single-point estimates during the process in order to account for potential uncertainties inherent in the assessment process, so that the distributions of final financial outcomes reflect the risks associated with achieving those outcomes.

Therefore, decision-makers can better assess the risk associated with predicted financial performance and make more informed decisions concerning investing in sustainable options. The case study describes in detail how to generate distributions of outcomes in each step and integrate them into the assessment process.

The level of uncertainty in the first step, e.g. energy performance, is negatively related to the level of knowledge of practitioners regarding the selected technologies. The more advance technologies and lower level of knowledge typically involve a higher level of uncertainty associated with their projected performance.

As more research will be conducted on the quantitative relationship between performance indicators, such as daylighting or ventilation, with non-energy performance benefits, such as health and productivity, comfort, and satisfaction, the level of uncertainty in the second step will decrease and the distributions of whole-building performance factors will be narrowed.

As more market evidence related to green buildings becomes available and more structured methods are developed to assess and present the relationship between sustainability with risk, the value variables could be predicted with a higher level of confidence and distributions of DCF inputs in the third step will be narrower. As a result, there will be a lower risk associated with achieving the final outcomes of the framework.

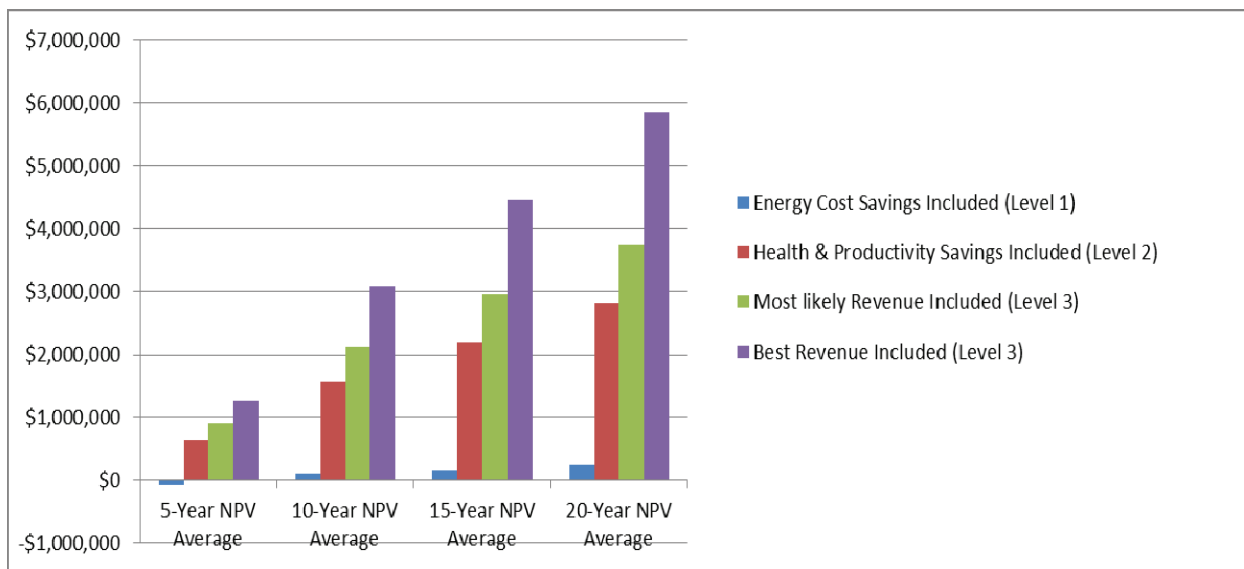
The tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and high level of confidence in achieving the expected outcome (mean). Flat distribution with large standard deviation denotes a great degree of risk and uncertainty and low level of confidence.

## 6.2.2 Importance of Integrating Value in the Financial Assessment Process

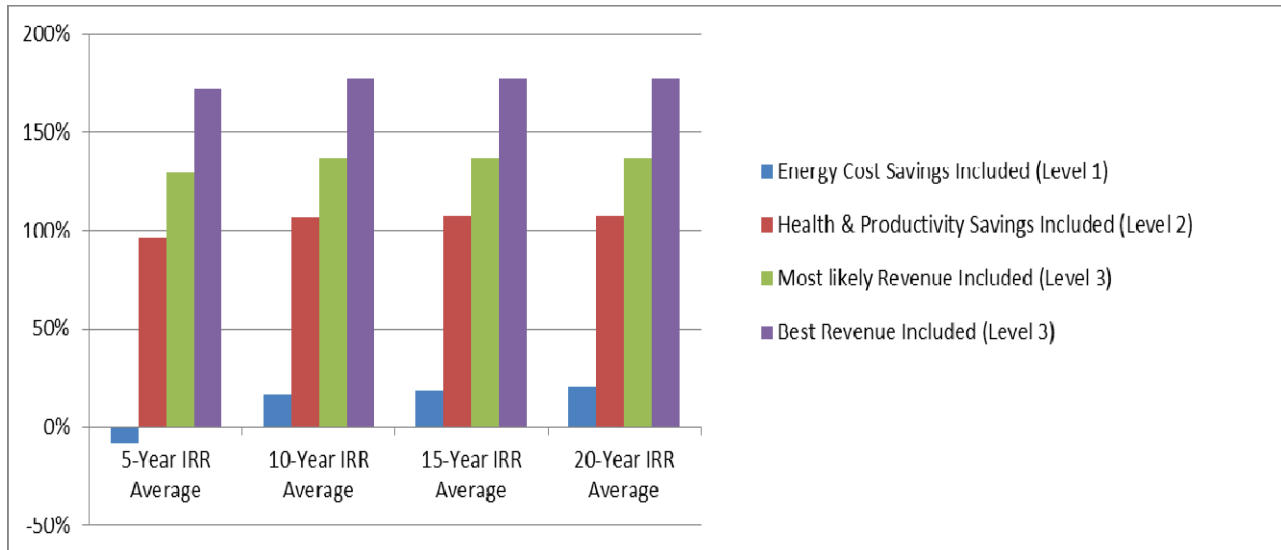
In the case study, the two following scenarios were considered for performing the value-based analysis; each of them requires a different approach:

**1) The owner-occupied building scenario:** TMC is an owner-occupied building and Davis Construction is the owner who has occupied 2/3 of the building. In this scenario, it was assumed that Davis Construction will reap the improved employee’s health and productivity benefits. Thus, the health and productivity savings related to Davis Construction’ employees and 1/3 of incremental revenue are included in the financial analysis in addition to energy cost savings.

Figure 6-3, Figure 6-4, and Table 6-1 illustrate the comparison between the outcomes of three financial analysis levels in the owner-occupied building scenario to show how the proposed approach might impact the final financial outcomes and ultimately alter the investment decisions:



**Figure 6-3: Impact of Including Health & Productivity Savings and Revenue on the NPVs – the Owner-Occupied Scenario**



**Figure 6-4: Impact of Including Health & Productivity Savings and Revenue on the IRRs - the Owner-Occupied Scenario**

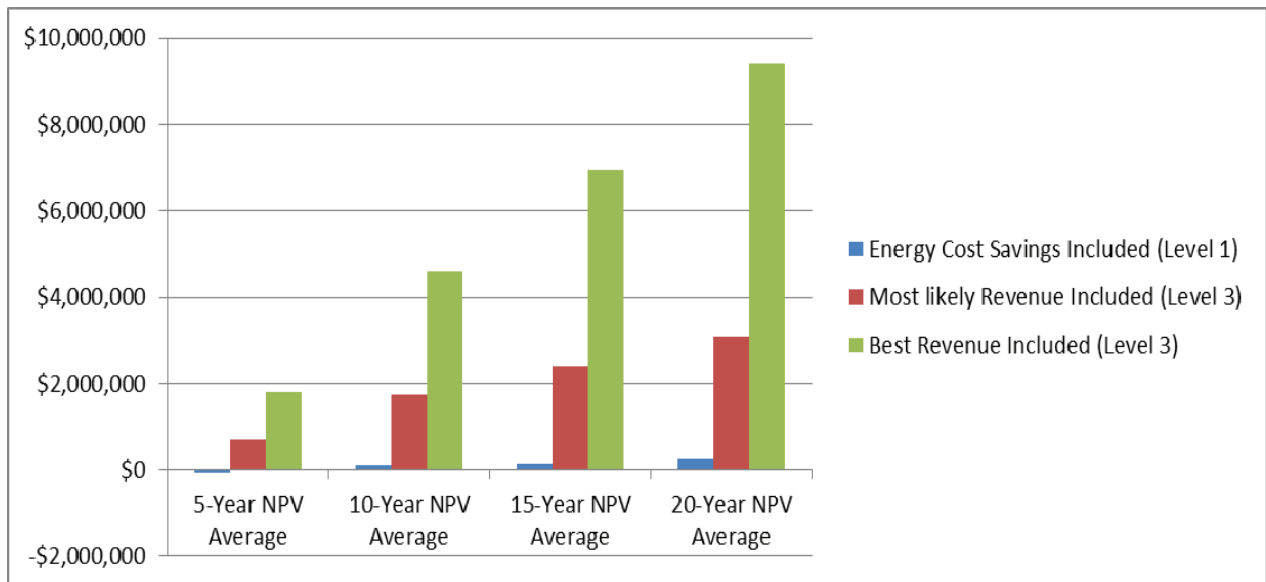
As shown in Table 6-1, the final NPVs and IRRs have increased significantly when health and productivity savings are considered in the financial analysis. The impact is coupled with including revenue. For example, the average of 5-year NPV in the most-likely case has increased by 1246%, from -\$78,550 to +\$900,060. This will make this retrofit option a very attractive investment option for property owners who require a positive return in five years; they will not invest in this options based on the negative 5-year NPV.

**Table 6-1: Comparison of the Value-Based Financial Analysis with Level 1 Analysis - the Owner-Occupied Scenario**

Metric (Average)	% Increase in Most-Likely Case in Compared to Level 1	% Increase in Best Case in Compared to Level 1	% Increase in Best Revenue Case in Compared to level 2	% Increase in Most-Likely Revenue Case in Compared to level 3
<b>5-Year NPV</b>	1246%	1723%	40%	98%
<b>10-Year NPV</b>	2079%	3048%	35%	95%
<b>15-Year NPV</b>	1863%	2869%	34%	103%
<b>20-Year NPV</b>	1401%	2250%	33%	109%
<b>5-Year IRR</b>	1788%	2347%	35%	80%
<b>10-Year IRR</b>	708%	948%	28%	66%
<b>15-Year IRR</b>	645%	865%	28%	66%
<b>20-Year IRR</b>	578%	778%	28%	66%

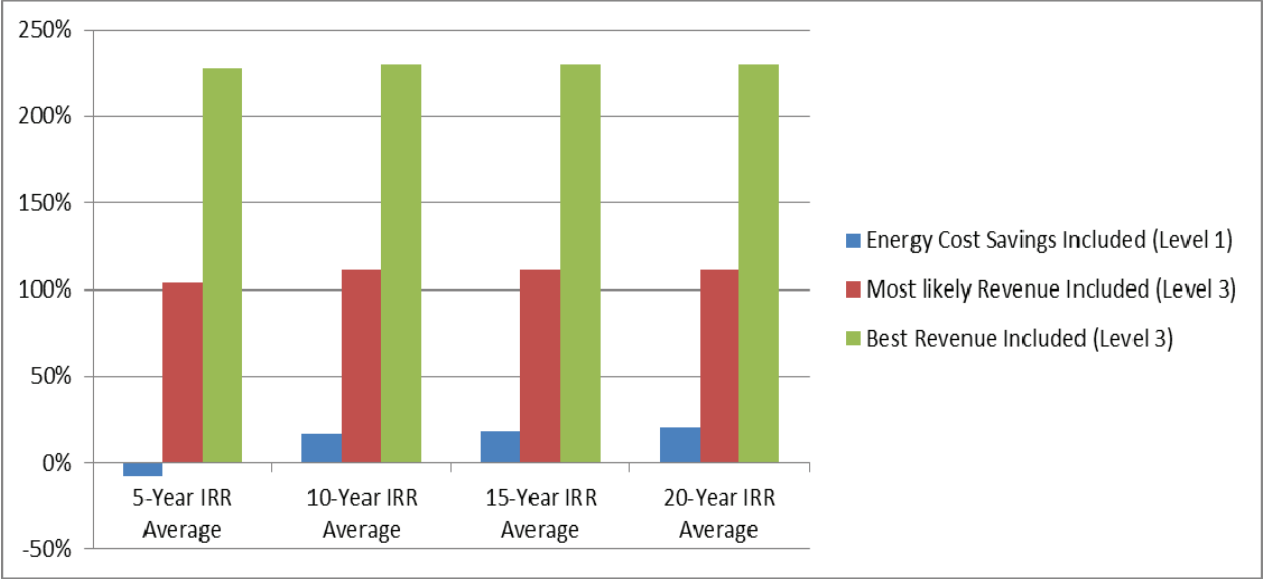
**2) The owner-investor building scenario:** TMC is an owner-investor type building and Davis Construction is the major tenant but not the owner of the building. In this scenario, since the landlord will collect the increased revenue, the entire incremental revenue is included in the financial analysis in addition to energy cost savings. Health and productivity savings are not included.

Figure 6-5, Figure 6-6, and Table 6-2 illustrate the comparison between the outcomes of three financial analysis levels in the owner-investor building scenario to show how the proposed approach might impact the final financial outcomes and ultimately alter the investment decisions:



**Figure 6-5: Impact of Including Revenue on the NPVs – the Owner-Investor Scenario**





**Figure 6-6: Impact of Including Revenue on the IRRs – the Owner-Investor Scenario**

As shown in Table 6-2, the final NPVs and IRRs have increased significantly when this revenue is included in the financial analysis. For example, the average of 5-year NPV in the most-likely case has increased by 973%, from -\$78,550 to +\$686,101. This will make this retrofit option very attractive for a property landlord/investor who requires a positive return in five years; they will not invest in this options based on the negative 5-year NPV.

**Table 6-2: Comparison of the Value-Based Financial Analysis with Level 1 Analysis - the Owner-Occupied Scenario**

<b>Metric (Average)</b>	<b>% Increase in Most-Likely Revenue Case in Compared to Level 1</b>	<b>% Increase in Best Case in Compared to Level 1</b>
<b>5-Year NPV</b>	973%	2404%
<b>10-Year NPV</b>	1701%	4605%
<b>15-Year NPV</b>	1496%	4514%
<b>20-Year NPV</b>	1129%	3675%
<b>5-Year IRR</b>	1454%	3065%
<b>10-Year IRR</b>	558%	1261%
<b>15-Year IRR</b>	506%	1152%
<b>20-Year IRR</b>	451%	1039%

Therefore, by including potential revenue and uncertainties in the assessment process, the proposed framework provides more comprehensive and reliable information about the financial performance of sustainable options and enables decision-makers to enhance the quality of their investment decisions concerning greening their existing income-producing properties.

As the public awareness increases about the full scope benefits of sustainability and their relations to value creation and risk mitigation, and more market evidence becomes available, the value analysis level becomes a more critical part of the financial assessment of sustainability investment. In the future, the financial analysis of sustainable options in real estate investment will not be complete without a full consideration of potential impacts on revenue and risk.

It should be noted that a complete value-based analysis includes consideration of both revenue and risk. In fact, cash flow risk could play a major role in financial performance of sustainable options as risk reduction is one of the most important benefits of sustainability in real estate investment. In the DCF model, the unmitigated risks, such as inflation, construction risk, or market risk, could be incorporated by varying the discount rate and cap rate. The discount rate is the rate of return that investors require to achieve in their investment given the level of risk they are taking. The cap rate a measure of investor demand that reflects the risk associated with projected income from property/residual value. Investors utilized higher discount rates and cap rates in their financial analyses when the investment is riskier, and vice versa. It is expected that lower discount rates and cap rates would be considered in sustainable property valuation due to risk reduction benefits of sustainability investment.

### **6.3 Limitation of Research and Areas of Improvement**

The main purpose of this research is to map a practical assessment procedure in detail that decision-makers need to go through to evaluate the financial performance of sustainable options more completely. The case study attempts to demonstrate a way of quantifying and integrating the value and uncertainty into the financial assessment process. This research is mainly concerned with the development of the process rather than outcomes.

A complete financial assessment of sustainable options involves many areas in which current data/evidence is not sufficient for making reliable assumptions/inputs, for example, the quantitative relationship between sustainable options performance and social benefits such health and productivity savings. These benefits are often ignored in decision-making due to the lack of knowledge or inability of quantifying them in the evaluation process. This research aims to utilize the best available data to develop and demonstrate a more complete assessment procedure in order to assist decision-makers to

acknowledge these social benefits—health and productivity savings—and consider them when evaluating a sustainable options to invest. What is important here is that those benefits will not be ignored in the assessment process of any sustainability investment. In future, as more research will be conducted and more evidence will become available, these benefits could be projected with higher level of confidence. The introduction and inclusion the ranges instead of single-point estimates in the assessment process helps to explain the level of uncertainty associated with these factors.

This research is not intended to create a decision-making tool for sustainability investment in real estate but to explore a detailed assessment process to assist decision-makers to consider factors that are often ignored in current cost-benefit analysis, including value, risk, and uncertainty, when evaluating sustainable options investment.

The proposed framework is applicable for evaluating major green retrofit options for existing income-producing properties from the perspective of private investors and owner-occupants. However, each particular property is unique in nature and might have different priorities in its development of sustainability criteria and performance indicators due to its specific function, characteristics, and market condition. On the other hand, differences in investors, type of decisions, and sustainable features may require different methods for financial analysis and different forms of outcomes. Therefore, it is necessary to develop distinct analysis procedures for evaluating different types of decisions for different types of sustainable properties/features to assist different investors. The methodology of this research can be adaptable for addressing other types of decisions and decision-makers while evaluating the different combinations of sustainable options in other property types.

The case study solely focuses on utilizing an energy simulation program (eQuest) and generating distributions of the energy performance indicators (KWh and KW savings). However, any building performance outcome that is of interest to occupants could play a direct role in the financial performance of a building and therefore, are important to be considered in the performance evaluation. It is not just energy cost saving that matters. For a thorough performance assessment, the existing buildings and retrofit options need to be modeled through different modeling tools in order to evaluate as many performance indicators as possible that might have impacts on occupant performance.

**Limitations in Step 1:** The accuracy of the simulation results in assessing the building performance indicators associated with retrofit options greatly depends on 1) the accuracy of the base model and the thoroughness of the calibration process, 2) the accuracy of modeling inputs related to the performance of the selected retrofit options, and 3) the capability of simulation tools. A thorough calibration process

requires on-site measurements, experimental study, surveys and interviews with occupants, etc., which are beyond the scope of this case study, given its main goal of demonstrating the process. The base model for the case study was mainly developed based on the original drawings of the building. As-built data was not available. No measurement or experimental study was performed for collecting the actual data other than 2009 utility records. No survey or interview was conducted with occupants other than the director of sustainability of Davis Construction for collecting the data in this step. Assumptions for developing multiple base models were made based on the researchers' professional judgments and the interview with the director of sustainability of Davis Construction who was a tenant in the building. Assumptions for the selected retrofit option, the lighting controls package, were made based on the available literature and the manufacturer's manual, and were confirmed with professionals from Lutron Electronics. eQuest, which was used for modeling the lighting controls, involved some limitations in modeling the occupancy sensors. Therefore, the accuracy of simulation outcomes, energy consumptions, is limited to researcher's professional judgment, literature, and opinions of professionals from Lutron Electronics.

**Limitations in Step2:** The case study was not intended to generate any new information about non-cost benefits of green systems, such as comfort, health, and productivity, or their quantitative relationships with financial performance throughout this dissertation. All assumptions related to the impacts of lighting controls on comfort, health, productivity, and security was made based on available literature. For example, health and productivity savings estimates were obtained from the Guidelines for High Performance Buildings by NSF/IUCRC Center for Building Performance and Diagnostics at Carnegie Mellon University. The existing literature on the quantitative relationship between green systems and their building performance are not sufficient to accurately predict their impacts. Therefore, the accuracy of the estimated building performance in the case study is limited to the current literature concerning the quantitative relationship between lighting controls and their non-cost benefits.

**Limitations in Step 3:** A through market research to understand the market response to sustainability is a critical step in determining the incremental value associated with green investment. What matters most is how the space users and investors in the particular sub-market react to benefits of sustainability, green, or energy efficiency investment. If there is a clear indication for higher demand for green buildings or attributes when compared to conventional buildings, there might be premiums for some of the key value variables, if not for all of them. A thorough market research investigation would be done through 1) a detailed analysis of comparable buildings and market evidence; 2) independent surveys among brokers, tenants, investors, owner-occupants, and other stakeholders in the sub-market; and 3) a detailed analysis of historic market trend and forecasts of demand, rents, and other key variables. However, currently market evidence for properties with sustainable features is not sufficient to enable valuers to reliably

predict the incremental value variables. Until sufficient market evidence will be generated, more focus should be placed on independent surveys among real estate stakeholders who are familiar with the sub-market and have experience with sustainable properties. Thus, a database which includes the information/profile of real estate experts in the area of sustainable property valuation / investment could be very helpful.

It is very difficult or impossible at this time to determine a quantitative link between a specific sustainability benefit, such improved productivity or contribution to a LEED certification, and the valuer's judgments about value variables. There might be overlaps when considering some of the non-energy and non-cost benefits of sustainability investment in the value-based analysis. For example, LEED buildings are perceived to have a higher health and productivity, and therefore, when the increased probability of achieving LEED certifications is considered in the value-based analysis, the health and productivity benefits might be already taken into account in the decision-making process. However, there is no valid way to specifically determine the impacts of each benefit on the financial inputs separately.

**Limitations in Step 4:** A complete value-based analysis includes consideration of both revenue and cash flow/investment risk. Real estate people tend to mitigate risk and uncertainty as much as they can through various mechanisms such as insurance, surety, contracts, better planning, integrated design, or commissioning. The market perception of unmitigated risk and uncertainty is reflected in the discount rate and cap rate. A full DCF analysis is typically conducted over a 10 years life cycle. The 11<sup>th</sup> year NOI is capitalized using the cap rate to estimate the property sale price and the net sale/residual value is estimated by deducting various costs such as cost of debt from the property sale price. The net sale along with the NOIs for the 10 years are then discounted to estimate the present value using the discount rate. However, the value-based financial analysis in this case study is conducted over a 20-year life cycle to be consistent and comparable with the cost-based analyses and primarily focuses on including revenue into the cash flow stream. It does not estimate any residual property value, nor includes the cap rate in the analysis. No analysis was conducted for deriving the market value of the subject property and the cap rate estimates were not utilized to estimate the residual value in the financial analysis. Thus, a complete property valuation analysis is required to consider a larger number of financial inputs, including capitalization rate, for assessing the potential impacts on both revenue and risk and capturing the incremental value associated with sustainability investment.

The final financial distributions in this case study are generated based on 75 estimates, three DCF cases by 25 lighting controls savings cases, to be more comparable with distributions previously estimated in the cost-based analysis. Risk analysis software and techniques such as Monte Carlo simulation could be

used to run several iterations, estimate a larger number of outcomes, e.g. 50000 values, and generate more accurate distributions. Therefore, the accuracy of distributions of final financial indicators in the value-based analysis is limited due to the following:

- The opinions of the stake-holders who participated in the survey;
- Insufficient market evidence and limited comparable green buildings data found through CoStar and GBIG databases for the Rockville area;
- Lack of sufficient literature concerning incremental value of green buildings/certifications;
- The limited number of DCF inputs that were analyzed for calculating the incremental revenue;
- Inclusion of incremental revenue and not the residual value (net property price) in the value-based financial analysis—reduced capitalization rate is not considered; and
- Generating distributions in Excel based on 75 estimates without using any risk analysis software.

Finally, this research is a starting point for the creation of an in-depth process for deriving and including value and uncertainty in the financial assessment of sustainable features, and is not considered to be the final product. The dissertation explores the critical challenges, weaknesses, as well as principles of implementing sustainability investment decisions in real estate and provides guidance and solutions to improve the quality of investment decisions, and then tests the application of proposed hypotheses and solutions through a case study on a real life property.

The proposed framework and processes could be extended to incorporate more factors in sustainable property valuation and evaluate the interactive effect of the different combinations of sustainability options with more building performance indicators. It is expected that the developed process serves as foundation for creating improved applied tools and methods that would allow practitioners to better integrate value, risk, and uncertainty into sustainable real estate investment decision-making.

### **6.3.1 Future Research**

Every proposed solution and analytic technique did not turn out perfect, or the execution perhaps too difficult or costly for current practical application, but the work is an admirable step forward, helping guide future research development of improved tools and methods to integrate value and risk into sustainable investment decision-making (Muldavin, 02/05/2012, dissertation review notes).

In order to better demonstrate the application of the proposed model and best selection of the inputs in the mapping process, this study focuses on the development of a process for major energy retrofits of existing

office buildings from the perspective of investors and owner-occupants. Therefore, further research is needed to address the performance of other sustainable options, such as water efficiency, material, etc.

More studies need to be done to establish more robust relationships between sustainable options, building performance factors, and key financial model inputs. More focus needs to be placed on the development of more structured assessment and presentation of the impact of sustainable options on the value creation and risk mitigation at the property-specific level. With further study, more accurate estimation of distributions for factors involved in the valuation process could be created, and more reliable projections for financial performance outcome could be generated.

The broader view of this research is the creation of a specific interactive tool for “Sustainable Buildings Investment Decision Support (SBIDS)” which is able to evaluate all types of sustainable property for various types of decisions and decision-makers in a single tool. SBIDS should be a computerized program (software) which is able to select and evaluate a large number of sustainable options and building performance factors, and their interactive combinations.

Another possible direction is to incorporate the sustainable real estate valuation issues into an emerging technology and a process called Building Information Modeling (BIM)—a collaborative tool in the design and building communities. Currently, BIM is managing the project design data (3D model) along with schedule/time (4D model) and cost (5D model) to visualize and simulate the day-by-day progress of a given project, and identify the possible issues or conflicts ahead of time. This helps all parties involved in a project including architects, engineers, general contractors and subcontractors in making better decisions from the early stages of planning and design all the way through construction and operation. By incorporating issues related to sustainable real estate valuation, financial models, green buildings’ performance and their related financial performance, and issues related to risk and uncertainty into the current 5D model, investors and lenders can enter into this collaborative process as well. Therefore, sustainable property valuation and financial models can be another dimension that can be added to BIM to enhance its capabilities of evaluating sustainability investments or financing decisions.

#### 6.4 **Author’s Biography and Research Dissemination**

In 2007, the author, Alireza (Ali) Bozorgi, joined Virginia Tech for a PhD program in Design Research in the College of Architecture and Urban Studies. While conducting his PhD studies, he has been pursuing an MBA in the Pamplin College of Business at Virginia Tech to gain a deeper understanding of finance, valuation, risk analysis, and investment decision making. His MBA studies will provide him with the necessary knowledge and skills required to conduct an interdisciplinary research in one of the hottest



topics in the building industry, that of the area of sustainability and green building investment. He also received a Master of Science in Architecture with a focus on Building Science from the School of Architecture + Design in 2009. Since May 2010, Ali has been working for the energy efficiency division of ICF International, a leading global consulting company, where he has been involved in energy performance assessment, simulation, cost-effectiveness analysis, energy efficiency potential modeling, demand side management, and energy policy and standards analysis.

During his studies at Virginia Tech, Ali obtained the ‘Construction Manager in Training’ (CMIT) and the ‘LEED Green Associate’ accreditations. He is the recipient of several nationally recognized scholarships and awards, including: the James R. Webb American Real Estate Society Foundation fund, the Alpha Kappa Alpha scholarship, the Pension Real Estate Association scholarship, American Council for an Energy Efficiency Economy fund, the Construction Management Association of America scholarships, the ARCC king student medal for Excellence in Architectural & Environmental Design Research, the GSA Research Symposium and Exhibition award, and Student Initiated Research Grant Award from College of Architecture and Urban Studies at Virginia Tech.

Prior to Virginia Tech, Ali had received a Bachelor in Architectural Engineering and a Master of Architectural Engineering with a focus on Landscap and Environmental Design Planning. He was an Assistant Professor in the School of Architecture and Urban Design at Shiraz Azad University where he taught several design studios. While pursuing his academic career, Ali was involved in the development, design, and construction of several multifamily residential buildings. He also worked for P.M.Sh. Engineering Consultants as an architect and design manager for about three years, where he was responsible for managing the design process of several large-scaled projects, supervising a group of architects and CADD technicians, presenting the projects to clients and the City Hall Architecture committee to obtain their approvals. He was recognized as a distinguished architect by the Tehran City Hall.

The combination of Ali’s background in architectural engineering, building science, finance, and business has provided him a unique perspective to look at the sustainability and energy efficiency from the investment decision-making standpoint and tackle the challenge of integrating technical simulation tools with sophisticated financial and risk analysis through his PhD research. Ali has developed a new systematic framework for assessing the financial performance of sustainable options in the context of value and risk. The framework is a first-of-its-kind approach to link building performance evaluation into valuation and investment decision-making while explicitly including uncertainty.



In an effort to disseminate this research and solicit constructive feedback from academics and industry professionals in fields of energy efficiency and real estate, Ali has presented his findings in several peer-reviewed national and international venues, including the Improving Energy Efficiency in Commercial Buildings (IEECB) conference, the American Council for an Energy Efficiency Economy (ACEEE) summer study, American Real Estate Society (ARES) annual meeting, the Architectural Research Center Consortium (ARCC) annual meeting, and the Graduate Student Assembly (GSA) Research Symposium and Exposition at Virginia Tech. Thus, the quality of his research has been reviewed and controlled several times during the process. Below, a list of his publications, presentations, and posters associated with his PhD research is presented:

1. Bozorgi, A., “**A New Process for Assessing Financial Performance and Uncertainty Associated with Energy Efficiency Systems and Strategies**”, Poster presented at 26<sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech, Blacksburg, VA, March 24<sup>th</sup>, 2010
2. Bozorgi, A. and Jones, J. R., “**A Framework for Estimating and Communicating the Financial Performance of Energy Efficiency Improvements in Existing Commercial Buildings While Considering Risk and Uncertainty**” published in the conference proceedings and presented in the Sixth International Conference on IEECB: Frankfurt, Germany, April 12-14, 2010, pp.91-103.
3. Bozorgi, A. and Jones, J. R., “**A Valuation Process for Estimating and Communicating the Financial Performance along with Uncertainty associated with Sustainable Options in Real Estate Investment**” presented in the 2010 ARES Annual Meeting: Naples, FL, April 14-17, 2010.
4. Bozorgi, A., Jones, J. R., “**A Framework for Linking Projected Energy Performance Uncertainty with Investment Decision-making**” published in the conference proceedings and presented in the 2010 ACEEE Building Summer Study: Pacific Grove, California, August 15-20, 2010, pp. 3-14 – 2-27.
5. Bozorgi, A. “**The Next Generation of Building Energy Simulation Programs: A New Eight-Step Procedure for Deriving the Financial Value and Risk of Energy Retrofit Options**”, Poster presented at 27<sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech, Blacksburg, VA, March 24<sup>th</sup>, 2011
6. Bozorgi, A. and Jones, J. R., “**A Case Study on the Integration of Value and Uncertainty in the Green Retrofit Options Analysis**” will be presented in a doctoral seminar in the 2011 ARES Annual Meeting: Seattle, WA, April 12-16, 2011.

7. Bozorgi, A. and Jones, J. R., **“What Else Do Design Professionals Need to Know About Sustainable Building Investment? A New Assessment Approach”** published in the conference proceedings and presented in of The 2011 ARCC Annual Meeting: Detroit, MI, April 20-24, 2011, pp. 407-417.
8. Bozorgi, A. and Jones, J. R., **“Improving the Quality of Energy Retrofits Investment Decisions by Including Uncertainty in Energy Modeling Process – A Case Study”** will be published in the conference proceedings and will be presented in the Seventh International Conference on IECEB: Frankfurt, Germany, April 18-19, 2010.
9. Bozorgi, A. and Jones, J. R., **“A Three-Level Analysis Approach for Deriving the True Financial Performance of Energy Retrofit Options”** is currently under development to be submitted to a related peer-review conference.
10. Bozorgi, A., Jones, J. R., **“Integrating Value and Uncertainty in the Sustainable Options Analysis in Real Estate Investment”** is currently under review in the Property Management (Journal) Emerald Publishing Group.
11. Bozorgi, A., Jones, J. R., **“A Case Study to Demonstrate a New Value-Based Framework for a More Comprehensive Assessment of the Financial Performance of a Green Retrofit Option in an Existing Office Building”** is currently under development to be submitted to the Journal of Sustainable Real Estate.

Ali has published others papers in the area of energy efficiency policy and Building Information Modeling (BIM). Following full papers, posters, and abstracts are included in APPENDIX G.

Full papers:

1. A Framework for Estimating and Communicating the Financial Performance of Energy Efficiency Improvements in Existing Commercial Buildings While Considering Risk and Uncertainty
2. A Framework for Linking Projected Energy Performance Uncertainty with Investment Decision-making
3. What Else Do Design Professionals Need to Know About Sustainable Building Investment? A New Assessment Approach
4. Improving the Quality of Energy Retrofits Investment Decisions by Including Uncertainty in Energy Modeling Process – A Case Study

Posters:

1. A New Process for Assessing Financial Performance and Uncertainty Associated with Energy Efficiency Systems and Strategies
2. The Next Generation of Building Energy Simulation Programs: A New Eight-Step Procedure for Deriving the Financial Value and Risk of Energy Retrofit Options”

Abstracts:

1. Integrating Value and Uncertainty in the Sustainable Options Analysis in Real Estate Investment
2. A Three-Level Analysis Approach for Deriving the True Financial Performance of Energy Retrofit Options

# **APPENDICES**

## **APPENDIX A: Lighting Control Systems Analytics (LCSA) Model**

The Lighting Control Systems Analytics (LCSA), an excel-based model, was developed for estimating the final lighting controls energy savings and for performing economic analyses for each case. It takes the KWh and KW estimates from energy models as inputs, and perform a comprehensive analysis to estimate energy savings and financial performance indicators such as simple payback, simple ROI, NPV and IRR as outputs.

LCSA is a single excel model with several tabs that are developed for various purposes including estimating the errors indicators of the base models, forecasting the Pepco electricity rates, entering building characteristics and lighting controls assumptions, estimating the savings and conducting LCCA on five lighting controls cases for each base mode, estimating health and productivity savings, and generating the distribution of financial outcomes, presented in Chapter 4.

In this appendix, parts of five tabs are presented:

- Estimation of Errors Indicators of the Five Selected Base Models
- Pepco Electricity Rate Assumption and Forecast
- Energy Savings, Simple Cost, and LCC Analysis for BM (-2)
- Summary of LCCA
- Health and Productivity Savings Analysis

Table 1: Estimation of Errors Indicators of the Five Selected Base Models

Comply with FRMP guideline and very close to ASHREA and IPMVP														
	261.7	230.3	217.8	162.5	151	160.9	161.5	174.7	155.1	153.7	198.5	248.8	2,276.50	
<b>BM (0): Best Model</b>														
Measured Monthly Energy Use 2009	285180.97	227532.86	213519.68	165108.00	160737.10	153264.00	160913.23	174959.03	163215.00	166683.87	185770.00	219547.74	2276431.47 Mean month=	189702.6
Higher Consumption: Simulated OC 76 OH2 UC 76 UH 70 with cold deck rest constant 60	261700.00	230300.00	217800.00	162500.00	151000.00	160900.00	161500.00	174700.00	155100.00	153700.00	198500.00	248800.00	2276500.00	
M-S	23480.97	-2767.14	-4280.32	2608.00	9737.10	-7636.00	-586.77	259.03	8115.00	12983.87	-12730.00	-29252.26		
<b>EER month= (M-S)/M </b>	<b>8.23%</b>	<b>-1.22%</b>	<b>-2.00%</b>	<b>1.58%</b>	<b>6.06%</b>	<b>-4.98%</b>	<b>-0.36%</b>	<b>0.15%</b>	<b>4.97%</b>	<b>7.79%</b>	<b>-6.85%</b>	<b>-13.32%</b>		
EER month/12	0.69%	-0.10%	-0.17%	0.13%	0.50%	-0.42%	-0.03%	0.01%	0.41%	0.65%	-0.57%	-1.11%	<b>EER year =</b>	<b>0.00%</b>
(M-S)^2	551355846.10	7657079.59	18321161.39	6801664.00	94811053.59	58308496.00	344303.95	67097.71	65853225.00	168580905.31	162052900.00	855694601.87	RSME month=	12877.14 <b>CV (RMSE m)=</b> <b>6.79%</b>
	265.4	233.2	222.8	174.9	157.4	158.2	155.5	169.7	154.1	166.8	206.5	251	2,315.60	
<b>BM (+2): Good model: highest energy use prediction</b>														
Measured Monthly Energy Use 2009	285180.97	227532.86	213519.68	165108.00	160737.10	153264.00	160913.23	174959.03	163215.00	166683.87	185770.00	219547.74	2276431.47 Mean month=	189702.6
Higher Consumption: Simulated OC 76 OH2 UC 76 UH 70 with cold deck rest constant 58 EER 14&15, MF 25 and 20	265400.00	233200.00	222800.00	174900.00	157400.00	158200.00	155500.00	169700.00	154100.00	166800.00	206500.00	251000.00	2315500.00	
M-S	19780.97	-5667.14	-9280.32	-9792.00	3337.10	-4936.00	5413.23	5259.03	9115.00	-116.13	-20730.00	-31452.26		
<b>EER month= (M-S)/M </b>	<b>6.94%</b>	<b>-2.49%</b>	<b>-4.35%</b>	<b>-5.93%</b>	<b>2.08%</b>	<b>-3.22%</b>	<b>3.36%</b>	<b>3.01%</b>	<b>5.58%</b>	<b>-0.07%</b>	<b>-11.16%</b>	<b>-14.33%</b>		
EER month/12	0.58%	-0.21%	-0.36%	-0.49%	0.17%	-0.27%	0.28%	0.25%	0.47%	-0.01%	-0.93%	-1.19%	<b>EER year =</b>	<b>-1.71%</b>
(M-S)^2	391286684.81	32116508.16	86124387.20	95883264.00	11136214.88	24364096.00	29303013.63	27657420.29	83083225.00	13485.95	429732900.00	989244537.36	RSME month=	13539.90 <b>CV (RMSE m)=</b> <b>7.14%</b>
	263.2	232.8	220.4	168.8	153.5	158.2	158.2	170.8	153.7	159.4	202.8	249.8	2,291.50	
<b>BM (+1): Good model: Higher energy use prediction</b>														
Measured Monthly Energy Use 2009	285180.97	227532.86	213519.68	165108.00	160737.10	153264.00	160913.23	174959.03	163215.00	166683.87	185770.00	219547.74	2276431.47 Mean month=	189702.6
Simulated OC 75 OH 68 UC75 UH 68 with cold deck rest constant 55 MAF30&20 EER 13&14	263200.00	232800.00	220400.00	168800.00	153500.00	158200.00	158200.00	170800.00	153700.00	159400.00	202800.00	249800.00	2291600.00	
M-S	21980.97	-5267.14	-6880.32	-3692.00	7237.10	-4936.00	2713.23	4159.03	9515.00	7283.87	-17030.00	-30252.26		
<b>EER month= (M-S)/M </b>	<b>7.71%</b>	<b>-2.31%</b>	<b>-3.22%</b>	<b>-2.24%</b>	<b>4.50%</b>	<b>-3.22%</b>	<b>1.69%</b>	<b>2.38%</b>	<b>5.83%</b>	<b>4.37%</b>	<b>-9.17%</b>	<b>-13.78%</b>		
EER month/12	0.64%	-0.19%	-0.27%	-0.19%	0.38%	-0.27%	0.14%	0.20%	0.49%	0.36%	-0.76%	-1.15%	<b>EER year =</b>	<b>-0.62%</b>
(M-S)^2	483162942.87	27742793.88	47338838.81	13630864.00	52375569.72	24364096.00	7361594.28	17297549.32	90535225.00	53054776.27	290020900.00	915199118.00	RSME month=	12981.03 <b>CV (RMSE m)=</b> <b>6.84%</b>
	252.1	220.2	203	147.8	145.2	160.2	160.6	175	153.7	144.4	180.8	238.7	2,181.60	
<b>BM (-1): Good model: Lower energy use prediction</b>														
Measured Monthly Energy Use 2009	285180.97	227532.86	213519.68	165108.00	160737.10	153264.00	160913.23	174959.03	163215.00	166683.87	185770.00	219547.74	2276431.47 Mean month=	189702.6
Lower Consumption: Simulated OC76 OH70 UC82 UH64 EER11&12 MF50&40 CDR61	252100.00	220200.00	203000.00	147800.00	145200.00	160200.00	160600.00	175000.00	153700.00	144400.00	180800.00	238700.00	2181700.00	
M-S	33080.97	7332.86	10519.68	17308.00	15537.10	-6936.00	313.23	-40.97	9515.00	22283.87	4970.00	-19152.26		
<b>EER month= (M-S)/M </b>	<b>11.60%</b>	<b>3.22%</b>	<b>4.93%</b>	<b>10.48%</b>	<b>9.67%</b>	<b>-4.53%</b>	<b>0.19%</b>	<b>-0.02%</b>	<b>5.83%</b>	<b>13.37%</b>	<b>2.68%</b>	<b>-8.72%</b>		
EER month/12	0.97%	0.27%	0.41%	0.87%	0.81%	-0.38%	0.02%	0.00%	0.49%	1.11%	0.22%	-0.73%	<b>EER year =</b>	<b>4.06%</b>
(M-S)^2	1094350426.74	53770793.88	110663613.01	299566864.00	241401376.17	48108096.00	98110.41	1678.36	90535225.00	496570905.31	24700900.00	366808988.97	RSME month=	15347.58 <b>CV (RMSE m)=</b> <b>8.09%</b>
	244.4	213.4	200.5	150.4	142	154.4	154.5	167.9	147.6	144.4	182.8	228.5	2,130.90	
<b>BM (-2): Good model: lowest energy use prediction</b>														
Measured Monthly Energy Use 2009	285180.97	227532.86	213519.68	165108.00	160737.10	153264.00	160913.23	174959.03	163215.00	166683.87	185770.00	219547.74	2276431.47 Mean month=	189702.6
Simulated OC 76 OH 70 UC80 UH 68 with cold deck rest constant 60 MAF 25&20	244400.00	213400.00	200500.00	150400.00	142000.00	154400.00	154500.00	167900.00	147600.00	144400.00	182800.00	228500.00	2130800.00	
M-S	40780.97	14132.86	13019.68	14708.00	18737.10	-1136.00	6413.23	7059.03	15615.00	22283.87	2970.00	-8952.26		
<b>EER month= (M-S)/M </b>	<b>14.30%</b>	<b>6.21%</b>	<b>6.10%</b>	<b>8.91%</b>	<b>11.66%</b>	<b>-0.74%</b>	<b>3.99%</b>	<b>4.03%</b>	<b>9.57%</b>	<b>13.37%</b>	<b>1.60%</b>	<b>-4.08%</b>		
EER month/12	1.19%	0.52%	0.51%	0.74%	0.97%	-0.06%	0.33%	0.34%	0.80%	1.11%	0.13%	-0.34%	<b>EER year =</b>	<b>6.24%</b>
(M-S)^2	1663087329.97	199737651.02	169512000.10	216325264.00	351078795.53	1290496.00	41129465.24	49829936.42	243828225.00	496570905.31	8820900.00	80142924.45	RSME month=	17130.27 <b>CV (RMSE m)=</b> <b>9.03%</b>

	BM (-2): Lowest energy use prediction	BM (-1): Lower energy use prediction	BM (0): Best Model	BM (+1): Higher energy use prediction	BM (+2): Highest energy use prediction
Yearly energy use prediction (MWH)	2,130.90	2,181.60	2,276.50	2,291.50	2,315.60
EER month	-4.1% to +14.3%	-8.7% to +11.6%	-13.3% to +8.2%	-14.3% to +6.9%	-13.8% to +7.7%
EER year	6.24%	4.06%	0.00%	-0.62%	-1.70%
CV (RMSE m)	9.03%	8.09%	6.79%	6.84%	7.14%

Table 2: Pepco Electricity Rate Assumption and Forecast

Source: Pepco Rate Schedule, unless otherwise stated

<u>Generation</u>					Average	Average
	June-Oct	Nov-May	June-Oct	Nov-May	June-Oct	Nov-May
On Peak	\$0.08148	\$0.07686	\$0.08348	\$0.08082	\$0.08115	\$0.08017
Intermediate	\$0.08148	\$0.07686	\$0.08348	\$0.08082		
Off Peak	\$0.08148	\$0.07686	\$0.08348	\$0.08082		

<u>Transmission</u>	Number of months		Tax Included	
	June-Oct	Nov-May	June-Oct	Nov-May
All KWh	\$0.00231	\$0.00231	\$0.00236	\$0.00236
KW Charge On-peak	\$0.72040		\$0.73510	
KW Charge Maximum	\$0.28850	\$0.28850	\$0.29439	\$0.29439
Tax			2.0408%	

<u>Distribution Service</u>		
All KWh	\$0.01084	
On peak KW	\$2.75800	
On Maximum	\$1.05820	\$1.05820

<u>Other Non-tariff Surcharge</u>		
Prince Georges County Tax (1)	\$0.00745	\$0.00745
Maryland Environmental Surcharge	\$0.00015	\$0.00015
Montgomery County Surcharge	\$0.02259	\$0.02259
Delivery Tax	\$0.00062	\$0.00062
GENERATION PROCUREMENT CREDIT/CHARGE	\$0.00018	\$0.00018
EmPower MD Charge	\$0.00017	\$0.00017
<b>Total KWh</b>	<b>\$0.1255</b>	<b>\$0.1137</b>
<b>KW</b>	<b>\$4.846</b>	<b>\$1.353</b>
<b>Months Weights</b>	<b>41.7%</b>	<b>58.3%</b>

<b>Weighted Average Charge /KWH</b>	<b>\$0.12</b>
<b>Weighted Average Charge /KH</b>	<b>\$2.81</b>
<b>Electricity Escalation Rate</b>	<b>3.40%</b>

Inflation Rate (Source: ICF professional judgment)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Yearly Weighted Average Charge /KWH	\$0.12	\$0.12	\$0.13	\$0.13	\$0.14	\$0.14	\$0.14	\$0.15	\$0.15	\$0.16	\$0.17	\$0.17	\$0.18	\$0.18	\$0.19	\$0.20	\$0.20	\$0.21	\$0.22	\$0.22	\$0.23
Yearly Wighted Average Charge /KH	\$2.81	\$2.90	\$3.00	\$3.10	\$3.21	\$3.32	\$3.43	\$3.55	\$3.67	\$3.79	\$3.92	\$4.06	\$4.19	\$4.34	\$4.48	\$4.64	\$4.79	\$4.96	\$5.13	\$5.30	\$5.48

Table 3: Energy Savings, Simple Cost, and LCC Analysis for BM (-2)

Lighting Control Solutions - including daylight harvesting, occupancy sensors, high end tuning, personal dimming control strategies  
 Base Model -2

Variables	Cases 1	Cases 2	Cases 3	Cases 4	Cases 5
Lighting control methods (minimum light level)	5%	10%	10%	20%	20%
Lighting power density	1.1	1.3	1.5	1.5	1.6
Occupancy sensors (Schedule)	Low	Low-Medium	Medium	Medium-High	High
High end tuning strategy	21.0%	20.5%	20.0%	19.5%	19.0%
Personal dimming control	17.0%	16.0%	15.0%	14.0%	13.0%
Demand prediction adjustment multiplier	0.8	0.86	0.92	0.96	1

BM (-2): Lowest energy use prediction	
Occupied Cooling	76
Occupied Heating	70
Un-occupied Cooling	80
Un-occupied Heating	68
Cold Deck Reset	constant 60
EER HVAC 1 & 2	12&13
Yearly energy use prediction (KWH*1000)	2,130.90
EER month	> ±15%
EER year	6.24%
CV (RMSE m)	9.03%

	Modeled Area Lights MWH	Modeled Total MWH	Modeled Area Lights Demand (KW)		Adjusted Area Lights Demand (KW)		Adjusted Total Demand (KW)		MWH Savings - Daylight&occ sensors		KWH Savings - Daylight&occ sensors		Percentage of Lighting MWH Savings - Daylight&occ sensors	High end tuning - MWH reduction	High end tuning - KW reduction	Personal dimming control - MWH reduction	Personal dimming control - KW reduction	Total lighting control MWH savings	Percentage of Lighting Total MWH Savings	Total lighting control KW savings	Total lighting control \$ savings	Total Inverment Cost = Initial Capital - Incentive				
			Simple Payback	Simple ROI	\$ Saving per SqFt	\$ Saving per Employee	\$49,829	\$278,605	5.6	17.89%	\$0.56	\$208														
Base Model -2	439.7	2,130.90	1,333.40	8,388.70	1,333.40	8,388.70	252.10	2,918.58	57.33%	51.74	122.94	41.89	99.52	345.73	78.63%	3,141.05	\$49,829	\$278,605	5.6	17.89%	\$0.56	\$208				
Case 1	246.4	1,878.80	731.80	6,360.60	585.44	5,470.12	197.30	2,792.51	44.87%	57.50	146.81	44.88	135.24	299.68	68.16%	3,053.80	\$44,122	\$288,298	6.5	15.30%	\$0.50	\$185				
Case 2	280.5	1,933.60	832.70	6,507.20	716.12	5,596.19	163.80	2,312.74	37.25%	65.98	180.32	49.49	135.24	279.27	63.51%	2,628.30	\$40,505	\$292,968	7.2	13.83%	\$0.45	\$169				
Case 3	329.9	1,967.10	980.00	6,604.30	901.60	6,075.96	149.20	2,006.43	33.93%	65.29	186.06	46.87	133.58	261.36	59.44%	2,326.07	\$37,532	\$289,642	7.7	12.96%	\$0.42	\$157				
Case 4	334.8	1,981.70	993.90	6,648.20	954.14	6,382.27	98.30	1,586.50	22.36%	69.50	207.06	47.55	141.67	215.36	48.98%	1,935.24	\$30,978	\$280,460	9.1	11.05%	\$0.35	\$130				
Case 5	365.8	2,032.60	1,089.80	6,802.20	1,089.80	6,802.20	172.14	2,323.35	39.15%	62.00	168.64	46.14	124.92	280.28	63.74%	2,616.91	\$40,593	\$285,995	7.2	14.20%	\$0.46	\$170				
Average	332.85	1,987.45	993.60	6,885.20	930.08	6,452.57	172.14	2,323.35	39.15%	62.00	168.64	46.14	124.92	280.28	63.74%	2,616.91	\$40,593	\$285,995	7.2	14.20%	\$0.46	\$170				
Yearly Lighting \$ Savings 2012-2031	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031						
Case 1	\$51,523	\$53,275	\$55,086	\$56,959	\$58,895	\$60,898	\$62,968	\$65,109	\$67,323	\$69,612	\$71,979	\$74,426	\$76,957	\$79,573	\$82,279	\$85,076	\$87,969	\$90,960	\$94,052	\$97,250						
Case 2	\$45,622	\$47,173	\$48,777	\$50,435	\$52,150	\$53,923	\$55,757	\$57,652	\$59,613	\$61,639	\$63,735	\$65,902	\$68,143	\$70,460	\$72,855	\$75,332	\$77,894	\$80,542	\$83,281	\$86,112						
Case 3	\$41,882	\$43,306	\$44,779	\$46,301	\$47,875	\$49,503	\$51,186	\$52,926	\$54,726	\$56,587	\$58,511	\$60,500	\$62,557	\$64,684	\$66,883	\$69,157	\$71,508	\$73,940	\$76,454	\$79,053						
Case 4	\$38,808	\$40,128	\$41,492	\$42,903	\$44,362	\$45,870	\$47,430	\$49,042	\$50,710	\$52,434	\$54,216	\$56,060	\$57,966	\$59,937	\$61,974	\$64,082	\$66,260	\$68,513	\$70,843	\$73,251						
Case 5	\$32,032	\$33,121	\$34,247	\$35,411	\$36,615	\$37,860	\$39,147	\$40,478	\$41,855	\$43,278	\$44,749	\$46,271	\$47,844	\$49,470	\$51,152	\$52,892	\$54,690	\$56,549	\$58,472	\$60,460						
Average	\$41,973	\$43,400	\$44,876	\$46,402	\$47,980	\$49,611	\$51,298	\$53,042	\$54,845	\$56,710	\$58,638	\$60,632	\$62,693	\$64,825	\$67,029	\$69,308	\$71,664	\$74,101	\$76,620	\$79,225						

Life Cycle Cost Analysis (LCCA) - BM -2

20 Years Cash Flow		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Case 1	(\$227,082)	\$54,275	\$56,086	\$128,187	\$58,895	\$60,898	\$62,968	\$65,109	\$67,323	\$69,612	\$71,979	\$74,426	\$76,957	\$79,573	(\$77,984)	\$85,076	\$87,969	\$90,960	\$94,052	\$97,250	
Case 2	(\$242,676)	\$48,073	\$49,677	\$51,335	\$132,282	\$53,923	\$55,757	\$57,652	\$59,613	\$61,639	\$63,735	\$65,902	\$68,143	(\$98,707)	\$72,855	\$75,332	\$77,894	\$80,542	\$83,281	\$86,112	
Case 3	(\$251,085)	\$44,106	\$45,579	\$47,101	\$48,675	\$138,538	\$51,186	\$52,926	\$54,726	\$56,587	\$58,511	\$60,500	(\$115,513)	\$64,684	\$66,883	\$69,157	\$71,508	\$73,940	\$76,454	\$79,053	
Case 4	(\$250,834)	\$40,828	\$42,192	\$43,603	\$45,062	\$46,570	\$48,136	\$49,748	\$51,404	\$53,110	\$54,866	(\$130,914)	\$57,676	\$59,937	\$61,974	\$64,082	\$66,260	\$68,513	\$70,843	\$73,251	
Case 5	(\$248,429)	\$33,721	\$34,847	\$36,011	\$37,215	\$38,460	\$39,747	\$41,127	\$42,552	\$44,024	\$45,543	(\$146,676)	\$46,271	\$47,844	\$49,470	\$51,152	\$52,892	\$54,690	\$56,549	\$58,472	\$60,460
Average	(\$244,021)	\$44,200	\$45,676	\$61,247	\$64,426	\$67,678	\$71,005	\$74,410	\$78,845	\$83,310	\$87,805	\$92,330	\$96,895	\$101,500	\$106,145	\$109,930	\$113,855	\$117,920	\$122,125	\$126,470	
20 Years Cash Flow		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Case 1	\$0	(\$188,704)	\$56,086	\$128,187	\$58,895	\$60,898	\$62,968	\$65,109	\$67,323	\$69,612	\$71,979	\$74,426	\$76,957	\$79,573	(\$77,984)	\$85,076	\$87,969	\$90,960	\$94,052	\$97,250	
Case 2	\$0	(\$212,804)	\$49,677	\$51,335	\$132,282	\$53,923	\$55,757	\$57,652	\$59,613	\$61,639	\$63,735	\$65,902	\$68,143	(\$98,707)	\$72,855	\$75,332	\$77,894	\$80,542	\$83,281	\$86,112	
Case 3	\$0	(\$227,066)	\$45,579	\$47,101	\$48,675	\$138,538	\$51,186	\$52,926	\$54,726	\$56,587	\$58,511	\$60,500	(\$115,513)	\$64,684	\$66,883	\$69,157	\$71,508	\$73,940	\$76,454	\$79,053	
Case 4	\$0	(\$231,327)	\$42,192	\$43,603	\$45,062	\$46,570	\$48,136	\$49,748	\$51,404	\$53,110	\$54,866	(\$130,914)	\$57,676	\$59,937	\$61,974	\$64,082	\$66,260	\$68,513	\$70,843	\$73,251	
Case 5	\$0	(\$237,067)	\$34,847	\$36,011	\$37,215	\$38,460	\$39,747	\$41,127	\$42,552	\$44,024	\$45,543	(\$146,676)	\$46,271	\$47,844	\$49,470	\$51,152	\$52,892	\$54,690	\$56,549	\$58,472	\$60,460
Average	\$0	(\$219,393)	\$45,676	\$61,247	\$64,426	\$67,678	\$71,005	\$74,410	\$78,845	\$83,310	\$87,805	\$92,330	\$96,895	\$101,500	\$106,145	\$109,930	\$113,855	\$117,920	\$122,125	\$126,470	

LCCA where heat and productivity savings are included- BM -2

Yearly Cash Flow		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Case 1	\$160,894	\$416,870	\$394,960	\$444,891	\$354,881	\$337,520	\$321,494	\$306,722	\$293,129	\$280,646	\$269,207	\$258,751	\$249,223	\$240,570	\$232,480	\$225,697	\$219,990	\$213,783	\$208,841	\$204,529	
Case 2	\$67,227	\$336,355	\$317,846	\$300,795	\$364,338	\$269,789	\$256,562	\$244,448	\$233,376	\$223,280	\$214,098	\$205,775	\$198,257	\$22,330	\$185,447	\$180,069	\$175,323	\$171,174	\$167,590	\$164,539	
Case 3	(\$57,495)	\$223,356	\$211,551	\$200,779	\$190,970	\$270,292	\$173,181	\$165,884	\$159,317	\$153,430	\$148,180	\$143,527	(\$38,636)	\$135,867	\$132,793	\$130,185	\$128,016	\$126,261	\$124,899	\$123,910	
Case 4	(\$153,640)	\$130,407	\$124,754	\$119,696	\$115,194	\$111,208	\$108,942	\$103,949	\$101,315	\$99,075	\$97,204	(\$91,294)	\$94,482	\$93,592	\$92,990	\$92,670	\$92,798	\$93,225	\$93,880		
Case 5	(\$199,832)	\$78,305	\$75,750	\$73,537	\$71,642	\$70,045	\$68,724	\$173,904	\$66,244	\$65,653	(\$126,148)	\$65,103	\$65,122	\$65,322	\$65,695	\$66,233	\$66,930	\$67,779	\$68,774	\$69,912	
Average	(\$36,569)	\$237,059	\$224,972	\$227,940	\$219,405	\$211,771	\$204,981	\$198,982	\$190,676	\$184,417	\$180,508	\$176,973	\$173,689	\$171,536	\$169,882	\$168,971	\$168,454	\$168,359	\$168,266	\$168,134	
20 Years Cash Flow		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Case 1	\$0	\$589,026.41	\$394,960	\$444,891	\$354,881	\$337,520	\$321,494	\$306,722	\$293,129	\$280,646	\$269,207	\$258,751	\$249,223	\$240,570	\$232,480	\$225,697	\$219,990	\$213,783	\$208,841	\$204,529	
Case 2	\$0	\$408,624.59	\$317,846	\$300,795	\$364,338	\$269,789	\$256,562	\$244,448	\$233,376	\$223,280	\$214,098	\$205,775	\$198,257	\$22,330	\$185,447	\$180,069	\$175,323	\$171,174	\$167,590	\$164,539	
Case 3	\$0	\$161,261.12	\$211,551	\$200,779	\$190,970	\$270,292	\$173,181	\$165,884	\$159,317	\$153,430	\$148,180	\$143,527	(\$38,636)	\$135,867	\$132,793	\$130,185	\$128,016	\$126,261	\$124,899	\$123,910	
Case 4	\$0	(\$36,292.74)	\$124,754	\$119,696	\$115,194	\$111,208	\$108,942	\$103,949	\$101,315	\$99,075	\$97,204	(\$91,294)	\$94,482	\$93,592	\$92,990	\$92,670	\$92,798	\$93,225	\$93,880		
Case 5	\$0	(\$139,512.06)	\$75,750	\$73,537	\$71,642	\$70,045	\$68,724	\$173,904	\$66,244	\$65,653	(\$126,148)	\$65,103	\$65,122	\$65,322	\$65,6						

Table 4: Summary of LCCA

	BM (-2): Lowest energy use prediction	BM (-1): Lower energy use prediction	BM (0): Best Model	BM (+1): Higher energy use prediction	BM (+2): Highest energy use prediction	Min	Max	Delta	Average	Min - BMO	Max - BMO	Minimum Impact of modeling with different base cases = (Min - BMO) / BMO	Maximum Impact of modeling with different base cases = (Max - BMO) / BMO
						1	2	3	4	5	6	7	8
<b>1 Total \$ Savings</b>													
Case 1	\$49,829	\$46,439	\$47,183	\$48,536	\$46,514	\$46,439	\$49,829	\$3,390	\$47,700	-\$744	\$2,646	-2%	6%
Case 2	\$44,122	\$40,708	\$41,153	\$42,481	\$40,455	\$40,455	\$44,122	\$3,667	\$41,784	-\$698	\$2,969	-2%	7%
Case 3	\$40,505	\$36,851	\$37,304	\$38,811	\$36,732	\$36,732	\$40,505	\$3,773	\$38,040	-\$572	\$3,201	-2%	9%
Case 4	\$37,532	\$33,727	\$34,227	\$35,770	\$33,681	\$33,681	\$37,532	\$3,851	\$34,987	-\$546	\$3,305	-2%	10%
Case 5	\$30,978	\$27,112	\$27,415	\$29,035	\$26,975	\$26,975	\$30,978	\$4,003	\$28,303	-\$440	\$3,563	-2%	13%
Average	\$40,593	\$36,967	\$37,456	\$38,927	\$36,871	\$36,856	\$40,593	\$3,737	\$38,163	-\$600	\$3,137	-2%	9%
<b>2 Simple Paybacks</b>													
Case 1	5.6	6.0	5.9	5.7	6.0	5.6	6.0	0.4	5.8	-0.3	0.1	-5%	2%
Case 2	6.5	7.1	7.0	6.8	7.1	6.5	7.1	0.6	6.9	-0.5	0.1	-7%	2%
Case 3	7.2	8.0	7.9	7.5	8.0	7.2	8.0	0.7	7.7	-0.6	0.1	-8%	2%
Case 4	7.7	8.6	8.5	8.1	8.6	7.7	8.6	0.9	8.3	-0.7	0.1	-9%	2%
Case 5	9.1	10.3	10.2	9.7	10.4	9.1	10.4	1.3	9.9	-1.2	0.2	-12%	2%
Average	7.2	8.0	7.9	7.6	8.0	7.2	8.0	0.8	7.7	-0.7	0.1	-8%	2%
<b>3 Simple ROI</b>													
Case 1	17.89%	16.67%	16.94%	17.42%	16.70%	16.67%	17.89%	1.22%	17.12%	-0.27%	0.95%	-2%	6%
Case 2	15.30%	14.12%	14.27%	14.74%	14.03%	14.03%	15.30%	1.27%	14.49%	-0.24%	1.03%	-2%	7%
Case 3	13.83%	12.58%	12.73%	13.25%	12.54%	12.54%	13.83%	1.29%	12.98%	-0.20%	1.09%	-2%	9%
Case 4	12.96%	11.64%	11.82%	12.35%	11.63%	11.63%	12.96%	1.33%	12.08%	-0.19%	1.14%	-2%	10%
Case 5	11.05%	9.67%	9.77%	10.35%	9.62%	9.62%	11.05%	1.43%	10.09%	-0.16%	1.27%	-2%	13%
Average	14.20%	12.94%	13.11%	13.62%	12.90%	12.90%	14.20%	1.31%	13.35%	-0.21%	1.10%	-2%	9%
<b>Life Cycle Cost Analysis Summary</b>													
<b>4 5-Year NPV</b>													
Case 1	\$22,199	\$5,814	\$9,410	\$15,952	\$6,179	\$5,814	\$22,199	\$16,385	\$11,911	-\$3,596	\$12,789	-38%	136%
Case 2	(\$14,594)	(\$30,950)	(\$28,816)	(\$22,455)	(\$32,160)	(\$32,160)	(\$14,594)	\$17,566	(\$25,795)	-\$3,344	\$14,222	12%	-49%
Case 3	(\$98,002)	(\$115,352)	(\$113,202)	(\$106,044)	(\$115,917)	(\$115,917)	(\$98,002)	\$17,915	(\$109,703)	-\$2,715	\$15,200	2%	-13%
Case 4	(\$110,711)	(\$128,622)	(\$126,266)	(\$119,004)	(\$128,837)	(\$128,837)	(\$110,711)	\$18,126	(\$122,688)	-\$2,571	\$15,555	2%	-12%
Case 5	(\$133,991)	(\$152,030)	(\$150,616)	(\$143,058)	(\$152,667)	(\$152,667)	(\$133,991)	\$18,676	(\$146,472)	-\$2,051	\$16,625	1%	-11%
Average	(\$67,020)	(\$84,228)	(\$81,898)	(\$74,922)	(\$84,680)	(\$84,753)	(\$67,020)	\$17,733	(\$78,550)	-\$2,855	\$14,878	-4%	10%
<b>5 10-Year NPV</b>													
Case 1	\$225,171	\$194,977	\$168,176	\$213,660	\$195,650	\$168,176	\$225,171	\$56,995	\$199,527	\$0	\$56,995	0%	34%
Case 2	\$159,420	\$129,599	\$98,022	\$145,087	\$127,393	\$98,022	\$159,420	\$61,398	\$131,904	\$0	\$61,398	0%	63%
Case 3	\$117,297	\$85,990	\$51,526	\$102,786	\$84,971	\$51,526	\$117,297	\$65,771	\$88,514	\$0	\$65,771	0%	128%
Case 4	\$88,632	\$56,644	\$25,132	\$73,820	\$56,259	\$25,132	\$88,632	\$63,500	\$60,097	\$0	\$63,500	0%	25%
Case 5	\$36,226	\$4,330	(\$28,430)	\$20,193	\$3,204	(\$28,430)	\$36,226	\$64,657	\$7,105	\$0	\$64,657	0%	-227%
Average	\$125,349	\$94,308	\$62,885	\$111,109	\$93,495	\$62,885	\$125,349	\$62,464	\$97,429	\$0	\$62,464	0%	50%
<b>6 15-Year NPV</b>													
Case 1	\$334,067	\$292,237	\$301,418	\$318,119	\$293,169	\$292,237	\$334,067	\$41,830	\$307,802	-\$9,181	\$32,649	-3%	11%
Case 2	\$224,283	\$184,542	\$189,727	\$205,182	\$181,602	\$181,602	\$224,283	\$42,681	\$197,067	-\$8,125	\$34,556	-4%	18%
Case 3	\$171,029	\$128,495	\$133,765	\$151,315	\$127,111	\$127,111	\$171,029	\$43,919	\$142,343	-\$6,655	\$37,264	-5%	28%
Case 4	\$121,557	\$78,502	\$84,164	\$101,621	\$77,984	\$77,984	\$121,557	\$43,573	\$92,765	-\$6,180	\$37,393	-7%	44%
Case 5	\$40,654	(\$1,888)	\$1,448	\$19,270	(\$3,390)	(\$3,390)	\$40,654	\$44,043	\$11,219	-\$4,837	\$39,206	-334%	2708%
Average	\$178,318	\$136,378	\$142,104	\$159,101	\$135,295	\$135,109	\$178,318	\$43,209	\$150,239	-\$6,996	\$36,213	-7%	562%
<b>7 20-Year NPV</b>													
Case 1	\$478,213	\$426,577	\$437,910	\$458,527	\$427,728	\$426,577	\$478,213	\$51,636	\$445,791	-\$11,334	\$40,302	-3%	9%
Case 2	\$354,569	\$304,534	\$311,063	\$330,520	\$300,833	\$300,833	\$354,569	\$53,737	\$320,304	-\$10,230	\$43,507	-3%	14%
Case 3	\$271,137	\$219,571	\$225,961	\$247,236	\$217,893	\$217,893	\$271,137	\$53,244	\$236,360	-\$8,068	\$45,176	-4%	20%
Case 4	\$207,349	\$155,595	\$162,400	\$183,385	\$154,972	\$154,972	\$207,349	\$52,376	\$172,740	-\$7,428	\$44,948	-5%	28%
Case 5	\$106,171	\$55,452	\$59,428	\$80,677	\$53,661	\$53,661	\$106,171	\$52,510	\$71,078	-\$5,767	\$46,742	-10%	79%
Average	\$283,488	\$232,346	\$239,352	\$260,069	\$231,017	\$230,787	\$283,488	\$52,701	\$249,254	-\$8,565	\$44,135	-5%	30%
<b>8 5-Year IRR</b>													
Case 1	11%	8%	9%	10%	8%	8%	11%	3%	9%	-1%	2%	-7%	26%
Case 2	5%	3%	3%	4%	2%	2%	5%	3%	3%	-1%	2%	-17%	74%
Case 3	-11%	-14%	-14%	-13%	-15%	-15%	-11%	4%	-13%	-1%	3%	4%	-22%
Case 4	-13%	-17%	-17%	-15%	-17%	-17%	-13%	4%	-16%	-1%	3%	3%	-19%
Case 5	-19%	-23%	-23%	-21%	-23%	-23%	-19%	4%	-22%	0%	4%	2%	-17%
Average	-5%	-9%	-8%	-7%	-9%	-9%	-5%	3%	-8%	-1%	3%	-3%	9%
<b>9 10-Year IRR</b>													
Case 1	27%	24%	25%	26%	24%	24%	27%	3%	25%	-1%	2%	-2%	8%
Case 2	21%	19%	19%	20%	18%	18%	21%	3%	19%	0%	2%	-3%	11%
Case 3	18%	15%	15%	16%	15%	15%	18%	3%	16%	0%	2%	-3%	14%
Case 4	16%	13%	13%	15%	13%	13%	16%	3%	14%	0%	2%	-3%	16%
Case 5	12%	9%	10%	11%	9%	9%	12%	3%	10%	0%	2%	-3%	25%
Average	19%	16%	16%	17%	16%	16%	19%	3%	17%	0%	2%	-3%	15%
<b>10 15-Year IRR</b>													
Case 1	29%	27%	27%	28%	27%	27%	29%	2%	28%	-1%	2%	-2%	7%
Case 2	23%	21%	21%	22%	21%	21%	23%	3%	22%	0%	2%	-2%	10%
Case 3	20%	17%	17%	18%	17%	17%	20%	3%	18%	0%	2%	-2%	13%
Case 4	17%	14%	15%	16%	14%	14%	17%	3%	15%	0%	2%	-3%	17%
Case 5	12%	9%	9%	10%	9%	9%	12%	3%	10%	0%	3%	-4%	32%
Average	20%	18%	18%	19%	17%	17%	20%	3%	18%	0%	2%	-3%	16%
<b>11 20-Year IRR</b>													
Case 1	30%	28%	28%	29%	28%	28%	30%	2%	29%	-1%	2%	-2%	6%
Case 2	24%	22%	23%	23%	22%	22%	24%	2%	23%	0%	2%	-2%	8%
Case 3	21%	19%	19%	20%	19%	19%	21%	2%	20%	0%	2%	-2%	10%
Case 4	19%	16%	17%	18%	16%	16%	19%	2%	17%	0%	2%	-2%	13%
Case 5	15%	12%	12%	13%	12%	12%	15%	3%	13%	0%	2%	-2%	20%
Average	22%	19%	20%	21%	19%	19%	22%	2%	20%	0%	2%	-2%	11%



Table 5: Health and Productivity Savings Analysis

Productivity and Health Savings

1 Description	Productivity Savings					Health Savings					Total Savings for the Owner of TMC	Description	Case 1	Case 2	Case 3	Case 4	Case 5	Average	
	Productivity Assumptions and Savings	Increased Individual Productivity (Percentage)	Productivity Savings per Employee /Year	Productivity Savings for entire workers /Year	Productivity Savings for Davis employee /year	Health Assumptions and Savings	Health Savings per Employee /Year	Health Savings for entire workers /Year	Health Savings for Davis employee /year										
2 Case 1		4.00%	\$2,400	\$573,600	\$382,400		\$35.0	\$8,365	\$5,577	\$387,977	Productivity Assumptions and Savings								
3 Case 2		3.20%	\$1,920	\$458,880	\$305,920		\$25.0	\$5,975	\$3,983	\$309,903	Increased Individual Productivity (Percentage)	4.0%	\$1,920	3.2%	2.0%	\$600	\$300	\$1,284	2.1%
4 Case 3		2.00%	\$1,200	\$286,800	\$191,200		\$15.0	\$3,585	\$2,390	\$193,590	Productivity Savings per Employee /Year	\$2,400	\$458,880	\$286,800	\$143,400	\$71,700	\$306,876		
5 Case 4		1.00%	\$600	\$143,400	\$95,600		\$10.0	\$2,390	\$1,593	\$97,193	Productivity Savings for Davis employee /year	\$382,400	\$305,920	\$191,200	\$95,600	\$47,800	\$204,584		
6 Case 5		0.50%	\$300	\$71,700	\$47,800		\$5.0	\$1,195	\$797	\$48,597	Health Assumptions and Savings								
7 Average		2.14%	\$1,284	\$306,876	\$204,584		\$18	\$4,302	\$2,868	\$207,452	Health Savings per Employee /Year								
8	1	2	3	4	5	6	7	8	9	10	11	Health Savings for entire workers /Year	\$35	\$25	\$15	\$10	\$5	\$18	
9												Health Savings for Davis employee /year	\$8,365	\$5,975	\$3,585	\$2,390	\$1,195	\$4,302	
10												Total Savings for the Owner of TMC	\$5,577	\$3,983	\$2,390	\$1,593	\$797	\$2,868	
11												Minimum Impact of modeling with different base cases = (Min - BM0) / BM0	\$387,977	\$309,903	\$193,590	\$97,193	\$48,597	\$207,452	

1 Total Lighting Option \$ Savings

	BM (-2): Lowest energy use prediction	BM (-1): Lower energy use prediction	BM (0): Best Model	BM (+1): Higher energy use prediction	BM (+2): Highest energy use prediction	Min	Max	Delta	Average	Minimum Impact of modeling with different base cases = (Min - BM0) / BM0	Maximum Impact of modeling with different base cases = (Max - BM0) / BM0
Case 1	\$437,805	\$434,416	\$435,160	\$436,513	\$434,491	\$434,416	\$437,805	\$3,390	\$435,677	-0.2%	0.6%
Case 2	\$354,025	\$350,611	\$351,056	\$352,384	\$350,358	\$350,358	\$354,025	\$3,667	\$351,687	-0.2%	0.8%
Case 3	\$234,095	\$230,441	\$230,894	\$232,401	\$230,322	\$230,322	\$234,095	\$3,773	\$231,630	-0.2%	1.4%
Case 4	\$134,726	\$130,920	\$131,420	\$132,963	\$130,874	\$130,874	\$134,726	\$3,851	\$132,181	-0.4%	2.5%
Case 5	\$79,575	\$75,708	\$76,012	\$77,613	\$75,572	\$75,572	\$79,575	\$4,003	\$76,900	-0.6%	4.7%
Average	\$248,045	\$244,419	\$244,908	\$246,379	\$244,323	\$244,308	\$248,045	\$3,737	\$245,615	-0.3%	2.0%

2 Simple Paybacks/Years

Case 1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0	0.6	0.0	0.0
Case 2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0	0.8	0.0	0.0
Case 3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.0	1.3	0.0	0.0
Case 4	2.1	2.2	2.2	2.2	2.2	2.1	2.2	0.1	2.2	-0.1	0.0
Case 5	3.5	3.7	3.7	3.6	3.7	3.5	3.7	0.2	3.6	-0.2	0.0
Average	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0.1	1.7	0.0	0.0

Life Cycle Cost Analysis Summary

3 5-Year NPV

Case 1	\$1,772,496	\$1,753,738	\$1,757,855	\$1,765,344	\$1,754,156	\$1,753,738	\$1,772,496	\$18,758	\$1,760,718	-0.2%	0.8%
Case 2	\$1,386,562	\$1,367,668	\$1,370,134	\$1,377,481	\$1,366,271	\$1,366,271	\$1,386,562	\$20,291	\$1,373,623	-0.3%	1.2%
Case 3	\$769,160	\$748,939	\$751,444	\$759,788	\$748,281	\$748,281	\$769,160	\$20,880	\$755,522	-0.4%	2.3%
Case 4	\$336,411	\$315,352	\$318,121	\$326,659	\$315,098	\$315,098	\$336,411	\$21,312	\$322,328	-1.0%	5.6%
Case 5	\$99,401	\$78,005	\$79,683	\$88,646	\$77,250	\$77,250	\$99,401	\$22,152	\$84,597	-3.1%	22.2%
Average	\$872,806	\$852,740	\$855,447	\$863,584	\$852,211	\$852,127	\$872,806	\$20,679	\$859,358	-1.0%	6.4%

4 10-Year NPV

Case 1	\$3,312,006	\$3,271,076	\$3,280,060	\$3,296,402	\$3,271,988	\$3,271,076	\$3,312,006	\$40,930	\$3,286,306	-0.3%	1.0%
Case 2	\$2,614,018	\$2,572,793	\$2,578,172	\$2,594,203	\$2,569,743	\$2,569,743	\$2,614,018	\$44,275	\$2,585,786	-0.3%	1.4%
Case 3	\$1,691,264	\$1,647,141	\$1,652,608	\$1,670,813	\$1,645,705	\$1,645,705	\$1,691,264	\$45,559	\$1,661,506	-0.4%	2.3%
Case 4	\$956,900	\$910,950	\$916,992	\$935,623	\$910,397	\$910,397	\$956,900	\$46,503	\$926,172	-0.7%	4.3%
Case 5	\$543,971	\$497,285	\$500,945	\$520,504	\$495,636	\$495,636	\$543,971	\$48,335	\$511,668	-1.1%	8.3%
Average	\$1,823,632	\$1,779,849	\$1,785,755	\$1,803,509	\$1,778,694	\$1,778,512	\$1,823,632	\$45,120	\$1,794,288	-0.6%	3.4%

5 15-Year NPV

Case 1	\$4,402,236	\$4,335,100	\$4,349,836	\$4,376,641	\$4,336,596	\$4,335,100	\$4,402,236	\$67,136	\$4,360,082	-0.3%	1.2%
Case 2	\$3,439,925	\$3,372,306	\$3,381,129	\$3,407,425	\$3,367,303	\$3,367,303	\$3,439,925	\$72,622	\$3,393,617	-0.4%	1.7%
Case 3	\$2,212,995	\$2,140,622	\$2,149,590	\$2,179,451	\$2,138,267	\$2,138,267	\$2,212,995	\$74,728	\$2,164,185	-0.5%	2.9%
Case 4	\$1,243,875	\$1,168,506	\$1,178,416	\$1,208,976	\$1,167,599	\$1,167,599	\$1,243,875	\$76,277	\$1,193,474	-0.9%	5.4%
Case 5	\$679,064	\$602,487	\$608,490	\$640,572	\$599,782	\$599,782	\$679,064	\$79,281	\$626,079	-1.4%	11.0%
Average	\$2,395,619	\$2,323,804	\$2,333,492	\$2,362,613	\$2,321,910	\$2,321,610	\$2,395,619	\$74,009	\$2,347,488	-0.7%	4.5%

6 20-Year NPV

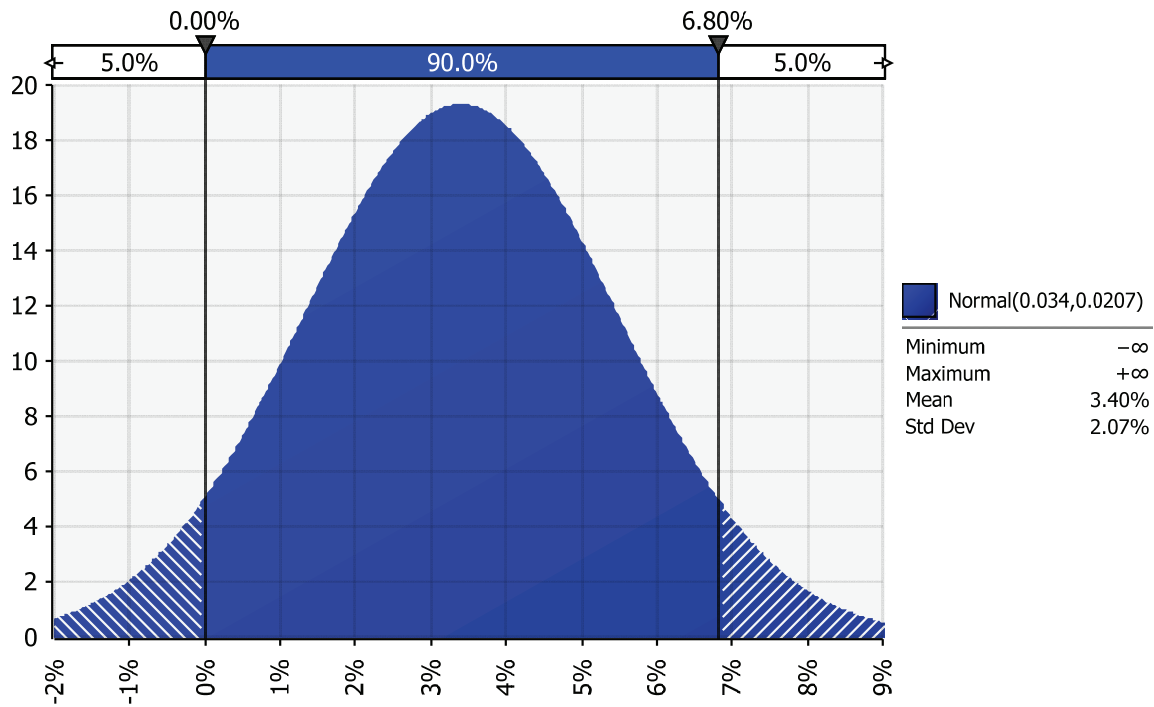
Case 1	\$5,313,582	\$5,218,976	\$5,239,741	\$5,277,513	\$5,221,085	\$5,218,976	\$5,313,582	\$94,606	\$5,254,179	-0.4%	1.4%
Case 2	\$4,231,394	\$4,136,107	\$4,148,540	\$4,185,595	\$4,129,058	\$4,129,058	\$4,231,394	\$102,336	\$4,166,139	-0.5%	2.0%
Case 3	\$2,903,762	\$2,801,776	\$2,814,414	\$2,856,492	\$2,798,458	\$2,798,458	\$2,903,762	\$105,304	\$2,834,980	-0.6%	3.1%
Case 4	\$1,862,698	\$1,756,490	\$1,770,456	\$1,813,519	\$1,755,211	\$1,755,211	\$1,862,698	\$107,486	\$1,791,675	-0.9%	5.1%
Case 5	\$1,218,524	\$1,110,614	\$1,119,074	\$1,164,282	\$1,106,804	\$1,106,804	\$1,218,524	\$111,720	\$1,143,860	-1.1%	8.5%
Average	\$3,105,992	\$3,004,793	\$3,018,445	\$3,059,480	\$3,002,123	\$3,001,701	\$3,105,992	\$104,290	\$3,038,167	-0.7%	4.0%

0 Financial Metrics

	Min	Max	Average
1 Total Lighting Option \$ Savings	\$75,572	\$437,805	\$245,615
2 Simple Paybacks/Years	0.6	3.7	1.7
3 5-Year NPV	\$77,250	\$1,772,496	\$859,358
4 10-Year NPV	\$495,636	\$3,312,006	\$1,794,288
5 15-Year NPV	\$599,782	\$4,402,236	\$2,347,488
6 20-Year NPV	\$1,106,804	\$5,313,582	\$3,038,167

## **APPENDIX B: Impact of Electricity Escalation on LCC Outcomes**

Trough @Risk software, Monte Carlo simulation method is used to estimate the impacts of escalation rate on the LCC outcomes. A normal distribution with 90% confidence of range of 0 – 6.8% is determined for electricity escalation rate and distributions of NPVs and IRRs are generated. Distributions and statistical summary of NPVs and IRRs are presented in this appendix:



**Figure 1: Electricity Escalation Rate**

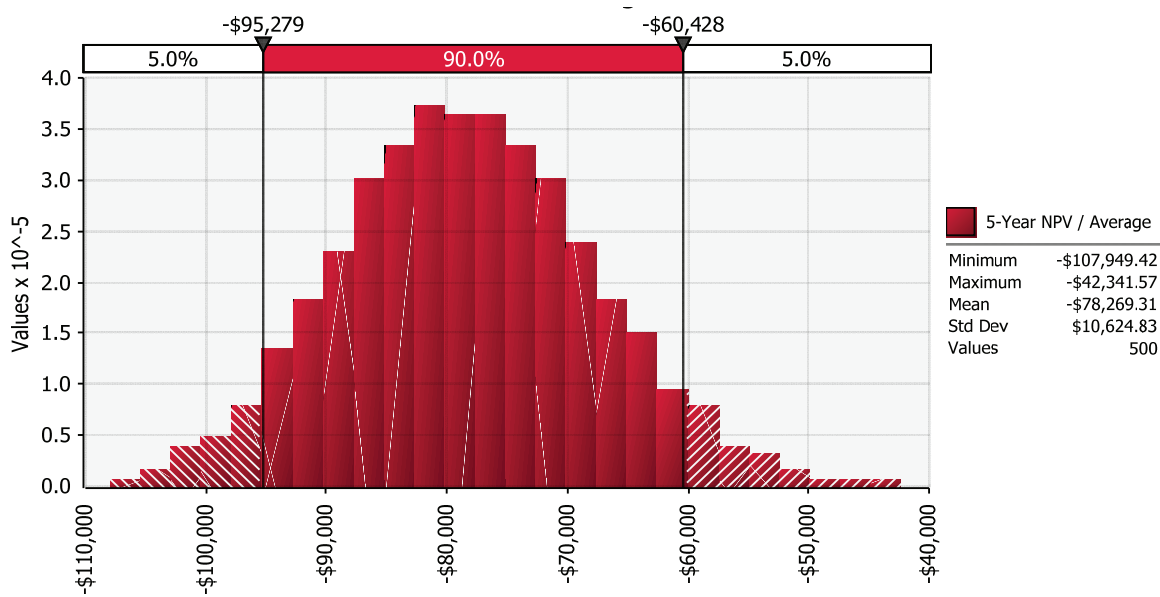


Figure 2: Average 5-Year NPV

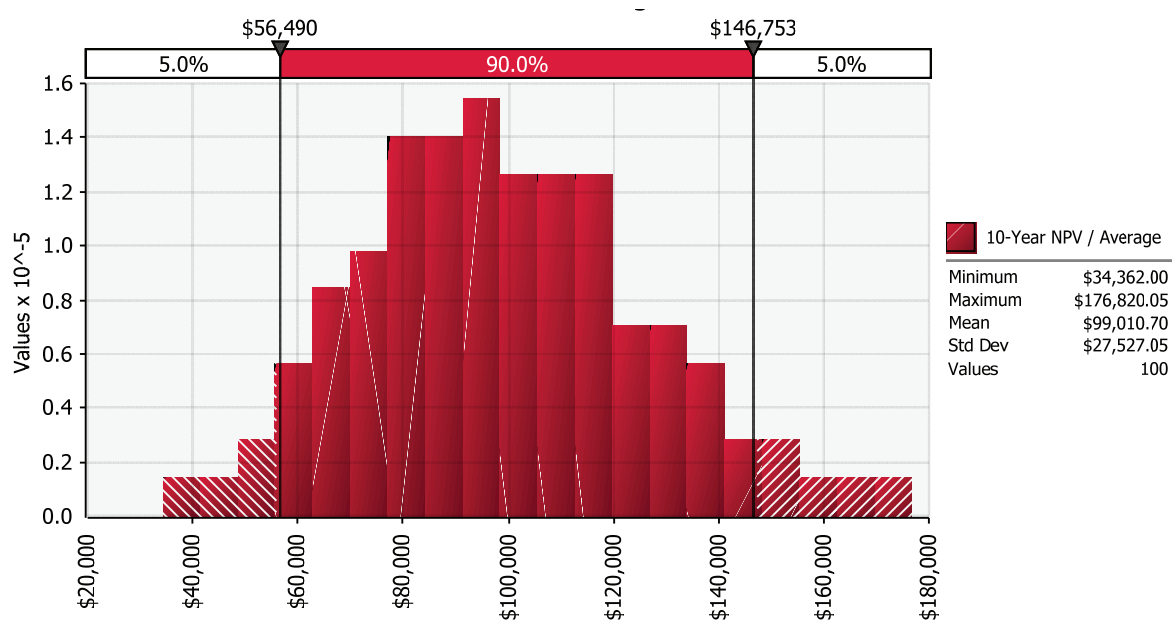


Figure 3: Average 10-Year NPV

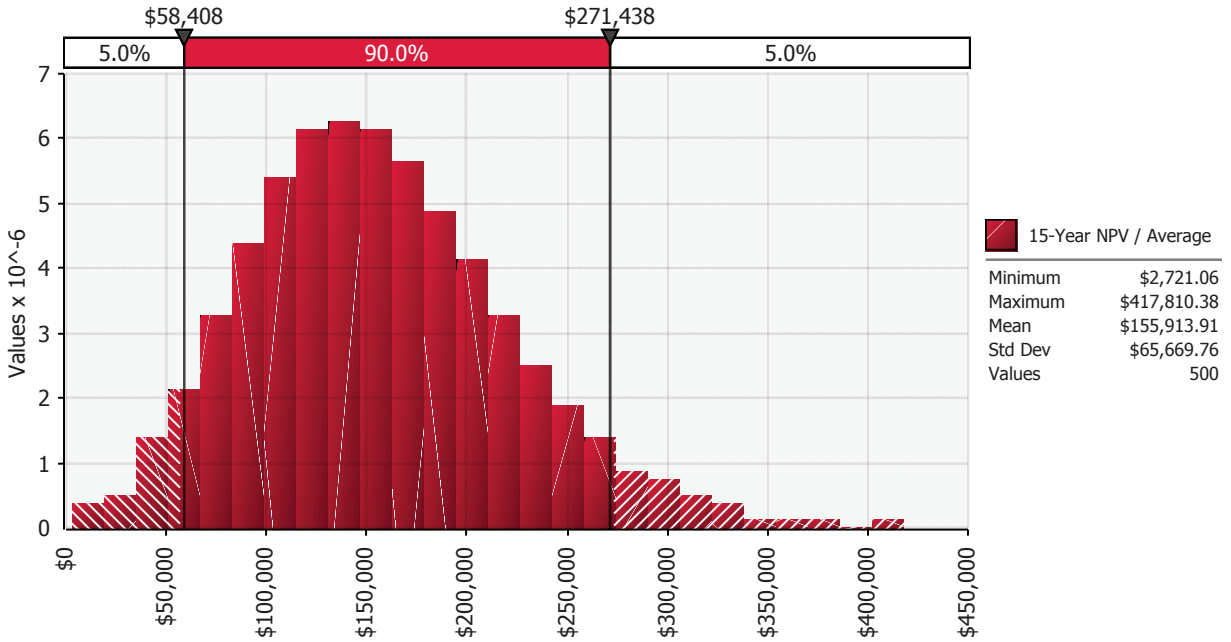


Figure 4: Average 15-Year NPV

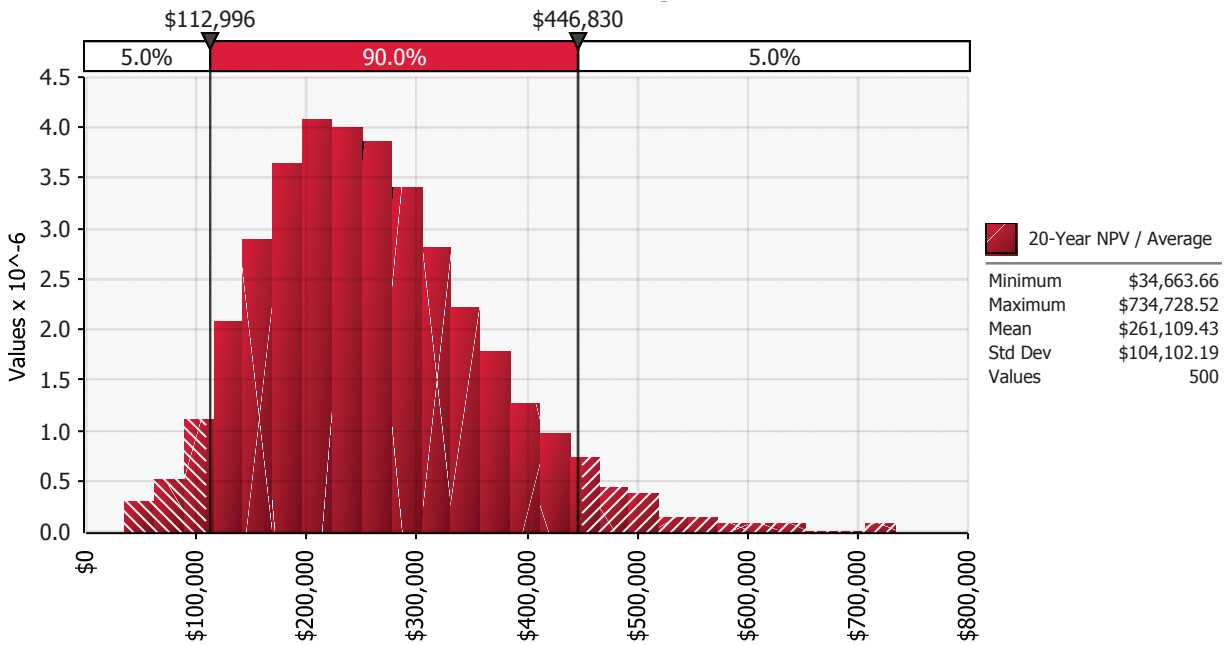


Figure 5: Average 20-Year NPV

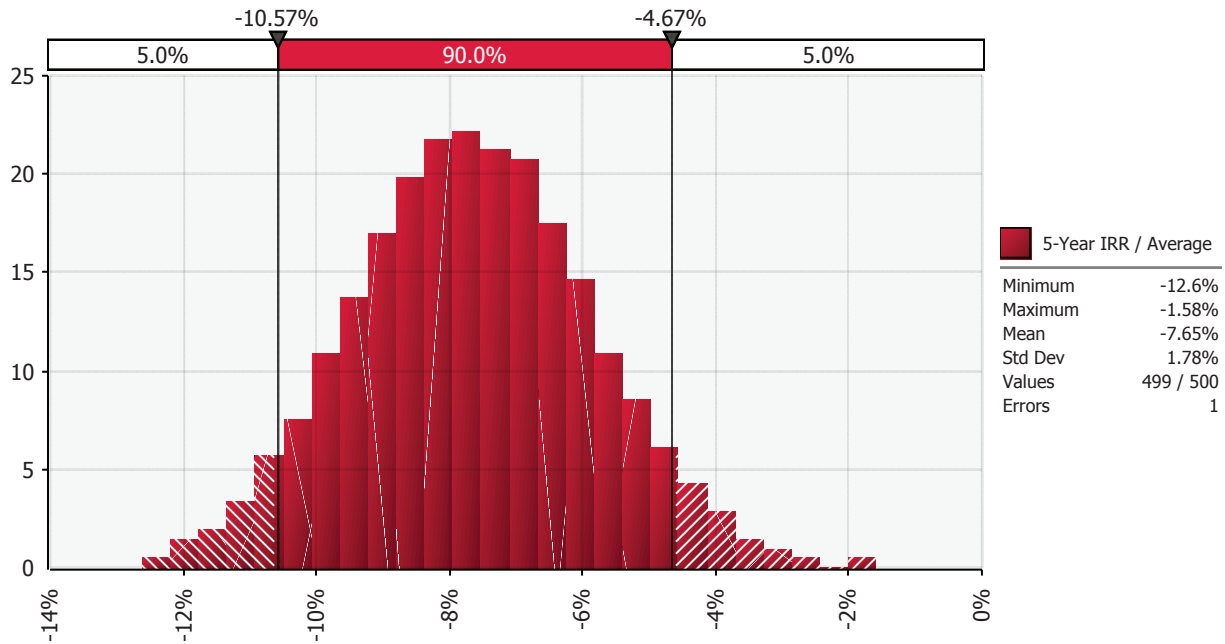


Figure 6: Average 5-Year IRR

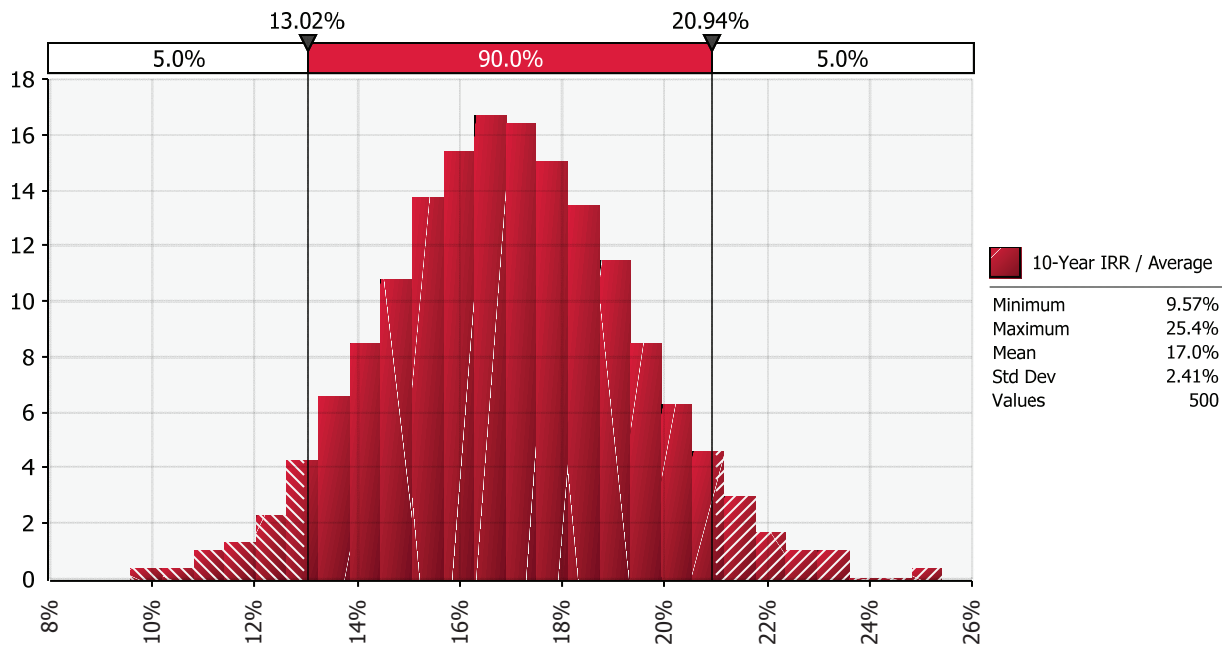


Figure 7: Average 10-Year IRR

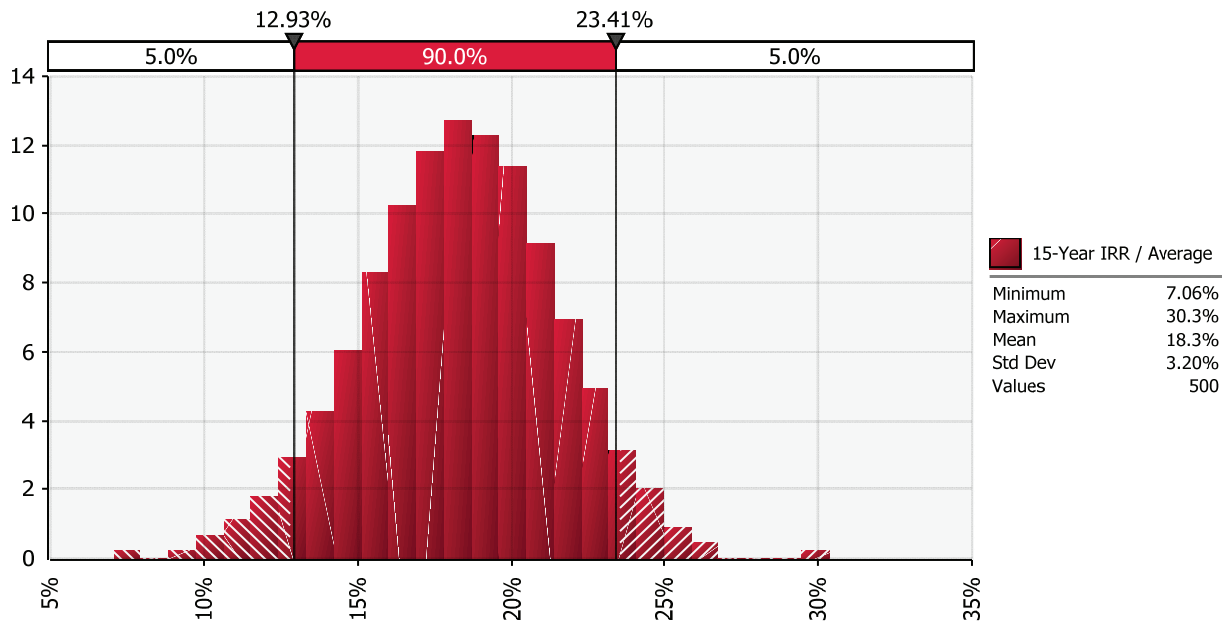


Figure 8: Average 15-Year IRR

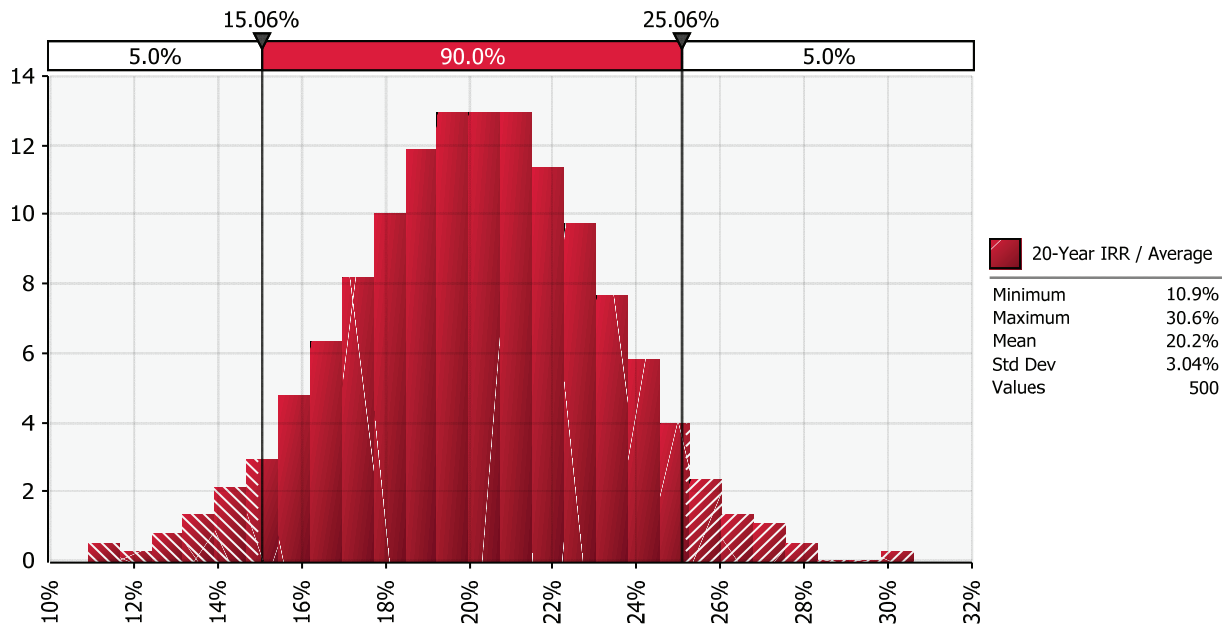


Figure 9: Average 20-Year IRR

## **APPENDIX C: Statements of Energy Performance**

A complete statement of current energy performance of the building is presented in the next six pages of this appendix. Graphic representations of the minimum, maximum, and average energy performance ratings that can be achieved by employing lighting controls are then presented.



# STATEMENT OF ENERGY PERFORMANCE

## Twinbrook Metro Center I

**Building ID:** 2931183  
**For 12-month Period Ending:** November 30, 2009<sup>1</sup>  
**Date SEP becomes ineligible:** N/A

**Date SEP Generated:** November 16, 2011

**Facility**  
 Twinbrook Metro Center I  
 12530 Parklawn Drive  
 Rockville, MD 20852

**Facility Owner**  
 N/A

**Primary Contact for this Facility**  
 N/A

**Year Built:** 2000  
**Gross Floor Area (ft<sup>2</sup>):** 91,420

**Energy Performance Rating<sup>2</sup> (1-100)** 38

**Site Energy Use Summary<sup>3</sup>**

Electricity - Grid Purchase(kBtu)	7,710,250
Natural Gas - (kBtu) <sup>4</sup>	0
<b>Total Energy (kBtu)</b>	<b>7,710,250</b>

**Energy Intensity<sup>5</sup>**

Site (kBtu/ft <sup>2</sup> /yr)	84
Source (kBtu/ft <sup>2</sup> /yr)	282

**Emissions (based on site energy use)**

Greenhouse Gas Emissions (MtCO <sub>2</sub> e/year)	1,092
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**Electric Distribution Utility**

Potomac Electric Power Co [Pepco Holdings Inc]

**National Median Comparison**

National Median Site EUI	74
National Median Source EUI	248
% Difference from National Median Source EUI	14%
Building Type	Office

**Stamp of Certifying Professional**

Based on the conditions observed at the time of my visit to this building, I certify that the information contained within this statement is accurate.

**Meets Industry Standards<sup>6</sup> for Indoor Environmental Conditions:**

Ventilation for Acceptable Indoor Air Quality	<b>N/A</b>
Acceptable Thermal Environmental Conditions	<b>N/A</b>
Adequate Illumination	<b>N/A</b>

**Certifying Professional**  
 N/A

**Notes:**

1. Application for the ENERGY STAR must be submitted to EPA within 4 months of the Period Ending date. Award of the ENERGY STAR is not final until approval is received from EPA.
2. The EPA Energy Performance Rating is based on total source energy. A rating of 75 is the minimum to be eligible for the ENERGY STAR.
3. Values represent energy consumption, annualized to a 12-month period.
4. Values represent energy intensity, annualized to a 12-month period.
5. Based on Meeting ASHRAE Standard 62 for ventilation for acceptable indoor air quality, ASHRAE Standard 55 for thermal comfort, and IESNA Lighting Handbook for lighting quality.



## ENERGY STAR® Data Checklist for Commercial Buildings

In order for a building to qualify for the ENERGY STAR, a Professional Engineer (PE) or a Registered Architect (RA) must validate the accuracy of the data underlying the building's energy performance rating. This checklist is designed to provide an at-a-glance summary of a property's physical and operating characteristics, as well as its total energy consumption, to assist the PE or RA in double-checking the information that the building owner or operator has entered into Portfolio Manager.

**Please complete and sign this checklist and include it with the stamped, signed Statement of Energy Performance.**

NOTE: You must check each box to indicate that each value is correct, OR include a note.

CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	<input checked="" type="checkbox"/>
<b>Building Name</b>	Twinbrook Metro Center I	Is this the official building name to be displayed in the ENERGY STAR Registry of Labeled Buildings?		<input type="checkbox"/>
<b>Type</b>	Office	Is this an accurate description of the space in question?		<input type="checkbox"/>
<b>Location</b>	12530 Parklawn Drive, Rockville, MD 20852	Is this address accurate and complete? Correct weather normalization requires an accurate zip code.		<input type="checkbox"/>
<b>Single Structure</b>	Single Facility	Does this SEP represent a single structure? SEPs cannot be submitted for multiple-building campuses (with the exception of acute care or children's hospitals) nor can they be submitted as representing only a portion of a building		<input type="checkbox"/>
Corporation office (Office)				
CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	<input checked="" type="checkbox"/>
<b>Gross Floor Area</b>	89,034 Sq. Ft.	Does this square footage include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, atria, vent shafts, etc. Also note that existing atriums should only include the base floor area that it occupies. Interstitial (plenum) space between floors should not be included in the total. Finally gross floor area is not the same as leasable space. Leasable space is a subset of gross floor area.		<input type="checkbox"/>
<b>Weekly operating hours</b>	50 Hours	Is this the total number of hours per week that the Office space is 75% occupied? This number should exclude hours when the facility is occupied only by maintenance, security, or other support personnel. For facilities with a schedule that varies during the year, "operating hours/week" refers to the total weekly hours for the schedule most often followed.		<input type="checkbox"/>
<b>Workers on Main Shift</b>	239	Is this the number of employees present during the main shift? Note this is not the total number of employees or visitors who are in a building during an entire 24 hour period. For example, if there are two daily 8 hour shifts of 100 workers each, the Workers on Main Shift value is 100. The normal worker density ranges between 0.3 and 5.3 workers per 1000 square feet (92.8 square meters)		<input type="checkbox"/>
<b>Number of PCs</b>	269	Is this the number of personal computers in the Office?		<input type="checkbox"/>
<b>Percent Cooled</b>	50% or more	Is this the percentage of the total floor space within the facility that is served by mechanical cooling equipment?		<input type="checkbox"/>
<b>Percent Heated</b>	50% or more	Is this the percentage of the total floor space within the facility that is served by mechanical heating equipment?		<input type="checkbox"/>
Printing Facility (Other)				
CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	<input checked="" type="checkbox"/>

<b>Gross Floor Area</b>	2,386 Sq. Ft.	Does this square footage include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, atria, vent shafts, etc. Also note that existing atriums should only include the base floor area that it occupies. Interstitial (plenum) space between floors should not be included in the total. Finally gross floor area is not the same as leasable space. Leasable space is a subset of gross floor area.	<input type="checkbox"/>
<b>Number of PCs</b>	7(Optional)	Is this the number of personal computers in the space?	<input type="checkbox"/>
<b>Weekly operating hours</b>	50Hours(Optional)	Is this the total number of hours per week that the space is 75% occupied? This number should exclude hours when the facility is occupied only by maintenance, security, or other support personnel. For facilities with a schedule that varies during the year, "operating hours/week" refers to the total weekly hours for the schedule most often followed.	<input type="checkbox"/>
<b>Workers on Main Shift</b>	5(Optional)	Is this the number of employees present during the main shift? Note this is not the total number of employees or visitors who are in a building during an entire 24 hour period. For example, if there are two daily 8 hour shifts of 100 workers each, the Workers on Main Shift value is 100.	<input type="checkbox"/>

## ENERGY STAR® Data Checklist for Commercial Buildings

### Energy Consumption

**Power Generation Plant or Distribution Utility:** Potomac Electric Power Co [Pepco Holdings Inc]

Fuel Type: Electricity		
<b>Meter: Pepco Meter (kWh (thousand Watt-hours))</b> <b>Space(s): Entire Facility</b> <b>Generation Method: Grid Purchase</b>		
Start Date	End Date	Energy Use (kWh (thousand Watt-hours))
10/24/2009	11/23/2009	183,600.00
09/24/2009	10/23/2009	160,800.00
08/25/2009	09/23/2009	163,950.00
07/24/2009	08/23/2009	178,170.00
06/24/2009	07/23/2009	155,880.00
05/24/2009	06/23/2009	152,610.00
04/23/2009	05/23/2009	162,300.00
03/26/2009	04/23/2009	165,810.00
02/24/2009	03/25/2009	224,970.00
01/27/2009	02/23/2009	228,090.00
12/24/2008	01/26/2009	296,160.00
<b>Pepco Meter Consumption (kWh (thousand Watt-hours))</b>		<b>2,072,340.00</b>
<b>Pepco Meter Consumption (kBtu (thousand Btu))</b>		<b>7,070,824.08</b>
<b>Total Electricity (Grid Purchase) Consumption (kBtu (thousand Btu))</b>		<b>7,070,824.08</b>
<b>Is this the total Electricity (Grid Purchase) consumption at this building including all Electricity meters?</b>		<input type="checkbox"/>

### Additional Fuels

Do the fuel consumption totals shown above represent the total energy use of this building?  
Please confirm there are no additional fuels (district energy, generator fuel oil) used in this facility.

### On-Site Solar and Wind Energy

Do the fuel consumption totals shown above include all on-site solar and/or wind power located at your facility? Please confirm that no on-site solar or wind installations have been omitted from this list. All on-site systems must be reported.

## Certifying Professional

(When applying for the ENERGY STAR, the Certifying Professional must be the same PE or RA that signed and stamped the SEP.)

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Signature: \_\_\_\_\_

Signature is required when applying for the ENERGY STAR.

# FOR YOUR RECORDS ONLY. DO NOT SUBMIT TO EPA.

Please keep this Facility Summary for your own records; do not submit it to EPA. Only the Statement of Energy Performance (SEP), Data Checklist and Letter of Agreement need to be submitted to EPA when applying for the ENERGY STAR.

**Facility**  
Twinbrook Metro Center I  
12530 Parklawn Drive  
Rockville, MD 20852

**Facility Owner**  
N/A

**Primary Contact for this Facility**  
N/A

## General Information

Twinbrook Metro Center I	
Gross Floor Area Excluding Parking: (ft <sup>2</sup> )	91,420
Year Built	2000
For 12-month Evaluation Period Ending Date:	November 30, 2009

## Facility Space Use Summary

Corporation office		Printing Facility	
Space Type	Office	Space Type	Other - Retail (Misc)
Gross Floor Area(ft <sup>2</sup> )	89,034	Gross Floor Area(ft <sup>2</sup> )	2,386
Weekly operating hours	50	Number of PCs <sup>o</sup>	7
Workers on Main Shift	239	Weekly operating hours <sup>o</sup>	50
Number of PCs	269	Workers on Main Shift <sup>o</sup>	5
Percent Cooled	50% or more		
Percent Heated	50% or more		

## Energy Performance Comparison

Performance Metrics	Evaluation Periods		Comparisons		
	Current (Ending Date 11/30/2009)	Baseline (Ending Date 11/30/2009)	Rating of 75	Target	National Median
Energy Performance Rating	38	38	75	N/A	50
Energy Intensity					
Site (kBtu/ft <sup>2</sup> )	84	84	55	N/A	74
Source (kBtu/ft <sup>2</sup> )	282	282	183	N/A	248
Energy Cost					
\$/year	\$ 278,309.17	\$ 278,309.17	\$ 181,161.65	N/A	\$ 244,914.71
\$/ft <sup>2</sup> /year	\$ 3.04	\$ 3.04	\$ 1.98	N/A	\$ 2.68
Greenhouse Gas Emissions					
MtCO <sub>2</sub> e/year	1,092	1,092	711	N/A	961
kgCO <sub>2</sub> e/ft <sup>2</sup> /year	12	12	8	N/A	11

More than 50% of your building is defined as Office. Please note that your rating accounts for all of the spaces listed. The National Median column presents energy performance data your building would have if your building had a median rating of 50.

Notes:

o - This attribute is optional.

d - A default value has been supplied by Portfolio Manager.

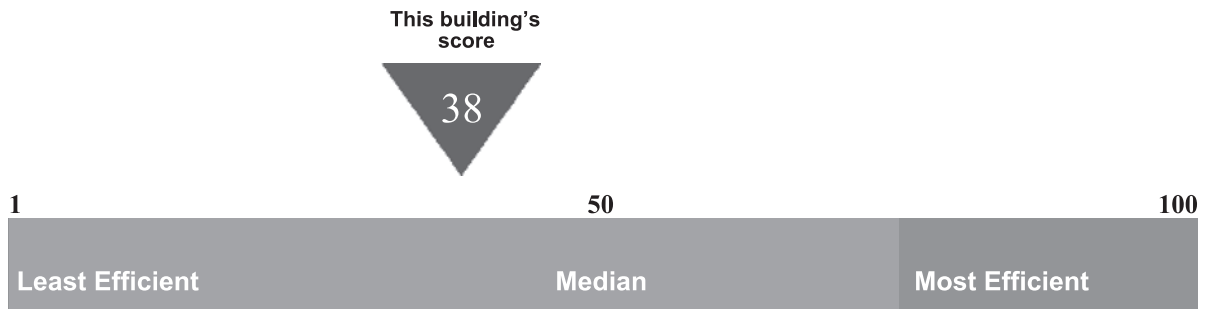
# Statement of Energy Performance

## 2009

Twinbrook Metro Center I  
12530 Parklawn Drive  
Rockville, MD 20852

Portfolio Manager Building ID: 2931183

The energy use of this building has been measured and compared to other similar buildings using the Environmental Protection Agency's (EPA's) Energy Performance Scale of 1–100, with 1 being the least energy efficient and 100 the most energy efficient. For more information, visit [energystar.gov/benchmark](http://energystar.gov/benchmark).



This building uses 282 kBtu per square foot per year.\*

\*Based on source energy intensity for the 12 month period ending November 2009

Buildings with a score of 75 or higher may qualify for EPA's ENERGY STAR.

I certify that the information contained within this statement is accurate and in accordance with U.S. Environmental Protection Agency's measurement standards, found at [energystar.gov](http://energystar.gov)

Date of certification



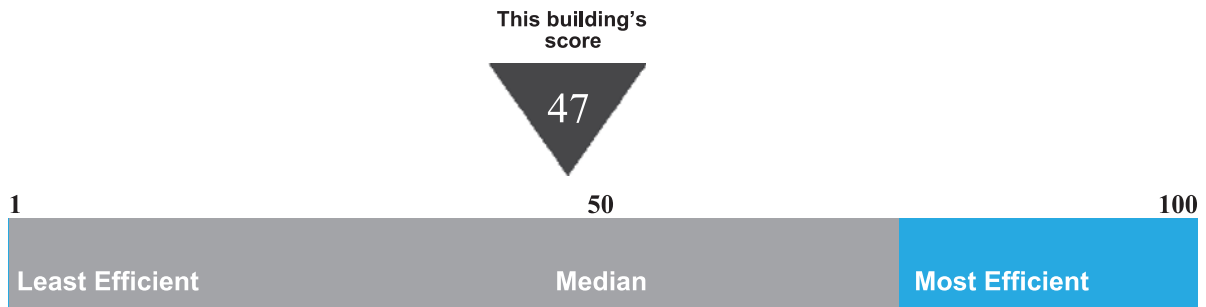
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Twinbrook Metro Center I  
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Rockville, MD 20852

Portfolio Manager Building ID: 2931183

The energy use of this building has been measured and compared to other similar buildings using the Environmental Protection Agency's (EPA's) Energy Performance Scale of 1–100, with 1 being the least energy efficient and 100 the most energy efficient. For more information, visit [energystar.gov/benchmark](http://energystar.gov/benchmark).



This building uses 255 kBtu per square foot per year.\*

\*Based on source energy intensity for the 12 month period ending November 2009

Buildings with a score of 75 or higher may qualify for EPA's ENERGY STAR.

The minimum energy performance rating that can be achieved by employing lighting controls

I certify that the information contained within this statement is accurate and in accordance with U.S. Environmental Protection Agency's measurement standards, found at [energystar.gov](http://energystar.gov)

Date of certification



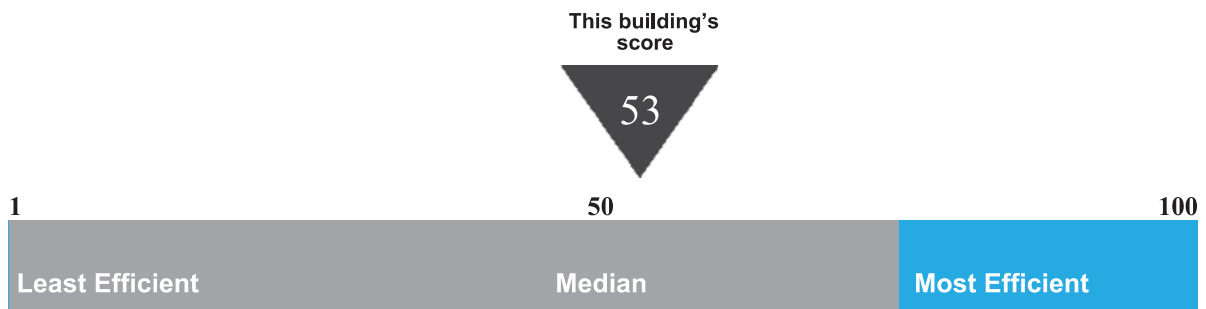
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Rockville, MD 20852

Portfolio Manager Building ID: 2931183

The energy use of this building has been measured and compared to other similar buildings using the Environmental Protection Agency's (EPA's) Energy Performance Scale of 1–100, with 1 being the least energy efficient and 100 the most energy efficient. For more information, visit [energystar.gov/benchmark](http://energystar.gov/benchmark).



This building uses 238 kBtu per square foot per year.\*

\*Based on source energy intensity for the 12 month period ending November 2009

Buildings with a score of 75 or higher may qualify for EPA's ENERGY STAR.

The maximum energy performance rating that can be achieved by employing lighting controls

I certify that the information contained within this statement is accurate and in accordance with U.S. Environmental Protection Agency's measurement standards, found at [energystar.gov](http://energystar.gov)

Date of certification



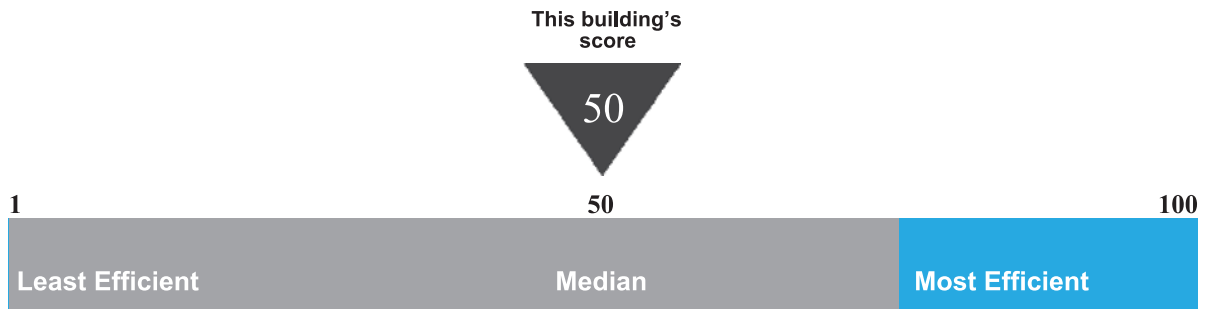
# Statement of Energy Performance

## 2009

Twinbrook Metro Center I  
12530 Parklawn Drive  
Rockville, MD 20852

Portfolio Manager Building ID: 2931183

The energy use of this building has been measured and compared to other similar buildings using the Environmental Protection Agency's (EPA's) Energy Performance Scale of 1–100, with 1 being the least energy efficient and 100 the most energy efficient. For more information, visit [energystar.gov/benchmark](http://energystar.gov/benchmark).



This building uses 247 kBtu per square foot per year.\*

\*Based on source energy intensity for the 12 month period ending November 2009

Buildings with a score of 75 or higher may qualify for EPA's ENERGY STAR.

The average energy performance rating that can be achieved by employing lighting controls

I certify that the information contained within this statement is accurate and in accordance with U.S. Environmental Protection Agency's measurement standards, found at [energystar.gov](http://energystar.gov)

Date of certification





## **APPENDIX D: Survey Introductions**

### **Introduction for the Property Owner & the President of Davis Construction**

#### **Research Summary**

This case study is part of a PhD research project in the College of Architecture and Urban Studies at Virginia Tech which focuses on the financial assessment of sustainable options investment in real estate. The goal is to develop a framework to assess the financial performance of sustainable options investment in existing buildings while explicitly considering risk and uncertainty. It demonstrates the assessment process that decision-makers could follow to derive the benefits of sustainable attributes, both cost savings and non-cost benefits, and link them to the financial model inputs, such as rent, occupancy, discount rate, etc. As a result of applying this new process, property owners/ investors could better understand the true value of sustainability and make more informed decisions about greening their property.

The Twinbrook Metro Center I (TMC) building was selected to thoroughly explore and explain the function of the proposed procedure in numeric terms. A Lighting Controls package was selected as green retrofit option for the building and its energy performance was evaluated through energy simulation. The non-energy benefits associated with lighting controls, such as improved health and productivity, occupants' comfort, contribution to achieving LEED certification, or Greenhouse Gas emissions reduction were identified and quantified to the extent possible through an extensive literature review and experts' interviews. A summary of impacts as well as the results of cost-based financial analyses related to lighting controls are presented in the next section: Green Retrofit Impacts.

Evidence shows that sustainability could improve the value of a property by reducing the operation costs, minimizing real estate risks, meeting compliance requirements, improving marketability, and increasing the key financial variables such as rents, occupancy, or tenant retention. It could also improve the enterprise value by enhancing reputation, improving recruitment, or reducing risk of future earnings. A list of potential enterprise-level benefits is also presented in the next section.

The final step of this case study is a value-base analysis, where the green retrofit impacts link to the key valuation inputs/DCF inputs to estimate the potential incremental value. As part of this step, I am conducting interviews with real estate experts to get their insights about demand and tenants' behavior in this sub-market. The goal is to ultimately determine ranges/three-point estimates for the financial variables that are likely to be impacted.

Since TMC is an owner occupied property, your opinion regarding the value of sustainable attributes is critically important to complete the final step of the research. We are particularly interested in the following questions: How do you value the green retrofit options, given the potential benefits of lighting control to your property and Davis Construction Company, presented in next section? Do they have any minimum standards / requirements relative to green/energy efficiency for the space you are occupying? If you were not the owner of this building, would you still renew your lease to stay? How important is sustainable owned or leased real estate to the types of tenants expected to be leasing space in the building?

Six comparable buildings, three LEED and three non-LEED buildings, in Rockville, MD are identified through GBIG and COSTAR databases and their key characteristics are presented in the end of this document. These buildings are not meant to be the best comparable buildings, but they can provide some insights about the average rents and tenant mix in the sub-market. I would also like to know your opinion about the comparable buildings, if you are aware of any. It should be noted that in this study the emphasis is on demonstrating the assessment process and not on the accuracy of final numeric results. All your inputs for completing this study are greatly appreciated.

## **Green Retrofit Impacts**

### **1. Energy Cost Savings and Financial Outcomes:**

In the following financial analysis, only energy-related (KWh and KW) cost savings related to lighting controls are considered.

<b>Financial Metrics</b>	<b>Range</b>		<b>Average</b>
	<b>Min</b>	<b>Max</b>	
<b>Annual \$ Savings</b>	\$26,975	\$49,829	<b>\$38,163</b>
<b>Simple Paybacks</b>	5.6	10.4	<b>7.7</b>
<b>Simple ROI</b>	9.62%	17.89%	<b>13.35%</b>
<b>5-Year NPV</b>	(\$152,667)	\$22,199	<b>-\$78,550</b>
<b>10-Year NPV</b>	(\$28,430)	\$225,171	<b>\$97,429</b>
<b>15-Year NPV</b>	(\$3,390)	\$334,067	<b>\$150,239</b>
<b>20-Year NPV</b>	\$53,661	\$478,213	<b>\$249,254</b>
<b>5-Year IRR</b>	-23%	11%	<b>-8%</b>
<b>10-Year IRR</b>	9%	27%	<b>17%</b>
<b>15-Year IRR</b>	9%	29%	<b>18%</b>
<b>20-Year IRR</b>	12%	30%	<b>20%</b>

## 2. Improved Health and Productivity:

The assumptions for improved employees' health and productivity are primarily made based on the findings of extensive research by Carnegie Mellon University. The health and productivity savings associated with lighting controls are specifically estimated for the employees of Davis Construction Company. Thus, the saving estimates demonstrate the total potential savings that Davis Construction Company could collect by investing in lighting controls. For estimating the productivity savings for employees of Davis Construction, the annual salary of \$60,000 was assumed for 160 employees.

Description	Range		Average
	Min	Max	
<b>Productivity Assumptions and Savings</b>			
Increased Individual Productivity	0.5%	4.0%	2.1%
Savings per Employee /Year	\$300	\$2,400	\$1,284
Savings for Davis's Employee /year	\$47,800	\$382,400	\$204,584
<b>Health Assumptions and Savings</b>			
Savings per Employee /Year (Insurance)	\$5	\$35	\$18
Savings for Davis employee /year	\$797	\$5,577	\$2,868
<b>Total Savings for Davis Construction Company</b>	<b>\$48,597</b>	<b>\$387,977</b>	<b>\$207,452</b>

In the following financial outcomes, health and productivity savings are also taken into account in addition to energy costs savings.

Financial Metrics (health & productivity savings are included)	Range		Average
	Min	Max	
<b>Annual \$ Savings</b>	\$75,572	\$437,805	<b>\$245,615</b>
<b>Simple Payback</b>	0.6	3.7	<b>1.7</b>
<b>5-Year NPV</b>	\$77,250	\$1,772,496	<b>\$859,358</b>
<b>10-Year NPV</b>	\$495,636	\$3,312,006	<b>\$1,794,288</b>
<b>15-Year NPV</b>	\$599,782	\$4,402,236	<b>\$2,347,488</b>
<b>20-Year NPV</b>	\$1,106,804	\$5,313,582	<b>\$3,038,167</b>

## 3. Contribution to the Building Energy Performance Rating:

As shown below, currently the energy consumption and Greenhouse Gas (GHG) emissions in the building are 15% above the national average. By employing the lighting controls option, the average energy and GHG emissions would become equal to the national average, and energy cost would go below the national average. As a result the Energy Performance Rating of the building will increase from 38 to 50.

Performance Metrics	Current	After lighting retrofit			National Average	Rating of 75
		Min	Max	Average		
Site (kBtu/sq.ft/yr)	85	72	77	74	74	55
Source (kBtu/sq.ft/yr)	283	239	257	248	248	183
Greenhouse Gas Emissions (MtCo2e/yr)	1180	996	1070	1033	1,033	764
Energy Cost (\$/yr)	\$284,428	\$234,599	\$257,452	\$246,265	\$250,477	\$185,276
Energy Cost (\$/yr/sq.ft)	\$3.11	\$2.57	\$2.82	\$2.69	\$2.74	\$2.03

#### 4. Increased Probability of achieving LEED Certifications:

Many studies show that certifications/labels could enhance the investors' and space users' demand/marketability, and therefore, the property value. Lighting controls could contribute up to 40 points of 110 possible points in the LEED rating system and therefore, could increase the likelihood of achieving the LEED certification. For estimating the increased probability of achieving each level of LEED certification, it is assumed that 10-30 points could be achieved through employing lighting controls in this building—a probability is equal to the number of points that is assumed to be achieved in each case divided by the minimum points required for achieving a certain level of LEED certification. It is assumed that this building could meet all the pre-requisites defined by LEED.

LEED Certification Level	Range	Average
Certified	25%-75%	50.0%
Silver	20%-60%	40.0%
Gold	17%-50%	33.3%
Premium	13%-38%	25.0%

#### 5. \*Improved Occupants' Comfort:

Scores of studies have confirmed the direct relationships between lighting controls with lighting quality, visual comfort, and overall environmental satisfaction. One study shows the workers are 6% more comfortable with proper lighting controls.

#### 6. \*Improved Safety & Security:

Lighting controls can be connected to the fire alarm and security systems to turn on lights in case of an emergency and therefore, improve the safety and security of employees.

\*The quantitative data about was believed to improve comfort and safety but there was not sufficient sources in the literature to make numeric assumptions for these benefits of lighting controls.

## **7. Potential Enterprise-Level Sustainability Benefits:**

### **A) Reduction in Resource Use**

Reduction in energy and water use, building waste, pollution emissions, and carbon footprint

### **B) Improved Reputation / Leadership**

Recruiting; Employee retention / satisfaction; public relations / brand management; retain “social license” to operate; improved marketing and sales; increased company market value; and increased company market liquidity

### **C) Compliance with Internal / External Policies / Initiatives**

Corporate energy / sustainability requirements; corporate social responsibility reporting; global reporting initiative; and carbon disclosure project

### **D) Reduced Risk to Future Earnings**

Legal risks—sick building syndrome and mold claims, business interruptions, remediation costs, etc.; reduced sub-leasing risk if downsizing, relocating, etc.; reduced operating cost volatility; reduced risk to reputation; improved defense of competitive advantages; and reduced risk of future compliance cost (Muldavin, 2010)

## **Comparable Buildings in Rockville, MD**

### **LEED buildings from GBIG**

1) Twinbrook Place: 7-story Class A office property within 0.3 miles from TMC, 140,000 sqft, LEED Gold in 2010, built in 2009, rent: \$37.5/sqft for 20000 sqft and 120 months lease

2) Element: 4-story Class A office building in the same parkway within 0.2 mile from TMC, 90,000 sqft, LEED Gold, built in 1960s and renewed in 2009, LEED Gold in 2010, fully leased by GSA

3) 801 Anderson Ave: 3-story office building with in the 0.5 mile from TMC, built in 1963 renovated in 1999, LEED Gold EBOM in 2009, Mix of tenants: government, acquisition date: December 2007

### **Non-LEED buildings from COSTAR**

4) Washington Science Center: 4-story office building within 1.4 miles from TMC, 110,000 sqft, built in 1974 and renovated in 2006, walking distance of a Metro station, energy efficiency rate of 75, parking

ratio of 3.2/1000 sqft, renovation includes new exterior skins, core elements, energy efficient systems, etc., rent \$32.5/sqft for 10 years lease

5) 6000 Executive Blv.: 6-story office building within 1.7 miles from TMC, 125,000 sqft, built in 1972 and renovated in 2007, walking distance of a Metro station, parking ratio of 3.1/1000 sqft, rent \$30/sqft for 5-10 years lease

6) Blackwell One: 5-story office building within 6 miles from TMC, 120,000 sqft, built in 2000, Energy Star labeled in 2009, parking ratio of 3.8/1000 sqft, rent \$32.5/sqft for 3-10 years lease

### **Highlights:**

5. A LEED building built in 2009 close to TMC (0.3 miles) is asking for 23% higher rent A LEED building built in 1960s & renovated in 2009 a couple blocks from TMC (0.2 miles) is fully leased by Government tenants – high demand + potential government tenants
6. The mix of tenant is government in a LEED building within the walking distance of TMC (0.5 miles)—potential government tenants
7. A building built in 1974 & renovated in 2006, but with some energy efficient systems, is asking for about 6% higher rent than TMC
8. A building built in 1972 & renovated in 2007 is asking for about 2% lower rent than TMC
9. A building built in 2000, the same year as TMC, but with Energy Star label, is asking for about 6% higher rent than TMC

## **Introduction for the Appraisers and Brokers**

### **Research Summary**

This study is part of a PhD research project in the College of Architecture and Urban Studies at Virginia Tech which focuses on the financial assessment of sustainable options investment in real estate. The goal is to develop a framework to assess the financial performance of sustainable options investment in existing buildings while explicitly considering risk and uncertainty. It demonstrates the assessment process that real estate investment decision-makers could follow to derive the benefits of sustainable attributes, both cost savings and non-cost benefits, and link them to the financial model inputs, such as rent, occupancy, tenant retention, discount rate, etc. As a result of applying this new process, property owners/ investors could better understand the true value of sustainability and make more informed decisions about greening their property.

As a vital part of this research, an office building in Rockville, MD is selected to thoroughly explore and explain the function of the proposed procedure in numeric terms. The building information is summarized in the following sections: General and Financial Information. A Lighting Controls package is selected as green retrofit option for the building and its energy performance was evaluated through energy simulation. The non-energy benefits associated with lighting controls, such as improved health and productivity, occupants' comfort, contribution to achieving LEED certifications, or Greenhouse Gas emissions reduction were identified and quantified to the extent possible through an extensive literature review and experts' interviews. A summary of impacts is presented in the Green Retrofit Impacts section.

The final step of this case study is a value-base analysis, where the green retrofit impacts link to the key valuation inputs/DCF inputs to estimate the potential incremental value. As part of this step, I am conducting interviews with knowledgeable stakeholders such as yourself to get your insights about demand and tenants' behavior in this sub-market. For example, how important is sustainable owned or leased real estate to the types of tenants expected to be leasing space in the building? The goal is to ultimately determine ranges/three-point estimates for the financial variables that are likely to be impacted.

Six comparable buildings, three LEED and three non-LEED buildings, in Rockville, MD are identified through GBIG and COSTAR databases and their key characteristics are presented in the end of this document. These buildings are not meant to be the best comparable buildings, but they can provide some insights about the average rents and tenant mix in the sub-market.

It should be noted that in this study the emphasis is on demonstrating the assessment process and not on the accuracy of final numeric results. All your inputs for completing this study are greatly appreciated. For your help I will provide to you a pre-publication copy of my research findings and make myself available for possible application of the new process framework.

### **General Information**

Property type: a four-story office building + basement  
Location: Rockville, MD  
Public Access: walking distance from Twinbrook Metro station  
Year of built: 2000  
Gross floor area: 91,420 Sq.Ft  
Parking Ratio: 3.2/1000 Sq.Ft



## Tenant Information:

Tenant Name	Sq.Ft.	2011 Rent PSF	Rent End Date	Business Type
Davis Construction (Headquarter)	51600	\$30.39	2020	Office – the largest general contractor in the DC area
SAIC, Inc.	16000	\$31.30	2014	Office – a fortune 500 company which provides services in the areas of energy and environment, health, etc.
A. Morton Thomas (Headquarter)	4550	\$30.39	2015	Office – an consulting engineers which provide services in LEED certification, environmental, technology etc.
CTA, Inc. (Headquarter)	4000	\$38.82	2011	Office – an information technology firm
ABC Imaging	2400	\$42.73	2013	Printing services

## Financial Information

Rent	Average rent in 2010: \$32.46 /Sq.Ft Average utility cost: \$4.59 /Sq.Ft. Rental growth rate: 3%
Occupancy	Total lease Sq.Ft.: 96.6%; Not leased Sq.Ft.: 3.4%
Improvement Cost	No tenant improvement in last six years

## Green Retrofit Impacts

**Retrofit Option:** Lighting Control Systems, a combination of four lighting control strategies including daylight harvesting, occupancy sensing, high-end trim, and personal dimming control.

Impact Description	Range	Average
<b>1. Energy Cost Savings</b>		
Annual Energy Cost Savings	<b>\$26,975-\$49,829</b>	<b>\$38,163</b>
<b>2. Improved Health and Productivity</b>		
Increased Individual Productivity	0.5% - 4.0%	2.1%
Productivity Cost Savings per Employee /Year	\$300 - \$2,400	\$1,284
Health Cost Savings per Employee /Year	\$5 - \$35	\$18
Annual Health & Productivity Savings per Employee	<b>\$305 - \$2,435</b>	<b>\$1,302</b>
<b>3. Increased Probability of achieving LEED Certifications</b>		
Certified	25%-75%	
Silver	20%-60%	
Gold	17%-50%	
Premium	13%-38%	



#### 4. Improved the Building Energy Performance Rating and Greenhouse Gas (GHG) Emissions

Currently the energy consumption and GHG emissions in the building are 15% above the national average. By employing the lighting controls option, the average energy and GHG emissions would become equal to the national average, and energy cost would go below the national average. As a result the Energy Performance Rating of the building will increase from 38 to 50.

Performance Metrics	Current	After lighting retrofit		National Average	Rating of 75
		Ranges	Average		
Site (kBtu/sq.ft/yr)	85	72-77	74	74	55
GHG Emissions (MtCo2e/yr)	1180	996-1070	1033	1,033	764
Energy Cost (\$/yr/sq.ft)	\$3.11	\$2.57-\$2.82	\$2.69	\$2.74	\$2.03

**5. Improved Occupants' Comfort\*:** Scores of studies have confirmed the direct relationships between lighting controls with lighting quality, visual comfort, and overall environmental satisfaction. One study shows the workers are 6% more comfortable with proper lighting controls.

**6. Improved Safety & Security\*:** Lighting controls can be connected to fire alarm and security systems to turn on lights in case of an emergency.

\*The quantitative data was believed to improve comfort and safety, but there was not sufficient resource in the literature to make numeric assumptions for these benefits of lighting controls.

### **Comparable buildings in Rockville, MD**

#### **LEED buildings from GBIG**

- 1) Twinbrook Place: 7-story Class A office property within 0.3 miles from TMC, 140,000 sqft, LEED Gold in 2010, built in 2009, rent: \$37.5/sqft for 20000 sqft and 120 months lease
- 2) Element: 4-story Class A office building in the same parkway within 0.2 mile from TMC, 90,000 sqft, LEED Gold, built in 1960s and renewed in 2009, LEED Gold in 2010, fully leased by GSA
- 3) 801 Anderson Ave: 3-story office building with in the 0.5 mile from TMC, built in 1963 renovated in 1999, LEED Gold EBOM in 2009, Mix of tenants: government, acquisition date: December 2007

#### **Non-LEED buildings from COSTAR**

- 4) Washington Science Center: 4-story office building within 1.4 miles from TMC, 110,000 sqft, built in 1974 and renovated in 2006, walking distance of a Metro station, energy efficiency rate of 75, parking

ratio of 3.2/1000 sqft, renovation includes new exterior skins, core elements, energy efficient systems, etc., rent \$32.5/sqft for 10 years lease

5) 6000 Executive Blv.: 6-story office building within 1.7 miles from TMC, 125,000 sqft, built in 1972 and renovated in 2007, walking distance of a Metro station, parking ratio of 3.1/1000 sqft, rent \$30/sqft for 5-10 years lease

6) Blackwell One: 5-story office building within 6 miles from TMC, 120,000 sqft, built in 2000, Energy Star labeled in 2009, parking ratio of 3.8/1000 sqft, rent \$32.5/sqft for 3-10 years lease

**Highlights:**

- A LEED building built in 2009 very close to TMC (0.3 miles) is asking for 23% higher rent than TMC
- A LEED building built in 1960s & renovated in 2009 a couple blocks from TMC (0.2 miles) is fully leased by Government tenants – high demand + potential government tenants
- The mix of tenant is government in a LEED building within the walking distance of TMC (0.5 miles)—potential government tenants
- A building built in 1974 & renovated in 2006, but with some energy efficient systems, is asking for about 6% higher rent than TMC
- A building built in 1972 & renovated in 2007 is asking for about 2% lower rent than TMC
- A building built in 2000, the same year as TMC, but with Energy Star label, is asking for about 6% higher rent than TMC

## **APPENDIX E: List of Market Questions**

- 1) What do you think the mix of potential new tenants (governments, top 500 fortune companies, high end professionals, typical office, etc.) might be for such office buildings in the Rockville market? Do you think that there would be more government-based tenants if the building were “greener”?
- 2) In your experience, what percentage of tenants specifically asks for green features when deciding about renting a space in this sub-market?
- 3) In general how important (not at all, somewhat or very important) is sustainability or energy efficiency in terms of perceived better working environment, for meeting compliance requirements such as LEED, higher productivity and satisfaction to potential tenants? Are these benefits important enough to influence their decisions about staying in the building when their current leases are expiring? Do they have any minimum standards or requirements relative to green/energy efficiency for the space they are occupying?
- 4) Who the potential investors/buyers are likely to be for this building in this sub-market?
- 5) How important is sustainability for these investors? Do you think that investors value the green features in this sub-market? For example, if there are two buildings with the same NOI, one has green features and one does not, would they value those differently? If so, do you know how and by how much?
- 6) Have you seen an increase in demand for green/energy efficiency in the Rockville market? If so, would you estimate the increase in demand to be slight, moderate or significant? Based on your experience how this increased demand has been primarily expressed into value? For example does it have influence on rental rate, rental growth, occupancy, absorption, retention, or discount rate.
- 7) Do you have any comments on the 6 comparable buildings and the highlights section in my summary? These buildings are very close to Twinbrook Metro Center I, some of them are just a couple of blocks away, and have LEED or energy Star labels. Even the older building that were recently renovated, show higher rents or higher occupancy rates?  
For example, one of them which was built in 2000 and was renovated in 2009 and received the Energy Star label and its rent is 6% higher than the average rent of TMC. Do you think the perceived higher performance and Energy Star label of the building play a major role in driving the rental rate?
- 8) Do you have any other thoughts about the market response and tenant’s behavior in Rockville? Any information that you think might be helpful in this case study would be greatly appreciated.

## **APPENDIX F: Summary of Interviews**

### **President of Davis Construction Company and the Owner of the TMC**

**What made you decide to think about upgrading the building? And what were you hoping to achieve by undertaking green retrofit?** We're building a lot of sustainable buildings for our clients; we needed to see if there are ways that we could economically make some revision to our own building, so we are more energy conservative. It has not been driven by desire or need to try to reduce the energy costs. As we make modification, we would invest in more energy conservative fixtures, but we didn't have a mission just to go out and replace perfectly good equipment with more energy efficiency equipment just for the sake of doing it. Light fixture is perfectly fine; if you're going to throw them away just to buy the light fixtures that are more energy more conservative, it doesn't make sense to me. What we're looking to do is to do smarter when we plan to do replacements and renovations.

**Have you undertaken or plan for any energy upgrades?** I think the only really substantial things that we've done is we did invest in purchasing electricity from a green source, such as wind power or solar power. However, with the economic recession, we didn't do any renovation to the office space.

**Considering green benefits, how important sustainability or energy efficiency is generally to you as the president of Davis Construction?** It is important to us; our building is designed in such a way that everybody gets a lot of natural light in space. What we need to consider is mechanical systems and its controls. They're 12 years old, at some point they would be 20 years old and time to be renovated. We will plan for more energy efficiency systems when it's time to renovate them. [It doesn't seem that they have any minimum green standards for their occupied space]

**How do you value green retrofit options when you want to make a decision about whether or not to invest in a green retrofit option?** What factors are more important? Well it would be the value achieved for the money spends. Does it have an impact on quality of life and lower the energy consumption? We would spend extra money for sustainable products to achieve the benefits.

**Do you have any particular requirement in mind in terms of cost-benefit ratio or payback period?** We would analyze the payback period when it's time to renovate systems. We would look at the more efficient; we intend to be in this building for a long time. That would lead us to making decisions that maybe have a longer payback period. We have higher cost and take a longer payback, because we know we would be here. We're not going to rush in make changes and find new equipment fast.

**If we assume that you are not the owner of the building and Davis construction is a regular tenant, how important green benefits are to you then?** I think having the landlord provide more energy efficient and LEED compliments; we want him to know it would have a higher importance to us.

**Are these benefits important enough to influence your decision about staying in the building when your current lease is expiring?** No, there are not important enough, we won't leave the building because the landlord didn't upgrade the mechanical systems.

**Are you willing to pay more to lease a green space?** Yes, we would.

**What is your opinion of improved property value?** It's very hard to judge the property value in this current environment as to whether or not the LEED building has a green value.

**Are you willing to invest in lighting controls with the financial outcomes where only energy cost savings is considered (payback of 7.7)?** The answer is we should investigate that. Davis intends to be in this building for a long time, so the fact that it's an 8 years vs. 5 doesn't bother me that much.

**When we include the health and productivity savings in the financial analysis, the payback period goes down to less than 2 years. Would this have an impact on your investment decision?** No, I don't think so, because in my assessment of the building first of all people gets a lot of natural lights, secondly, most of people are in and out an awful lot, going to the jobsites. We're not a company that people just seat here in front of computer all day long and so I think 50% of people are out 50% of a time. So I don't see lighting controls having a dramatic effect of health and productivity of our people.

**Some of the comparable buildings that have LEED or energy Star labels, even the older building that was recently renovated, shows higher rents than your building. Do you think the perceived higher performance and Energy Star label of the building play a major role in driving the rental rate?** One of large component of the rental rate is paying back for the tenants improvements. Essentially when you're paying your rent, you're paying borrowing money from landlord to build out your space. In our case, the landlord didn't offer any money to go towards improvement of the space. So the rental rate dropped a lot. If the comparable building was significantly renovated and therefore have new tenants, a large component of the rental rate maybe for paying all the new improvements that the landlord is putting to those office spaces. I don't certainly agree with you that our rent is lower. Maybe lower on face value but landlord is not paying off any improvements on the spaces.

**What type of tenants are you expecting in your building?** Davis is currently leasing 65% of the building, maybe 25% is leases by government contractors, and the other 10% is solely private sectors. My expectation is a mix of government contractors and private sectors tenants.

**Comments:** your study is very helpful, but as company as much as we would like to be energy efficient the economic part is an important part of these investment decisions. The idea of just simply replacing equipment or materials for the sake of having a more energy efficient systems doesn't make economic sense to me. I do think companies as they do their renovation in the future, are going to be very focused with energy impacts of their decisions over time, having much more energy efficient buildings.

### **The Property Manager of TMC, Cushman & Wakefield:**

**The importance of green retrofit to the current tenants:** The current tenants are not very much concerned about sustainability issues—they never had a new tenant since the building was built in 2000. The other part is that the operating cost will go down and that would make the building a little more attractive to tenants, because the current operating cost is very high in this building. The reason that current tenant would want to renew their lease is because of operating expenses will go down.

**The green retrofit impact:** The impact would be more marketing for Davis Construction from the standpoint that this building is their headquarter—when they're bidding, they can say that their own headquarter is certified and they're pushing sustainability themselves.

**Value variables:** The variable that might change the most is “tenant retention”.

**Why the comparable buildings in the area with LEED or Energy Star labels have higher rents?** There are different driving factors as far as rental rates go. The main reason is that the owner is the primary occupant, so if they increase the rental rates they essentially increase their own rental rate and I can foresee them not doing that. Other factor is that even though by increasing the rental rates they are increasing the value of their property, they have no intention of selling their building, so they just have to pay more real estate tax because they have to file the incremental expense report.

### **The Senior Vice President at TRANSWESTERN, Office Brokerage in MD**

**The mix of tenants:** Service companies especially health services firms, because the national institute of health is located in the general area of this building, and government contractors make up a large portion of the tenants as well.

**Importance of sustainability to tenants:** If the building is greener they might get more government and large corporate tenants. However, we don't have a large amount of large corporate tenants in Montgomery County. Our typical tenants are in the 5000 to 7500 sqft. range, and they're considered smaller tenants and it's less important to that size of tenants to be in a green buildings. It's less of a concern for most tenants that we're dealing with in this sub-market, for most of them green initiatives doesn't really matter, they're looking for the best deals. At this point, I don't think tenants are willing to pay more for green yet, except for the larger corporate tenants that have mandates or plan for green initiatives or for those which is a good business to be green.

**Importance of sustainability to Investors/buyers:** all things being equal, they would certainly lean toward the green building but it's hard to get people to buy in about improved health issues at this point, and maybe it's just a matter of time. We've come a long way in last 5 years, it used to be it will never take place or it is going to be very slow, but it's here and people are dealing with.

The institutional owner like TIAA-CREF and those types of owners certainly focus on these issues, but the more local entrepreneurs are less inclined to do it because the cost associated with that.

**Impact of LEED and ENERGY STAR labels:** I really don't think that having a LEED or Energy Star labels play a major role in driving the rental rates of the comparable buildings you've identified. Again, I don't think the tenants have reached to the point to pay more. There might be a few tenants willing to pay more, but I think the types of tenants that we deal with in this market, they're looking for the cheapest deal.

## **The Senior Appraiser at Cushman & Wakefield**

**The mix of potential tenants:** government tenants and government contractors. Regulatory commission is there. Rockville is well served by Metro, which is a big element that GSA looks for. The national institute of health is located in south of Rockville and the FDA is currently in Rockville.

**Were more government tenants in the building if it was greener?** Not sure about government precisely but government contractors or related tenants maybe.

**How important green is to the potential tenants:** it is important from marketing point of view. LEED buildings haven't been able to achieve higher rents than other buildings. They need to be competitive like any other building. I haven't seen any market evidence yet suggesting higher rents compare to the building next door that doesn't have it, all other things being equal. One of the characters that

government agencies are looking for is certified buildings. Having certifications at would allow building to be more competitive and more tenants come along.

**Do you think that this might change in the next 2-5 years as people become aware of issues of sustainability?** Yes, the time frame, I don't know. Once we get out of this recession and we build buildings again, I'm sure the buildings coming out of ground are going towards LEED certifications and green standards. I think they have to, from marketing point of view. That's what tenants would be looking for. The older buildings with less green features are going to become less and less competitive, as more green products become available. You're going to recapture additional cost through your rents, there would be a premium for being certified. That's going to take while. So, from marketing point of view, I think it's important, but when it gets to financial decisions, I think they still are going to go to the building that is competitive with rents.

**Have you seen any impact on other value variables like occupancy, cap rate, etc.:** Not as yet. Again, the most of the supply out there is not green buildings. There was a building recently sold with certification, but its cap rate was competitive with other buildings that are not green. Other thing that really surprised me, there is not a lot of differences in operating expenses. You would think that the utility costs or maintenance costs would be substantially less in the green building compare to the older buildings, but it's not the case.

**What are your thoughts on where those competitive edges are coming from? Is it perceived that they think a space in a LEED building has higher quality lighting, higher quality ventilation?** Yes, exactly. That perception would be a better work space for your employee, better lighting and ventilation. It is sort of the intangibles of quality of space that results in the competitive edge. From the tenants' point of view, it is not just there yet. I think it all comes to too much competitions especially in the market these days, higher vacancy rate and things like that. It is too much competition out there keeping rents from showing the additional cost of green features.

**From the owner/investor point of view, if we assume the energy cost is less in green buildings and rents is the same, isn't it a better deal?** It's not going to have significant impact on the value, because you utility cost is slightly less. (50 cents per sqft).

Currently people just have to do it to be competitive to be able to get the prospected tenants. It is a long term return. By going to LEED, you're not going to get the return that makes the investment worthwhile, other than making more marketable building.



**With that, would you think that an owner occupant would more likely invest in green, because generally their time frame tends to be longer?** Yes, I think so. I think it's a matter of perception. Some of these pension fund would like to say our portfolio has X% of building that are LEED certified.

**DCF inputs predictions for such building in sub-market:**

- **Rental rate:** lower mid 30's. Your current rent is a good market range right now.
- **Cost:** Your average utility cost is high. Utility cost: 3 to 4\$ per sqft, total cost: 10-12\$ per sqft
- **Rental growth:** current 3% is good.
- **Tenant improvement:** for new lease: \$25 to \$30 sqft. To renew a lease:\$5-\$10.
- **Occupancy rate:** 5-6% vacancy rate.
- **Cap rate:** 7%-7.75%
- **Renewal probability:** 70%

**The President of PGH Consulting, LLC**

**Green technologies value:** Green technologies potentially can increase the value and there is a reasonable reason to expect that it may eventually. But based on what I've seen that hasn't been manifested itself yet. The value items, until the market start paying for them, they don't translate into increased value. I would expect it's going to manifest itself, but until it does I can't recognize it. Until it shows up in actual value, appraisers can't include them. Appraisers are not allowed to include any incremental value until they actually see it reoccurring in the market

**Importance of green to tenants:** The type of the building that would occupy this type of building would be tenants that saw some benefits to show that we are in a green building, so that's an image thing. Someone who perceived some sort of benefit, either it could be obtained from their clients or in the case of contractors who works for government. I don't see the typical tenant going to green building simply because everything else is equal and the alternative choice isn't.

I do a lot of work for GSA and haven't noticed they're seeking out green buildings. They have some criteria about size or distance to metro, but not for green buildings.

**Which value variables do you expect to be changed after green retrofit:** Rental rate probability if the expenses are recognizes to be less. Occupancies probably not. With green features rental rate probably increase if the expenses are recognized to be less...I expect to see different cap rate for green building, but I haven't seen it yet.

**Typical cap rate:** for office building is in a 7.5% range.

## **Directors of Research & the Brokerage Group at Cushman & Wakefield**

**The mix of potential tenants:** Government tenants have been the most prominent in this market, followed by the FIRE (Finance, Insurance and Real Estate) sector, information and tech sectors.

Main drivers for government leases are total costs; proximity to Metro is also important. GSA leases 10,000 sf and greater must be in buildings with an Energy Star rating of 75 or above (currently or brought up to that rating) and LEED-Silver is the minimum.

**The potential investors:** REITS are the dominant investors in this sub-market. There are institutional investors that may also be interested.

**What percentage of tenants specifically asks for green features when deciding about renting a space?** I have not had any tenants ask. They appear interested when told but very few seem to really care.

**Importance of sustainability to tenant: Are these benefits important enough to influence their decisions about staying in the building when their current leases are expiring?** If a tenant is currently in a building with energy efficiency and sustainability, they are not going to be interested in going backwards. It can be a part of “flight to quality”.

**Importance of sustainability to investors:** I believe this differentiator is more important for the investor than for the tenant. I do not know what value they would place on it.

**Current value variables for green buildings:** Current asking rents for a sampling of LEED properties in Rockville range from \$35-\$49 while average class A asking rents in Rockville were \$36.53 at 3<sup>rd</sup> quarter 2011. LEED is only one of many factors driving the higher asking rents. For instance, 2000 Tower Oaks has the highest asking rent (\$45-\$49), but it is also a new building (completed in 2008) with high-tech green features and top of the line amenities.

It demands a higher rent but typically because it is in a newer or renovated building. It is only a secondary to the general location, quality and amenities.

## **Senior Managing Director and Principal at Cassidy Turley**

In DC itself that has more green building than the rest of the region because of mostly GSA and local legislation, there was \$5 sqft incremental rents and 100 points vacancy difference between existing buildings, which have gone through green retrofits or LEED EB, and non-green buildings.

## APPENDIX G: Published Papers

6<sup>th</sup> International Conference on IE ECB'10: Frankfurt, Germany - Full Paper

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JRC Scientific and Technical Reports

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### **Proceedings of the 6<sup>th</sup> International Conference on Improving Energy Efficiency in Commercial Buildings: IE ECB Focus 2010**

13<sup>th</sup> - 14<sup>th</sup> of April, 2010, Frankfurt am Main (Germany)



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# **A Framework for Estimating and Communicating the Financial Performance of Energy Efficiency Improvements in Existing Commercial Buildings While Considering Risk and Uncertainty**

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## **Abstract**

There is substantial evidence suggesting that property professionals, such as owners, investors and lenders who are involved in the investment decision-making process are increasingly interested in energy efficiency improvements (EEIs). One of the primary barriers to EEI is a lack of clear information regarding the true value, both revenue and risk, of EEI investments. EEI investments often include many non-quantifiable benefits as well as risks that current energy performance assessment tools and methods do not simultaneously incorporate. Nor are the outcomes typically presented in appropriate terms to be understood and utilized in the investment decision-making process.

In this paper, an analytical method and systematic framework is proposed to evaluate the financial performance of EEI alternatives in existing commercial buildings, while simultaneously addressing the risks and uncertainties associated with the process. The framework is a robust valuation process that takes EEI alternatives, uses current energy simulation programs to forecast estimates of the energy efficiency outcomes, links the predicted building performance to financial model inputs, and derives ranges/distributions of their bottom line financial performances. A Monte Carlo simulation model, based on the Discounted Cash Flow approach, is suggested for modeling the uncertainties of valuation process and estimating the financial performance. It is the objective of this study to create a single platform to bridge the gap between the design and investment communities and translate the technical language to financial language in order to present more reliable and understandable information regarding EEI's return on investment and its associated risk and uncertainty.

## **Introduction**

With rising energy costs, climate change and global warming, property professionals, such as owners, investors, real estate developers, asset managers, lenders and bankers who are involved in the investment decision-making process have become more interested in investing and financing energy efficiency. The property industry is now mature enough that portfolio and asset managers understand the economic and marketing benefits of improving energy efficiency across their portfolio of real estate. Historically, investor-owners have less of an incentive to invest in improvement for their properties rather than owner-occupiers who tend to have a longer outlook on their real estate holdings. Investor-owners have until recently received little or no additional monetary reward for the improvements incurred from the marketplace [1]. Today, investors-owners have found that sustainability is a necessary and appropriate defensive strategy for preserving occupancy, particularly for owners of older office buildings and shopping centers most at risk of losing tenants to newer, greener buildings coming into the market [2]. Improvement or green retrofits today are recognized as excellent investment opportunities among the investors and owners of existing property. The recent shift towards achieving LEED for Existing Building Certification among the investor-owners proves their increased awareness of potential returns inherent in improvement investment.

However, despite the increased general awareness of property professionals of positive financial performance and prediction of future growing demand, the magnitude of EEI investment is much lower than what it was expected to be. Real estate investors, owners, and managers still do not feel confident in investing and selecting the EEI alternatives. Essentially, these professionals need to ensure that their investment will generate a reasonable and competitive rate of return in the market with the lowest possible risk; they need to know if the risks associated with their investment are adequately compensated by expected returns generated. The authors believe that the process of investment decision making for selection of EEI for major retrofits is not different from typical property investment decision making from the perspective of risk and revenue. Thus, real estate professionals need to thoroughly recognize the market value, both revenue and risk, added by EEI in their financial analysis. There is also a significant amount of uncertainty associated with achieving the expected outcomes in EEI investment that needs to be explicitly taken into account in the investment decision making process. Simultaneous consideration of potential revenues, risks and uncertainties, which factor in the full scope of costs and benefits of EEI, will enable final decision makers to understand true financial performance of EEI, make more informed decisions about investing in energy efficiency and select the best possible EEI alternatives for major retrofitting of their existing building.

The existing tools and techniques primarily used by design professionals do not suffice in providing final decision makers with the comprehensive and reliable financial information they need for their investment decision making process. Accordingly, there is a need to explicitly connect building performance estimates from the design professionals to the more sophisticated financial tools used by property professionals to measure the financial impact of EEI alternatives and represent them in a language that can be understood and utilized in the investment decision making process. This is the deficiency that we aim to address throughout this paper.

## **Existing Energy Tools Used for Evaluating EEI**

In the last two decades, design professionals such as architects, engineers, construction consultants, and facility managers have been widely using building energy simulation programs, not only in designing and planning a new building but also in evaluating the energy performance of an existing building. These technical tools primarily provide users with forecasts of the impacts of design decisions on energy performance indicators such as electricity or gas usage. Some of them also perform simple financial evaluations primarily based on simple payback and simple return on investment approaches. They take the building systems and strategies as inputs, and evaluate and project the building performance or simple financial performance as outputs. Currently, many minor and major retrofitting decisions are made based on the outcomes of these tools. The models help decision makers explore the potential energy saving by each EEI alternative, compare them, and select the most effective options. However, there are two major problems with using energy simulation programs for making major EEI investment decisions:

- 1) Communication between Technical and Financial Decision Makers: these technical tools have been primarily designed to model and analyze the energy performance indicators of interactive energy related systems and their outcomes are described in technical language. Therefore, due to their technical outcomes rather than financial outcomes, these tools are not able to communicate the overall energy performance to the investment decision makers in the way they can understand and directly utilize in their investment decision making process. Although many of the financial performances are the result of non-financial factors of the EEI alternatives employed in the buildings, investors are more concerned with the final performance in financial language and not as much with the technical details associated with the building performance outcomes. Most of the current tools are well developed to deal with the complexity and dynamic interactions of building systems performance in evaluating the energy performance, but fail to properly link energy to financial performance and do not translate the technical language to financial language.

- 2) Simplistic Financial Analysis: the financial analyses that some of these tools perform are based on the initial cost and operational cost saving. Simple financial techniques, such as Simple Payback (PB), Simple Return on Investment (ROI) and Life Cycle Analysis (LCC), are utilized as the primary methods in these analyses. Traditionally, due to their simplicity, these types of financial techniques are used very often by decision makers for assessing the energy efficiency investment and selecting the best EEI alternative. However, they ignore many costs, benefits, and positive and negative risks of

energy efficiency investment, as well as uncertainties associated with the process of achieving those benefits. The full costs and benefits of energy efficiency are beyond the operational cost saving and traditional financial analysis; and ignoring them, may undervalue the investments and exclude many profitable investment opportunities from consideration, which ultimately would lead to underinvestment in EEI.

For example, investment in energy efficiency in a non-green office building will decrease energy cost but at the same time may increase the benefits such as access to incentives, improve worker health and productivity, reduce electricity consumption volatility, achieving energy certification, etc. The available incentives may pay for a significant portion of the investment costs and therefore should be considered in the investment analysis. Improved worker health and productivity in an office building may contribute to the significant cost savings for employers because of lower absenteeism and recruiting costs, and also increase the ability to meet evolving tenant demand, which would lead to lower turnover rate. Reducing electricity consumption volatility would reduce the risk of budgeting and cash flow management by increasing the predictability of energy consumption. Achieving energy certification, such as EnergyStar, or contributing to achieving sustainability certification, such as LEED, would increase the reputation and marketability of the subject building, which would lead to higher absorption rates. These are examples of the types of benefits that are ignored when making investment decision solely based on the results of energy simulation programs.

Accordingly, the current energy assessment tools do not simultaneously incorporate all of the costs, benefits, risks and uncertainties of EEI investment, nor represent them in appropriate terms to be understood and utilized in the investment decision-making process. None of them on their own are sufficient to rely upon for making high-quality investment decisions for major EEI [5]. Relying solely on their simulation results often undervalue the energy efficiency and therefore, many EEI profitable opportunities may be excluded from investment consideration. Below is list of some of the potential energy efficiency benefits that might impact the property market value after EEI, true return on investment of EEI, and ultimately EEI investment decisions [6]. They are typically ignored in current energy assessment models:

- Access to utility incentives, state agency incentives or federal government incentives;
- Tax saving benefits;
- Insurance saving benefits;
- Better financing options;
- Expedited Permits benefits;
- Reduce the carbon emission;
- Contributing to achieving sustainability or energy certification, such as LEED or EnergyStar;
- Improve worker health and productivity;
- Increase property reputation and marketability; and
- Increase asset value or revenue due to improved appeal to regulators, space users and investors, which would lead to higher rent, higher occupancy, lower turnover rate, higher absorption rate, etc.

Some of the potential positive risks include:

- Reduce the risk of losing value due to functional obsolesce;
- Reduce the risk of losing tenants due to availability of energy efficient buildings in the future markets;
- Reduce the risk of inaccuracy of projected building performance [7];
- Reduce the risk of energy price volatility;
- Reduce electricity consumption volatility;
- Reduce the risk of budgeting and cash flow management by increasing the predictability of energy consumption;
- Reduced liquidity risk; and
- Reduced legislative risk.

Some of the uncertainties inherent in the EEI valuation process include:



- Uncertainty associated with forecasting energy performance by energy simulation tools;
- Uncertainty associated with achieving any certification or energy label;
- Uncertainty associated with improving health and productivity;
- Uncertainty associated with achieving the expected rents, occupancy, etc.
- Uncertainty associated with future cost of oil or energy price;
- Uncertainty associated with future interest rates and inflation rate; and
- Uncertainty associated with future utility rates.

## Energy Performance Evaluation

Many valuation experts have argued that evaluating the actual building performance is the best way to determine the financial performance of a property. The actual building performance can be understood by looking at the utility bills such as electricity or water. The problem with this approach is that in new construction or major retrofits the investment decisions need to be made when measuring the actual performance is not possible, when the building systems are not yet installed and operation data are not available. In these situations the energy simulation software tools we discussed previously are the forecasting tools for the building performance. Evidence shows that actual energy performance may differ from what was forecasted by energy simulation models such as e-Quest or Energy-Plus. Energy forecasting models, while generally considered fairly accurate, are subject to some level of intrinsic error ranging from 10% to 20% or more [8]. Therefore, there is always a certain amount of uncertainty associated with projecting the energy use based on design assumptions. It is critical for decision makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building performance when making decisions based on the actual performance. In this paper, we suggest introducing ranges and distributions for reporting the building performance outcomes with the mean of modeled forecasts in order to incorporate the risks inherent in modeling projections.

Another important issue in evaluating the outcomes of energy efficiency systems is that most of the energy-related systems and strategies, which are typically employed in retrofitting existing buildings, have more benefits than just lowering energy consumption. For example: employing a new energy efficient HVAC system may reduce the energy consumption but at the same time may improve the ventilation rate, reduce the air pollution, reduce the noise level and therefore, improve indoor environmental quality. Also, they might have opposite results. For example, utilizing an insulating strategy may perform well for energy efficiency but badly for moisture. Implementing a bad daylighting strategy may improve the energy efficiency but increase glare and thereby, lower the user's satisfaction. Unfortunately, today most of the energy efficiency evaluations are based on the simulation of energy-related systems in a single energy simulation program, such as DOE 2, and therefore, their other potential impacts on performance, such as indoor air quality, thermal comfort, vision performance, acoustic performance, etc. are ignored. Thus, energy-related systems' and strategies' contribution to performance are beyond the direct energy cost savings, they do impact on other building performance mandates. Later, we have explained that these indirect-impacts on building performance or "non energy cost saving" could play a direct role in the financial performance of a building and therefore, are important to be considered in performance valuation.

Depending on the level of the accuracy and sophistication of energy performance valuation that is required by final decision makers, energy consultants could do the followings: Model the EEI with a energy simulation program, do research from available data and studies about other potential costs-benefits of that EEI and adjust their finding for their specific buildings. Or, they could model an EEI with multiple Building Simulation Programs (BSPs) to understand the range of impacts on other performance mandates. BSPs, which are widely used by design professionals to model and analyze building performance outcomes, are capable of dealing with the complexity and dynamic interactions of building performance. Each program has advantages and disadvantages in evaluating the specific indicators. A BPS might be a great tool for predicting the monthly energy consumption, but a poor estimator of building ventilation. For example, DOE-2 is widely used in the U.S. for calculating energy consumption, and CFD tools are generally accepted for the study of building ventilation, indoor air quality, or thermal comfort. To date, no program has been developed to evaluate all the performance indicators simultaneously. "It is a common fact nowadays that for any given problem there is usually more than one BSP that can meet the requirements." [9]. Due to the costs of software and modeling personnel, users usually model a building with a single simulation tool, and judge the building

performance based on the results of this tool. In some cases, this would lead decision makers to make poor decisions. Therefore, for a thorough energy efficiency valuation we encourage users to model an EEI with more than one simulation program.

## **The Financial Model for EEI Valuation: Discounted Cash Flow Approach**

One of the most common and powerful financial models currently used and widely accepted in real estate as the basis for investment decision making is the Discounted Cash Flow method (DCF). The DCF technique evaluates the present value of the projected future cash inflow and outflow over the holding period (generally a term of ten years for commercial office buildings). DCF inputs include rent, occupancy, operation costs, tax and capital costs, absorption rate, depreciation, holding period, discount and capitalization rate, etc. The DCF model makes explicit the assumptions on model inputs, projects the revenue over the holding period, and estimates the financial performance indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR). The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate its related expenses, revenues, and risks simultaneously. For example, one of the most important assumptions in a DCF model is the discount rate that is used to calculate the present value of all future cash flow streams. The discount rate reflects the risk associated with receiving the projected cash flows. The discount rate, which is estimated using the Capital Asset Pricing Model (CAPM) method, is the sum of the rate of return of a risk free asset and a risk premium. The risk premium represents the additional return that the investor requires as compensation for taking on the additional risk of this particular investment. Thus, the discount rate on an asset is positively related to its risk, that means investing in a property with lower investment risk will result in lower risk premium and thereby a lower discount rate will be selected for that investment. This is how risk is taken into account in DCF modeling.

The result of a study by Bowman and Wills (2008) has confirmed DCF as the most suitable method for assessing the valuation of green buildings. “Even though hard data is limited, the DCF approach allows valuers to factor in assumptions about the future shifts in value of Green Star buildings” [11]. “It [DCF analysis] provides the means to translate the “intermediate” sustainable property cost and benefit outcomes like health or productivity benefits, expedited permitting, or lower operating costs into financial measures like rate of return or net present value traditionally used by real estate capital providers” [8]. Thus, we encourage decision makers to use the concept of the DCF approach in lieu of simple PB, simple ROI, or LCC for estimating the financial performance of EEI alternatives. With the DCF method, potential direct and indirect costs, benefits and risks associated with energy efficiency investment, outlined previously, could be considered in generating the investment’s revenue.

## **Reporting Risk and Uncertainty of EEI Valuation: Monte Carlo Simulation**

### **Risk and Uncertainty**

“Risk and uncertainty relate to situations in which the performance measures have more than one possible outcome and the outcome is not known in advance”[12]. Risk is defined as a situation in which alternative outcomes and their probability of occurrence are known, where as uncertainty is a situation where information about future outcomes and their probability are not known. “Uncertainty is anything that is not known about the outcome of a valuation at the date of the valuation, whereas risk is the measurement of the value not being as estimated” [10]. Although, by definition, risk is a different from uncertainty, they are commonly used interchangeably in the context of property investment analysis. Uncertainty refers to the lack of knowledge of future events, which can lead to risk, whether it is a threat or an opportunity; and managing risk is really about managing uncertainty [22]. In the context of investment, risk is defined “as the extent to which the actual outcome of an action or decision may diverge from the expected outcome” [13]—the probability of not receiving the expected return. The variability of the expected return about its mean (the range of possible outcomes) is used as a description of risk, and the most popular measures of variability is variance—the spread of a probability distribution. Standard deviation is commonly used as a measure of spread.

### **Risk and Uncertainty in the Valuation Process**

There is general agreement that there are risks and uncertainties associated with all valuation procedures which need to be identified, assessed, and reported in a way that can be understood and



analyzed by investors or end users. For example, the uncertainty associated with DCF inputs (assumptions about future factors) and risk of not achieving value or rate of return as predicted in DCF (estimation of DCF outputs). “Risk and uncertainty are inherent parts of the valuation process as often the valuer is unable to specify and price accurately all current and future influences on the value of the asset” [14]. “Uncertainty is a universal fact of property valuation. All valuations, by their nature, are uncertain” [10] and the acknowledgement of this fact would provide investors with useful information about the level of confidence in receiving their expected return and therefore, a key insight into of desirability of proceeding.

“Risk is recognised as an inherent element within the valuation process and in the absence of perfect data across the property market it is likely that this situation will pertain to varying degrees. If risk cannot be eliminated the valuer is required to manage the analysis of risk within the valuation process so that its impact is minimised and the end user of the valuation can have confidence in the value estimate” [14]. The lack of consideration of risk and uncertainty inherent in valuation model such as DCF analysis requires a more sophisticated quantitative approach for the valuation process.

### **Reporting Uncertainty**

“Despite the unquestioned necessity for reporting a single point estimate of market value for particular valuation assignments (e.g. financial reporting, financial performance measurement, court valuations, etc.) valuers should not proceed in reporting this figure only and in ignoring elements of risk and uncertainty. Valuers cannot be expected to predict the future but they can be expected to be transparent with regard to their assumptions even if they are (by nature) subjective, highly uncertain and maybe wrong from an omniscient observers’ perspective” [16]. “This identification of the most probable value and a range of values gives the client a measure of risk in the estimation of value. It translates the uncertainty in the key input variables into the final figures” [15].

Therefore, risk and uncertainty need to be measured and considered simultaneously with other issues of the valuation process; otherwise the outcomes of the valuation process may be overestimated or even underestimated, and may lead to inappropriate investment decisions. Accounting for uncertainties inherent in the valuation process and risks associated with achieving final financial performance indicators will improve the reliability of outcomes and also the confidence level of decision-makers in their decision-making process. This will impact the future reputation of valuers or consultants.

In the proposed EEI valuation process, probability distributions are used for articulating risk and uncertainty. Probability distributions are the primary quantitative vehicle used for explaining risk or Value at Risk (VaR) in the risk management analysis methods. The probability distribution describes a range of possible values and the probability of any value within any subset of that range. All variables that are uncertain could be represented with probability distribution, and their associated risks could be estimated using statistical approaches based on specifications of a range of most likely values or extreme values.

### **Monte Carlo Simulation**

“Monte Carlo analysis is a widely used numerical computational analysis tool that draws information from input probability distributions, applies the data in a process, and generates an outcome distribution” [4]. This technique is able to account for uncertainties by allowing for a range for each input and their correlations at the same time, perform a random probabilistic sensitivity analysis and model a range of possible outcomes. In the Monte Carlo simulation data is processed and ranges of final outputs are estimated through the base model which describes the relationship between inputs and outputs. The output will express the likelihood of the inputs’ and outputs’ occurrence along with their values’ probability distribution. The results—whether shown graphically or reported numerically with summary of statistics, such as mean, variance, standard deviation, skewness, etc.— would allow decision makers to better analyze and interpret uncertainty and would provide them with more reliable information than a few discrete scenarios. “Monte Carlo simulation provides a structured approach that explicitly incorporates uncertainty into decision-making models” [17].

The Monte Carlo simulation technique has been suggested by many valuation experts to measure and express various risks and uncertainties in the valuation process by describing the range of possible values instead of a single-point estimate of value in the DCF model. Cash flows generated by Monte Carlo simulation provide more robust valuations than “traditional DCF valuations, permit the user to estimate the portfolio’s price distribution for any time horizon, [and] facilitate Values-at-Risk (VaR) computations”— estimation and presentation of risk with reference to the holding period and a confidence level [18].

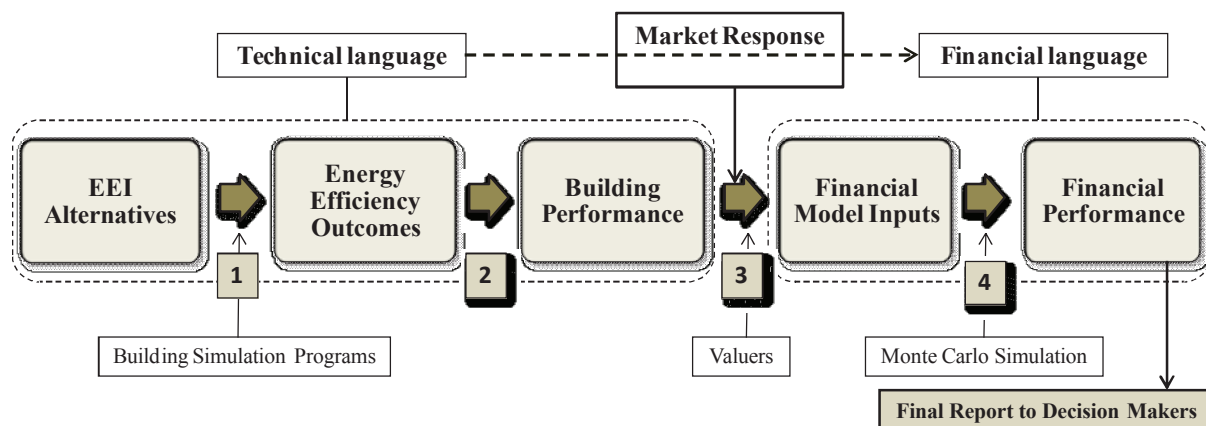
In this paper, the Monte Carlo simulation is suggested for estimating the final financial performance indicators of EEI alternatives. The base model for this simulation, which describes the relationship between inputs and outputs, is built based the DCF approach. This probabilistic model takes and analyzes the same DCF inputs, such as rent, occupancy and tenant retention, and outputs, such as NPV and IRR, but replaces single estimate points with appropriate ranges and probability distributions. The Monte Carlo simulation incorporates the uncertainties of achieving the DCF inputs and articulates the risk related to receiving these outcomes by looking at various combinations of inputs across their different distributions, performing multiple simulations (random sensitivity analysis), and generating a distribution of financial outputs.

## New EEI Valuation Framework

### Approach

As stated previously, while the best way for understanding the financial performance of green systems in existing buildings is measuring their actual building performance, it is not possible for major retrofits analysis. It is the responsibility of valuers or energy consultants (who aim to estimate the value of energy efficiency) to use the available tools and data to project the building performance, analyze the market’s response to the forecasted performance, and select the financial model inputs. Therefore, understanding the bottom line financial performance of green systems mainly depends on the decision makers’ predictions about the building performance and market response to these predictions. However, most of the current studies in the area of green/energy-efficient buildings performance focus on the assessment of the systems performance and building performance outcomes, and would not directly tie them to financial performance.

Muldavin (2009) has developed a “Green Building Finance Consortium (GBFC) Sustainable Property Performance Framework” which links the building performance to the financial performance through the assessment of market performance [8]. The proposed EEI valuation framework in this paper generally follows the process shown in Figure 1—adapted from the “GBFC Sustainable Property Performance Framework”—to derive the bottom line financial performance of each EEI alternative:



**Figure 1: An EEI Valuation Process for Deriving the Financial Performance of EEI Alternatives**

This process is a path that decision makers, either technical people (design community) or property professionals (investment community) should go through in order to fully understand the effect of their selection of EEI alternatives on the building financial performance at the pre-development stage. It

translates the EEI impacts into the financial language to be included in a financial model and communicates the final financial performance indicators to the end users in reliable and understandable terms. The proposed framework takes an EEI alternative as a input, estimates its related outcomes, projects the new building performance resulting from new EEI investment, links the building performance to the DCF inputs by evaluating the market's responses to the building performance, and finally, analyzes those inputs in the Monte Carlo model to derive financial performance indicators of the subject existing building.

- EEI Alternatives: green systems or strategies that could result in greater energy efficiency including high-efficiency HVAC systems, lighting systems, daylighting, green roof, under-floor ventilation, motion sensors, high-performance windows, solar hot water heating, operable windows, wind turbine, energy control systems, building commissioning, etc.
- Energy Efficiency Outcomes: full potential impacts of EEI investment that could directly and indirectly influence building performance and ultimately, financial performance of EEI alternatives. These include electricity or gas consumption, indoor air quality, thermal comfort, CO2 emissions, air pollution, solar shading, natural ventilation, lighting, noise level, moisture transport, temperature and humidity distribution, air flow, glare, illumination, etc.
- Building Performance: includes both green building performance and non-green building performance. Green building performance, which are the factors related to the energy efficiency retrofits or EEI, include development costs (hard/soft costs, timing, tax savings grants and financing costs), resource use, occupant satisfaction, health, productivity, contribution to green or energy certifications, achievable government incentives, reputation, marketability, public benefits, development and cash flow risks, etc. Non-green building performance, which are the critical factors in valuation of a property and not related to the retrofits, include location, access, age, size, security, market condition, etc.
- Financial Model Inputs: the financial model suggested for this process for estimating the financial performance is a traditional Discounted Cash Flow (DCF) model. The inputs of the DCF model for estimating the revenue of the building include: market rental rate, annual rental growth, building costs (such as operation cost, leasing expenses, tax and capital cost), occupancy, absorption rate, tenant retention, discounted rate and capitalization rate.
- Financial Performance: contains factors that people from investment communities are primarily concerned with when making decisions. These include revenue, IRR, NPV, etc.

### **The Process Steps, Methods and Considerations**

As shown in Figure 1, there are four main steps in the proposed process that decision makers need to follow in order to understand the financial performance of the selected EEI. It should be noted that in this paper we do not aim to provide any detailed information or guideline about data estimation, collection or forecast in each step of the proposed process. The primary goal here is to provide professionals who are involved in energy efficiency consulting or decision making with a new framework for evaluating the EEI alternatives. Below, the four main steps are presented:

#### *Step 1: Building Modeling*

As stated previously, energy-related systems' and strategies' may contribute to other performance mandates such as indoor air quality or thermal comfort. Their impacts are beyond the direct energy cost savings but important to be considered in valuation. The reason that these indirect-impacts on building performance mandates or "non energy cost saving" are important in valuation is that any building performance indicator that is of interest to occupants could play a role in the financial performance of a building. Several studies have confirmed that the outcomes such as thermal comfort, indoor air quality, or acoustical performance would affect the occupant performance, such as occupant satisfaction, health and productivity. These factors potentially increase demand, influence the financial model inputs such as absorption rate, vacancy rate, etc., and ultimately improve the bottom line financial performance. Thus, it is important to realize that there are other building performance outcomes beyond energy conservation or direct energy costs savings that impact the financial performance of a building.

We encourage users to model the existing building with each new EEI with more than one simulation program for a thorough valuation. The users need to identify the potential outcomes of EEI they are

interested in evaluating, carefully assess the capability of available modeling tools, and ultimately select the most appropriate tools that match their requirements. For example, if the users are only looking at evaluating energy consumption, they might use eQuest or EnergyPlus, but if they feel that the EEI might have impacts on indoor air quality or daylighting quality, they might need to model the building with a Computational Fluid Dynamics (CFD) modeling tool or Radiance Interface. The U.S. Department of Energy has suggested a list of “whole building simulation” tools [3] that users could go through these lists and select the appropriate tools based on the types of the decisions, building systems (inputs) and building performance (outputs) they are interested in evaluating.

### *Step 2: Building Performance Forecasting*

Green building performance includes factors that could be influenced by the energy efficiency investment. When evaluating a specific property, development and operation costs, resource use, possible achievable certifications and incentives, can be estimated relatively easily based on available data, guidelines, regulations, and modeling tools. However, factors such as users’ satisfaction, and health and productivity are more difficult to measure precisely. Currently, establishing the precise quantitative relationship between performance outcomes, health/productivity and market value seems to be almost impossible, due to limited data and difficulty in obtaining required information in a way that can be used directly in property level decision making. However, in the real estate investment world, perfect science or exact knowledge about the potential health/ productivity benefits of sustainable property is not required. What is required is appropriate caution in the use of health and productivity studies so as not to mislead decision-makers based on incorrect or incomplete presentation of results and caveats [8]. Therefore, it is particularly important that decision makers acknowledge the potential benefits to occupants and consider the occupants’ response to those benefits that result from EEI investment, even if the exact quantitative data is not available.

### *Step 3: Financial Model Inputs*

The traditional DCF approach is suggested to build up the base model for estimating the financial performance of the existing building with new EEI alternatives. This approach is able to thoroughly incorporate the potential direct and indirect costs, benefits and risks associated with energy efficiency/green building investment in generating the investment’s revenue. This step is a translation from technical to financial language. In this step, all the technical details concerning energy efficiency outcomes and information about building performance are translated to DCF inputs such as rents, occupancy, absorption rate, operation and financing costs, etc.

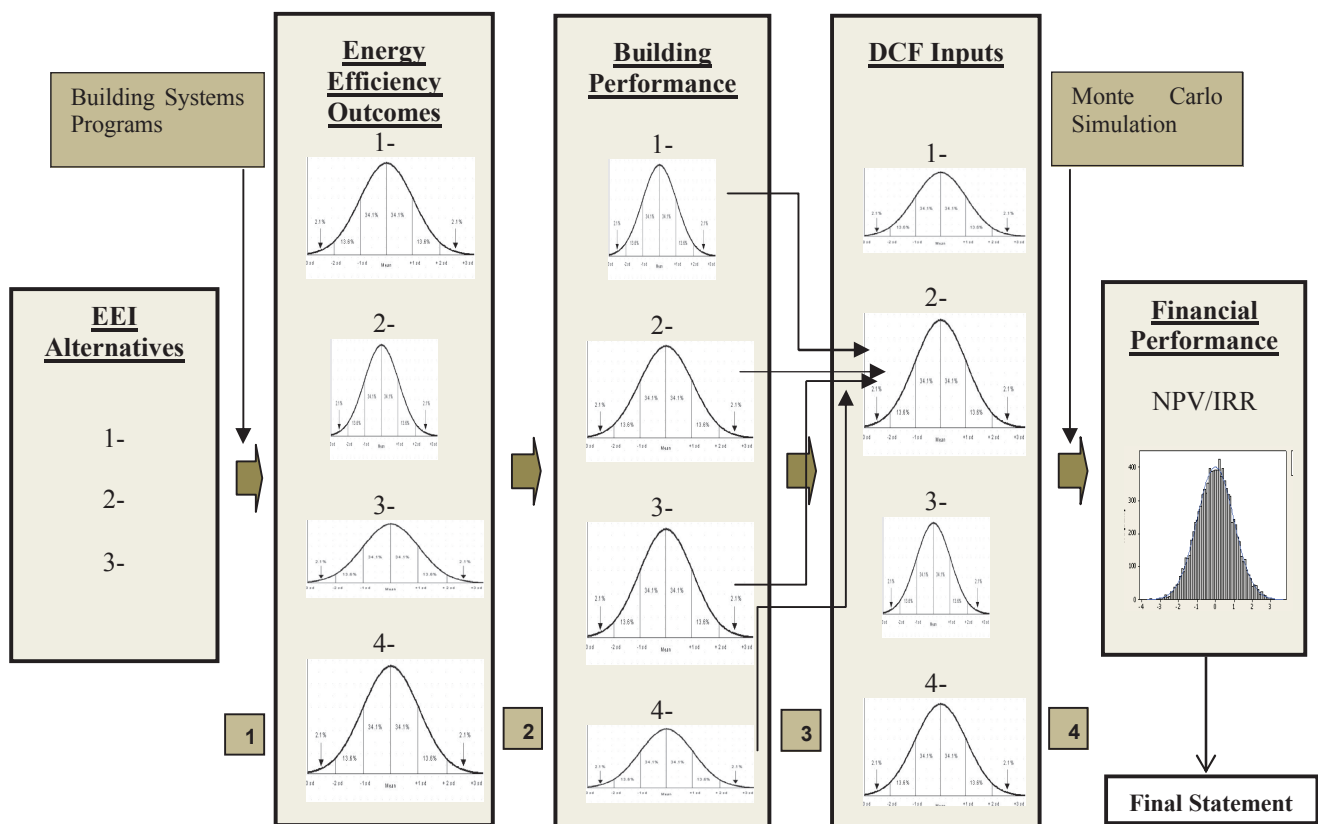
There are two important challenges in determining the DCF inputs: One is the nature of this analysis, which requires a simultaneous consideration of many factors, both green and non-green, in order to determine the DCF inputs to ultimately derive the property value (revenue and risk). In fact, the impact of green factors on the financial model inputs are typically limited when compared with the non-green factors and therefore, improvement or decline in financial performance of a green building could be primarily due to other non-green factors. The good news for existing buildings is that all non-green factors do not change after implementation of the green/energy retrofits. Having considered all non-green factors being equal in property valuation, all changes in the projected cash flow will be related to the DCF assumptions that are influenced by the selected EEI alternatives. Therefore, the procedure will measure and numerically communicate the market value added by investing on those selected EEI alternatives in the subject existing building.

Another challenge is related to the valuation process of all building types, either green or non-green: that is a consideration of both quantitative data and qualitative judgment in determination of DCF inputs. In order to select financial inputs, for each specific property the real estate valuers (underwriters, appraisers, due diligence persons) have to do as much research as possible in order to collect all related quantitative results, as well as other qualitative information. They must consider all the results and information simultaneously and assess the expected behavior of regulators, investors and space users (key driver of property value) for that particular market. “While the impact of green strategies may be clear in one market, it is the valuer’s responsibility to determine the market environment for high performance green features on a case-by-case basis” [19]. Adair & Hutchison (2005) also pointed out that “while the final single point estimate of value may become a statement of fact in the minds of the users of the valuation it nevertheless remains the opinion of an expert [valuer]”

[14]. It is not possible to develop a robust tool in order to perform this translation and produce the final financial inputs, such as a rent, to be directly included in the DCF model. Data has to go through a qualitative filter. Valuers are the ones who do this translation from technical language to financial language by integrating quantitative data from simulation tools or other assessment techniques with other qualitative information about specific subject property, and evaluating market response to the data and information in a specific situation.

*Step 4: Uncertainties modeling and financial performance estimating*

It is widely accepted that all forecasts about the future involve a certain amount of uncertainty. In the proposed valuation process, in each step all estimations and outcomes are based on projection, either objective, such as energy modeling, or subjective, such as DCF inputs selection. Therefore, there is a certain amount of uncertainty associated with measuring the outcomes of each step in the valuation process. Some of these uncertainties include: Uncertainty in Step 1: The degree of uncertainty associated with forecasting the potential energy efficiency outcomes. Uncertainty in Step 2: The degree of uncertainty in determining the building performance, such as health and productivity based on projected outcomes, such as ventilation rate, level of noise, lighting, etc. Uncertainty in Step 3: The degree of uncertainty about forecasting the financial model inputs due to limited sales data and absence of a robust pricing model on green buildings as well as the difficulty of precisely determining the impact of green investment on a property value. These are examples of the types of uncertainty associated with the energy efficiency valuation process that need to be considered in order to communicate reliable outputs to final decision-makers. Thus, we suggest specifying a probability distribution for all variables that are uncertain. A schematic diagram demonstrating the function of the proposed valuation process is shown in Figure 2. We suggest Monte Carlo model to estimate the final financial performance of EEI alternatives, while simultaneously incorporate and articulate uncertainties of the valuation process. This model will apply and measure various uncertainties in the valuation process by ascribing the range of possible outcomes, in order to communicate how the selection of EEI impacts the range of possible expected value with its confidence interval.



**Figure 2: A Schematic Diagram for Demonstrating the Function of the EEI Valuation Process**



The resulting ranges and the shape of distributions would reflect the uncertainty related to the estimation of simulation inputs (DCF inputs) and articulate the risks related to achieving the simulation outcomes (DCF outputs), which ultimately assist final users to make a better investment decision. For example, the tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and therefore the higher level of confidence that investors will receive the predicted outcome (mean). Flat distribution with large standard deviation denotes the great degree of risk and uncertainty and therefore, less confidence investors could be in achieving the expected outcomes.

### **Final Statement for the Decision Makers**

Finally, the results of the process will be reported to decision makers in the form of a more simple and understandable statement. The simulation results, along with a description of alternative outcomes and their probability of occurrence, will be presented either in simple matrices or clear graphics. This final statement must be very clear and easy to understand for end users. The details of the development of the input data and simulation processes do not need to be included in the report for investment decision-makers. As mentioned previously, investment communities are more concerned with the final key financial indicators as opposed to the technical details in the process. However, the details would be available to the decision makers if they would like to check the assumptions used in the valuation process to increase their level of confidence.

### **Conclusion**

The current energy simulation tools, widely used by decision makers, do not simultaneously incorporate all of the costs, benefits, risks and uncertainties of EEI investment, nor represent them in appropriate terms to be understood and utilized in the investment decision-making process. None of them on their own are sufficient to rely upon for making high-quality investment decisions for major EEI. Relying solely on their simulation results often undervalue the energy efficiency and therefore, many EEI profitable investment opportunities may be excluded from consideration. In this paper, a robust valuation process is suggested to connect building performance estimates from the design professionals to the more sophisticated financial tools used by property professionals to measure the financial impact of EEI alternatives and represent them in a reliable and understandable language. Its final outputs would provide decision-makers with a much more comprehensive view of investment outcomes, as opposed to traditional single-point estimates of conservative simple PB or ROI, and a clearer idea about inherent risks and uncertainties in the valuation process. The proposed process is a systematic framework that final users, both design and investment communities, could follow to better understand the true value-added by each EEI alternative as well as risk and uncertainty associated with achieving their possible additional returns on investment. They could compare the final market value of a building with different EEI alternatives and select the best possible EEI alternative for greening their buildings. In summary, the following principles are suggested throughout this paper for evaluating energy efficiency investment and also considered in development of the proposed valuation framework:

1. There is inaccuracy/error inherent in building modeling forecasts. The actual building performance may differ from what was projected by BSPs. It is critical for decision makers to consider this inaccuracy/error to avoid overestimating or underestimating the building performance when making decisions based on the actual performance.
2. Any building performance outcome that is of interest to occupants could play a direct role in the financial performance of a building and therefore, are important to be considered in energy performance valuation. It is not just energy cost saving that matters. We suggest modeling the existing building through different modeling tools in order to evaluate as many performance outcomes as possible that might have impacts on occupant performance.
3. Simple cost-based financial methods, such as simple PB, simple ROI or LCC, fail to address the true value of energy efficiency investment, both revenue and risk, and therefore, ignore many energy efficiency costs and benefits. Instead, we suggest to utilize the concept of DCF approach for the estimating the financial performance of EEI alternatives. With the DCF method, potential direct and indirect costs, benefits and risks associated with energy efficiency investment could be considered in generating the investment's revenue.

4. There is a degree of uncertainty associated with the forecasts in each step of EEI valuation process. Careful consideration of uncertainty is of vital importance in providing more reliable data to decision makers. We suggest introducing ranges and distributions for reporting the forecasted factors in order to incorporate and articulate the risks and uncertainties inherent in the EEI valuation process.
5. We propose the Monte Carlo simulation to estimate the final financial performance indicators of EEI alternatives. The base model for this simulation, which describes the relationship between inputs and outputs, is built based on the DCF approach. This probabilistic model takes and analyzes the same DCF input and outputs, but replaces single estimate points with appropriate ranges and probability distributions.

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**2010 ACEEE Building Summer Study: Pacific Grove, CA – Full Paper**



# **A Procedure for Linking Projected Energy Performance Uncertainty with Investment Decision-Making**

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## **ABSTRACT**

Energy consultants, design professionals, and property professionals have widely used building energy modeling tools to project energy performance when evaluating energy efficiency investment. These models help decision makers to explore the potential savings, estimate the simple payback (PB) and simple return on investment (ROI), compare the various energy efficiency systems and strategies (EESS), and select the most cost-effective options based on the results of their financial analyses. However, the primary issue with these financial outcomes is that they typically only focus on installation and operational costs when estimating the return on investment (ROI). Many benefits of energy efficiency investment, such as reduced risks and increased asset revenue, are beyond these analyses and ignoring them in the financial analysis may lead to poor investment decisions.

In this paper, primary challenges in evaluating the financial performance of energy efficiency investment are addressed. An eight-step procedure is proposed for a more holistic financial assessment of energy efficiency to incorporate all costs and benefits, in terms of revenues and risks, resulting from the EESS, while explicitly expressing uncertainties. This is an integrated procedure that explains how to build an accurate case-based model and address the uncertainty associated with the input assumptions, and then links the estimated building performance to financial performance indicators. It uses the Discounted Cash Flow approach and Monte Carlo simulation technique for calculating IRR and ROI in order to accommodate revenues, risks and uncertainties.

## **Introduction**

Over the last decade, many studies, such as Summary of The Financial Benefits of Energy Star Labeled Office Buildings (Kats & Perlman 2006), have been performed to articulate the financial performance of energy efficiency investment. The majority of these studies are “case-based” which focus on the financial performance of a single energy-efficient building or “causal-comparative studies” which focus on comparison of larger sets of energy-efficient buildings versus their peer conventional ones utilizing statistical modeling techniques, such as regression analysis. They attempt to recognize the value added by investing in energy efficiency. Their results have generally shown that the financial performance of buildings with higher energy efficiency features and certifications, such as Energy-Star, may have higher rents, higher occupancy levels, lower operation costs and higher absorption rates and therefore higher market values. These studies primarily focus on new building and less clear is whether and how existing buildings, which makes up for a bulk of commercial buildings, should be retrofitted and refurbished (Miller & Buys 2008). Ciochetti and McGowan (2009) in their recent study about the payoff of energy efficiency improvements, have concluded that while data representing the impact of investing in energy efficiency improvements continues to pose a challenge, investment in these projects produce a return on investment, increase the predictability of energy

consumption and add value by decreasing operating costs. The results of these studies, case-based or causal-comparative, are very helpful in providing decision makers with useful information and deeper insights into energy efficiency investment benefits and encouraging them to consider the EESS in their retrofit decision making process.

Building energy modeling programs are the primary tools used by design professionals such as architects, engineers, energy analysts, and facility managers for evaluating the energy performance, not only in designing a new building but also in evaluating existing building performance. These tools primarily provide users with forecasts of the impacts of design decisions on energy performance indicators such as electricity or gas usage. Some of them also perform simple financial evaluations. They take the building systems and strategies as inputs, and evaluate and project the building performance or simple financial performance as outputs. The U.S. Department of Energy (DOE) has developed a directory which contains information on more than 100 energy simulation tools including DOE-2, Energy Plus, etc. A short description is provided for each tool along with other information including expertise required, audience, input, output, etc. (DOE 2009). Users could go through these lists and select the appropriate tools based on the types of the decisions, building systems (inputs) and building performance (outputs) they are interested in evaluating. Currently, many minor and major retrofitting decisions are made based on the energy saving outcomes and simple financial analyses of these tools.

However, these modeling tools if not used properly could result in unreliable outcomes and may lead to inappropriate decisions about energy efficiency investment. The results of modeling tools on their own are not sufficient to rely upon for making high-quality investment decisions at the property level. In this paper, the important issues and challenges of utilizing modeling tools in existing income-producing property have been discussed and a new procedure is suggested for a thorough assessment of financial performance of the EESS investment.

## **Evidence of Inaccuracy/ Error of Energy Models Forecasts**

Evidence shows that actual energy performance may differ from what was forecasted by energy simulation models such as e-Quest or Energy-Plus. Energy forecasting models, while assumed to be good predictors of energy performance, are subject to some level of intrinsic error ranging from 10% to 20% (Muldavin 2009). This forecasting error is interpreted as the percentage error between actual energy consumption and forecasted energy use based on a building's actual design characteristics and use profile, including actual process energy. Below, two examples of model forecast inaccuracy are presented:

Turner and Frankel (2008) in "*Energy Performance of LEED for New Construction Buildings*" concluded that there is wide scatter among the individual results that make up the average savings. Some buildings do much better than anticipated. Measured Energy Use Intensities (EUIs) for over half the projects deviate by more than 25% from design projections, with 30% significantly better and 25% significantly worse. As shown in Equation 1 **Error! Reference source not found.**, the ratio between actual and modeled EUIs for individual building ranged from 50% to 280% and the mean value was approximately 99%.

### **Equation 1**

$$25\% < \text{Actual/Modeled} < 275\% \ \& \ \text{Mean} \approx 92\%$$

According to Newsham, Mancini, and Birt (2009), the average ratio between measured and designed EUI was close to unity, at 0.92, suggesting that modeled results over populations of buildings might represent a reasonable estimate of actual energy performance. However, as shown in Equation 2, the ratio for individual projects ranged from less than 0.25 to >2.75.

**Equation 2**  
**50% < Actual/Modeled < 280% & Mean ≈ 99%**

While the average ratios suggest that energy modeling forecasts are reasonably reliable, the estimates for an individual building are very scattered, and the distribution of results are quite varied. Thus, the degree of inaccuracy/error can be large in some cases, and the models might not be a good predictor of project-specific energy performance. It is critical for decision makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building energy performance when making decisions based on the predicted performance. Therefore, it is suggested to calculate ranges and distributions for reporting the energy performance outcomes with the mean of modeled forecasts in order to incorporate the errors inherent in modeling forecasts—risk of not achieving the predicted outcomes.

### Calibration Process

In the retrofit analysis of an existing building, it is critical that the base case model provide accurate estimates of current energy performance in order to be able to forecast the energy performance of retrofit options reliably. Calibration methods have been suggested by many researchers as a critical part of the simulation process of existing buildings. Existing buildings are typically modeled based on the necessary data and information obtained from supplied plans and construction details, specification books and operating schedules. The results of initial simulations usually indicate that despite the careful attention in creating the models, the actual measured energy use is different from what was projected by models. This discrepancy is primarily due to the significant uncertainty or error associated with the simulation inputs. The calibration process compares actual measured performance data with those values predicted by the software and repeatedly refines the models, and reduces the errors until it closely represents the actual measured data and complies with the calibration standards. The three guidelines, which specify the acceptable tolerances for the calibration of simulation, are presented in the table below:

**Acceptable Tolerance for Monthly Data Calibration**

Index	ASHREA 14 (%)	IPMVP (%)	FRMP (%)
ERR <sub>month</sub>	±5	±20	±15
ERR <sub>year</sub>	-	-	±10
CV (RMSE <sub>month</sub> )	±15	±5	±10

EER: mean bias error; CV (RMSE): coefficient of variation of the root-mean-squared error

Source: Pan, Huang & Wu 2007, 652

Mechanisms that are typically used to identify the errors and update the inputs include: using the most accurate as-built information, site visits, surveys and interviews with building operation managers and occupants, on-site measurement, such as outside air flow, temperature or light levels measurement, and checking the utility bills data, such as electricity bills and gas bills. These methods help to reduce uncertainty associated with inputs of existing buildings' models.

Researchers have suggested several calibration methods for simulated models of existing buildings, although none of them is accepted as a standard method.

Westphal and Lamberts (2005) have suggested using sensitivity analysis in the calibration process, and presented six stages for calibration of building simulation models:

1. Calibration of power and schedules of constant loads, such as lights and plug loads;
2. Simulation of design days for thermal loads analysis;
3. Sensitivity analysis over input parameters related to significant heat gains/loss;
4. Adjustment of input values of high level of influence and uncertainty;
5. Whole year simulation;
6. Final adjustments.

Pan et al. (2007) have also suggested six steps for the calibrated simulation procedure:

1. Produce a calibrated simulation plan;
2. Collect data;
3. Input data and run model;
4. Calibration of simulation model;
5. Refine model;
6. Calculate energy and demand savings.

## **Energy Performance Outcomes**

Most of the EESS, which are typically employed in retrofitting existing buildings, have more benefits than just lowering energy consumption. For example, employing a new energy efficient HVAC system may reduce the energy consumption but at the same time may improve the ventilation rate, reduce the air pollution, reduce the noise level and therefore, improve indoor environmental quality. Unfortunately, most of the EESS evaluations today are based on the simulation of energy-related systems in a single energy simulation program, such as DOE 2, and therefore, their other potential impacts on performance, such as indoor air quality, thermal performance, vision performance, acoustic performance, etc. are ignored. Rush (1986) has outlined the six building performance mandates and has examined how a building system, such as HVAC system, may contribute in different performance areas simultaneously. According to Rush (1986), the six performance mandates include spatial performance, acoustical performance, thermal performance, air quality, visual performance, and building integrity. Thus, energy-related systems' and strategies' contribution to performance are beyond the direct energy cost savings, they do impact on other building performance mandates.

These indirect-impacts on building performance or “non energy cost saving” could play a role in the financial performance of a building and therefore, are important to be considered in performance evaluation. In order to understand the ranges of impacts of the EESS on other performance mandates, it is desirable to model the subject building with multiple Building Simulation Programs (BSPs). Each BSP has advantages and disadvantages in evaluating the specific indicators. A BSP might be a great tool for predicting the monthly energy consumption, but a poor estimator of building ventilation. For example, DOE-2 is widely used in the U.S. for calculating energy consumption, Radiance Interface for evaluating the lighting and daylighting systems, and Computational Fluid Dynamics (CFD) tools for the study of building ventilation,

indoor air quality, or thermal comfort. To date, no program has been developed to evaluate all the performance indicators simultaneously. However, due to the costs of software and modeling personnel, users usually model a building with a single simulation tool, and judge the building performance based on the results of this tool. In some cases, this would lead decision makers to make poor decisions. Even if it is not possible to model a building through multiple BSPs, energy consultants are expected to acknowledge other potential impacts of the selected EESS, conduct a review of available data and studies, and adjust their findings for a specific property.

## **Investment Decision-Making Process**

Property professionals, such as real estate investors, owners, developers, managers and lenders, are becoming more interested in investing and financing energy efficiency during the last decade. The idea of energy efficiency has been around in US for a while, but it received dramatic attention among property professionals after the energy price crisis in 2006. These professionals are primarily concerned with the market value, both return and risk, that energy efficiency investment could add to their property. They need to know if the risks associated with their investment are adequately compensated by expected returns generated—risk and revenue trade off. They must truly recognize the financial return they might have received above the amount they would received when not investing in the EESS.

Historically, design professionals, such as architects, engineers, and construction consultants, would propose design options and provide property professionals with information concerning the impacts of their design suggestions (costs and benefits) on building performance. Property professionals process the cost-benefit information with their own decision-making techniques, and make the final decision about whether or not to proceed with investing in those proposed options. Therefore, it is the responsibility of design professionals to communicate the full scope of costs and benefits of energy efficiency to property professionals. Designers should be able to fully explain how their energy efficiency options impact the building performance and how those impacts could affect the property market value. This information, if presented in a reliable and understandable language, will enable real estate investors/owners to make more informed decisions about energy efficiency investment.

There are three major problems with using energy simulation programs for making major energy efficiency investment decisions:

1. These technical tools have been primarily designed to model and analyze the energy performance indicators of interactive energy related systems and their outcomes are described in technical language. Therefore, due to their technical outcomes rather than financial outcomes, these tools are not able to communicate the overall energy performance to the investment decision makers in the way they can understand and directly utilize in their investment decision making process. According to Lorch, Lützkendorf, and Lorenz (2007), “this largely technocratic approach is, on its own, not enough to bring about the necessary change. What is needed is to encourage dialogue and learning between the construction community and practitioners from the property, finance, insurance and banking industries”. Most of the current tools are well developed to deal with the complexity and dynamic interactions of building systems performance in evaluating the energy performance, but fail to properly link energy outcomes to financial performance and do not translate the technical language to financial language.



2. The financial analyses that some of these tools perform are based on both the initial and operational cost saving. Financial techniques, such as simple PB, simple ROI and Life Cycle Analysis (LCC), are utilized as the primary methods in these analyses. Traditionally, due to their simplicity, these financial techniques are used very often by decision makers for assessing the EESS investment and selecting the best options. However, they ignore many costs, benefits, and positive and negative risks of energy efficiency investment, as well as uncertainties associated with the process of achieving those benefits.

The full costs and benefits of energy efficiency are beyond the operational cost saving and traditional financial analysis; and ignoring them, may exclude many profitable investments opportunities from consideration, which ultimately would lead to underinvestment in energy efficiency. For example, investment in the EESS in a non-green office building will decrease energy cost but at the same time may increase the benefits such as access to incentives, improve worker health and productivity, reduce electricity consumption volatility, achieving energy certification, etc. Improved worker health and productivity in an office building may contribute to the significant cost savings for employers because of lower absenteeism and recruiting costs, and also increase the ability to meet evolving tenant demand, which would lead to lower turnover rate. Reducing electricity consumption volatility would reduce the risk of budgeting and cash flow management by increasing the predictability of energy consumption. Achieving energy certification, such as Energy Star, or contributing to achieving sustainability certification, such as LEED, would increase the reputation and marketability of the subject building, which would lead to higher absorption rates. Scores of studies, mentioned previously, have confirmed that all these benefits could directly or indirectly increase the property market value. These are examples of the types of benefits that are ignored when making investment decision solely based on the results of energy simulation programs.

3. These tools are unable to deal with potential uncertainty associated with their inputs. They only take single point estimates of inputs and ignore their potential variance resulting from differences between design assumptions and actual systems performance. As a result, their projected outcomes are usually interpreted inaccurate and unreliable.

Accordingly, the current energy assessment tools do not simultaneously incorporate all of the costs, benefits, risks and uncertainties of energy efficiency, nor represent them in appropriate terms to be understood and utilized in the investment decision-making process. Design professionals will not report the true financial performance of the EESS to their clients, if they solely rely upon the simplistic analysis of these technical tools. The outcomes of these tools on their own are insufficient for making high-quality investment decisions and often undervalue the energy efficiency investments.

In order to better communicate to investment communities, design professionals need to understand how property professionals value their investment choices, what techniques traditionally they use to financially evaluate their options, and how they account for risk and uncertainty in their investment decision making process.

## **The Traditional Discounted Cash Flow Approach**

One of the powerful financial methods currently used in real estate investment is the Discounted Cash Flow method (DCF). The DCF technique evaluates the present value of the projected future cash inflow and outflow over the holding period. The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate its related expenses, revenues, and risks simultaneously. It is the responsibility of valuers to do as much market research as possible and forecast the DCF assumptions. DCF inputs include rent, occupancy, operation costs, tax and capital costs, absorption rate, depreciation, holding period, discount and capitalization rate, etc.

We encourage design professionals to utilize the concept of DCF approach in lieu of simple PB, simple ROI, or LCC for estimating the financial performance of energy-efficient buildings. With the DCF method, potential direct and indirect costs, benefits and risks associated with energy efficiency investment could be considered in generating the investment's revenue. Consideration of both revenues and risks in the financial analysis will allow designers to provide their clients with the true financial performance of energy efficient buildings. In the proposed procedure in this paper, DCF approach is suggested as a base model for estimating the financial performance indicators of energy efficient properties.

## **The Monte Carlo Simulation Model**

There is a certain degree of risk and uncertainty involved in financial assessment of energy efficiency. For example, uncertainty associated with determination of design assumptions in energy modeling tools and risk of inaccuracy of model forecasts; or, uncertainty associated with determination of DCF inputs (assumptions about future factors) and risk of not achieving value or rate of return as predicted in DCF (estimation of DCF outputs).

Risk and uncertainty need to be measured and considered in assessment of energy performance; otherwise the outcomes of the evaluation process may be overestimated or even underestimated, and may lead to inappropriate investment decisions. Accounting for uncertainties inherent in the process and risks associated with achieving final financial performance indicators, such as IRR or NPV, will improve the reliability of outcomes and also the confidence level of decision-makers in their decision-making process.

In current energy modeling tools and the DCF model, inputs are included as single point estimates and therefore, the uncertainties of the input assumptions are not taken into account. Inability of the traditional technical tools and financial methods to deal with uncertainty in the energy performance evaluation process requires a more sophisticated quantitative approach to explicitly account for uncertainty.

“Monte Carlo analysis is a widely used numerical computational analysis tool that draws information from input probability distributions, applies the data in a process, and generates an outcome distribution”(Jackson 2008, 137). This technique is able to account for uncertainties by allowing for a range for each input and its correlations at the same time, perform a random probabilistic sensitivity analysis and model a range of possible outcomes. In the Monte Carlo, simulation data is processed and ranges of final outputs are estimated through the base model which describes the relationship between inputs and outputs. The results, whether shown

graphically or numerically with summary of statistics, allow decision makers to better analyze uncertainty and provide them with more reliable information than a few discrete scenarios.

In the proposed procedure, the Monte Carlo analysis is suggested for modeling uncertainty and estimating the final financial performance indicators of the EESS. The base model for this simulation is built based on the DCF approach. This probabilistic model takes and analyzes the same DCF inputs and outputs but replaces single estimate points with appropriate ranges and probability distributions.

## **A New Procedure for Energy Efficiency Investment Analysis**

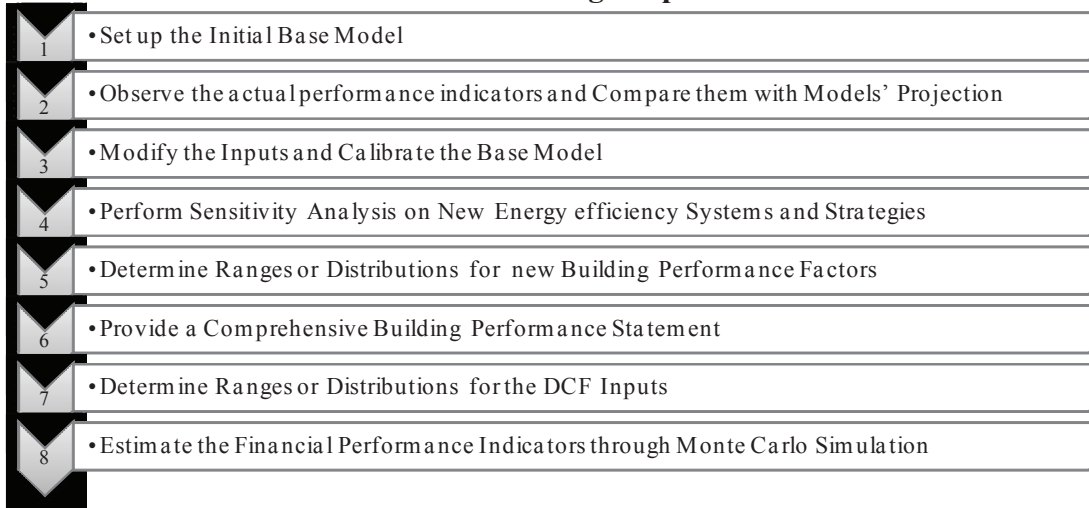
One of the major problems of financial analysis of energy efficiency investment is that most of the current tools and studies in the field of energy efficiency focus on the assessment of systems performance and building energy performance outcomes, and would not directly link them to financial performance in the way that investors require. Muldavin (2010) has developed a “Green Building Finance Consortium (GBFC) Sustainable Property Performance Framework” which links the building performance to the financial performance through the assessment of market performance. The proposed procedure in this paper generally follows the concept of the “GBFC Sustainable Property Performance Framework” in order to estimate the financial performance indicators of the EESS in a major energy retrofit of an existing income-producing property. In the development of this process, emphasis has been placed on three domains including: calibration process and a more holistic energy performance evaluation, financial analysis of the EESS investment, and incorporation and communication of uncertainties inherent in the procedure.

The process begins with modeling the property with existing characteristics and conditions and building up a reliable model to serve as a base case for evaluating the energy performance and generating ranges/distributions of energy performance indicators, resulting from investing in the new EESS. The outcomes of energy performance along with other related building performance factors would then be connected to the financial/statistical models which are used by investment communities in their investment decision-making process.

Figure 1 illustrates the steps in the procedure that decision makers should follow to arrive at more reliable estimates of financial performance of energy efficiency, while risk and uncertainty have been factored in. The results of the procedure will help decision makers in addressing the decisions about “whether or not to proceed with investing in energy retrofits” or “selecting the best possible EESS in retrofitting the existing buildings”.



**Figure 1: A Procedure for Financial Assessment of the EESS in Retrofits of Existing Income-Producing Properties**



Below, the subsequent eight steps, shown in Figure 1, are explained in more detail:

1. Set up the initial model based on available data, such as plans, construction details, specifications, operation schedule, or any as-built drawings or information; run the initial model and calculate the annual and monthly electricity and gas usage.
2. Observe the actual annual and monthly electricity and gas usage by looking at historic utility bills; compare the actual measured electricity and gas usages with those predicted by the simulation model, and calculate the annual and monthly mean bias error (EER) % and coefficient of variation of the root-mean-squared error (CV RMSE) by formulas presented in Equation 3.

Check if the calculated EER% and CV RMSE% falls in any of the three accepted tolerances for data calibration suggested by ASHRAE 14, IPMVP, and FEMP (presented in the table). If it falls in the suggested ranges, or very close to any of those ranges, the initial model is appropriate enough for evaluating the new EESS; if not, the initial model needs to be refined, and its outcomes should be compared with the actual usages again. The process will continue until its results closely match with the actual usages observed from utility bills.

Comments on Simulation: a) When practical, the simulation weather file should be for the actual year for which utility records are to be compared and not a Typical Meteorological Year (TMY) file. If a TMY file is used the actual monthly weather for the utility records year should be compared to the monthly TMY data as this can be a significant source of error. b) Some adjustment to the comparative data is often needed as utility records seldom correspond to the calendar month. Two possible procedures for dealing with this include: if available, sum the daily simulation values to correspond to the measured records; or normalize the measured records to correspond to the simulated monthly values.

### Equation 3: EER and RSME Formulas

$$ERR_{\text{month}} (\%) = \left[ \frac{(M - S)_{\text{month}}}{M_{\text{month}}} \right] \times 100\% \quad (1)$$

$$ERR_{\text{year}} (\%) = \sum_{\text{year}} \left[ \frac{ERR_{\text{month}}}{N_{\text{month}}} \right] \quad (2)$$

where  $M$ : measured electricity (kWh) or fuel consumption;  $S$ : simulated electricity (kWh) or fuel consumption;  $N_{\text{month}}$ : number of utility bills in the year.

$$CV (RSME_{\text{month}}) (\%) = \left[ \frac{RSME_{\text{month}}}{A_{\text{month}}} \right] \times 100\%$$

$$RSME_{\text{month}} = \left\{ \frac{\left[ \sum_{\text{month}} (M - S)_{\text{month}}^2 \right]}{N_{\text{month}}} \right\}^{1/2}$$

$$A_{\text{month}} = \left[ \frac{\sum (M_{\text{month}})}{N_{\text{month}}} \right]$$

where RMSE: root-mean-squared monthly error;  $A_{\text{month}}$ : mean of the monthly utility bills.

Source: Pan, et al. 2007

3. Identify the inputs with suspected high impacts on outcomes and any other possible sources for discrepancies and modify the initial model. Interviews with building operators as well as on-site measurement of systems performance could be helpful to obtain possible updated information about building systems performance and operation. Perform sensitivity analysis on each of those suspected input parameters, with a change of input value within a reasonable range, in order to specify a more accurate value for the model inputs. It will also verify which inputs have a significant influence and which are minor. Calibrate the model based on new inputs found from interviews and sensitivity analyses accordingly. It is probable that only those variables with greatest impacts on simulation outcomes will need to be adjusted.
4. Enter the new EESS selected for retrofitting as the new input assumptions to the calibrated model. Perform sensitivity analysis within the reasonable ranges of new inputs of each new EESS to project the new performance indicators, and finally, determine a range or distribution for each outcome based on the results of the sensitivity analysis and the model's error estimated by comparing the error statistics of the final base case model with those aforementioned standard tolerances presented in the table.
 

As stated previously, it is suggested to model the subject property with new energy conservation options through different BPSs to understand their full impacts on other building performance mandates such as indoor air quality, thermal comfort, or noise level.
5. Determine a range or probability of occurrence for the building performance factors both green and non-green. Green building performance, which are the factors related to the EESS investment, include development costs, resource use, occupant satisfaction, health, productivity, contribution to green or energy certifications, achievable incentives,

reputation, marketability, cash flow risks, etc. Non-green building performance, which are the critical factors in valuation of a property and not related to the retrofits, include location, access, age, size, security, etc. Energy efficiency outcomes estimated through BPSs in the previous step are a foundation for forecasting the green performance factors. When evaluating a specific property, development and operation costs, resource use, probability of achieving certifications and incentives, can be predicted relatively easily based on available data, guidelines, regulations, and modeling tools. However, factors such as users' satisfaction, and health and productivity are more difficult to measure precisely. Scores of studies, such as "Impacts of Building Ventilation on Health and Performance" conducted by Lawrence Berkeley National Laboratory, have shown that there is a positive relationship between green building performance outcomes, such as ventilation rate or daylighting, and space users' satisfaction, and health, and productivity. Other studies, such as "The Costs and Benefits of Green Buildings" (Kats 2003) demonstrate that improved health and productivity positively impact the cost savings and property value. Currently, establishing the precise quantitative relationship between performance outcomes, health/productivity and market value seems to be almost impossible, due to limited data and difficulty in obtaining required information in a way that can be used directly in property level decision making. However, in the real estate investment world, perfect science or exact knowledge about the potential health/productivity benefits of sustainable property is not required. What is required is appropriate caution in the use of health and productivity studies so as not to mislead decision-makers based on incorrect or incomplete presentation of results and caveats (Muldavin 2010). Forecasting ranges for health and productivity performance in a specific property will suffice. Therefore, it is particularly important that decision makers acknowledge the potential benefits to occupants and consider the occupants' response to those benefits that are results from energy efficiency investment, even if the exact quantitative data is not available.

The second type of building performance includes the non-green factors, such as location, access, age, etc. The good news about existing buildings is that most of these factors do not change after retrofits and therefore, could be considered equal in the financial analysis of energy efficiency. As a result, all changes in the final financial performance of the existing building are related to the EESS investment.

6. Provide a statement of building performance which includes all the historic financial and operation data—such as details on current rents, current expenses and current absorption rate—,all non-green factors—such as location and property quality—of the subject property, as well as new building performance information resulting from investing in the new EESS. This statement contains a summary of costs, benefits and risks of each employed option, both quantitative and qualitative information.
7. Determine a range or probability distribution for each DCF input based on quantitative and qualitative data included in the building performance statement. This step is where the technical details are connected to financial variables to be included in the financial analysis. Historically, the property professionals such as real estate valuers (appraisers, underwriters, or due diligence persons) have done this translation. They consider all the information in the statement, stated in previous step, simultaneously, assess the market

responses to those data and information in a specific property situation, and forecast the DCF inputs.

8. Set up a Monte Carlo model utilizing the DCF approach for describing the relationship between inputs and outputs. Run the model numerous times (e.g. 5000 times) and calculate the probability distributions of DCF outputs such as IRR and NPV. The resulting ranges and the shape of distributions would reflect the uncertainty related to the estimation of simulation inputs (DCF inputs) and articulate the risks related to achieving the simulation outcomes (DCF outputs), which ultimately assist final users to make a better investment decision. For example, as shown in Figure 2, the tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and therefore the higher level of confidence that investors will receive the predicted outcome (mean). Flat distribution with large standard deviation denotes the great degree of risk and uncertainty and therefore, less confidence investors could be in achieving the expected outcomes.

**Figure 2: General Interpretation of Shapes of Normal Distribution**



## Conclusion

The traditional modeling techniques and assessment approaches used by decision makers for evaluating energy efficiency are not typically sufficient to rely upon for making major energy efficiency investment decisions. The key conclusion of this paper is that the true financial performance assessment of energy efficiency needs a new integrated approach. It cannot be done by a single group of experts. The holistic assessment requires both design and property professionals to be involved, and both technical and financial/statistical techniques to be intelligently utilized in the evaluation process.

The proposed eight-step procedure is the initial step towards the development of an integrated approach for financial assessment of the EESS. Design professionals are expected to make the model as accurate as possible, consider the uncertainty of input assumptions in evaluation process, and thoroughly communicate the impacts of energy efficiency investment on all dimensions of building performance, as stated in step 1-5 of the suggested procedure. Inputs from property professionals, such real estate valuers, are necessary for determination of DCF model inputs, as state in step 7.

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# What Else Do Design Professionals Need to Know About Sustainable Buildings Investment? A New Assessment Approach

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**ABSTRACT:** Design professionals typically do not report the true value of sustainable building to their clients in reliable and understandable terms. It is necessary for designers, particularly architects, to understand how investment professionals value their investment choices, what techniques traditionally they use to evaluate their alternatives, and how they account for risk and uncertainty in their investment decision making process. In this paper, first, the deficiency of current building performance tools, such as building simulation programs, sustainability certifications, simple financial methods and building performance-based techniques in evaluation of sustainable buildings are presented. Recommendations are then provided regarding the additional knowledge of financial, risk and uncertainty modeling that designers need if they want to estimate and communicate a more complete assessment of value to the real estate decision makers. The Discounted Cash Flow approach is explained as a financial method, capable of incorporating all costs, benefits and risks for estimating the value. The Monte Carlo simulation is suggested for modeling uncertainties inherent in the evaluation process. Finally, a new assessment process is proposed to align the environmental and social benefits with economic returns of sustainability and to thoroughly evaluate the true value of sustainable buildings, while explicitly including uncertainty.

Conference theme: on measurement: quantifying sustainability, are we using the correct measures?

Keywords: true value of sustainability, sustainable building assessment techniques, financial performance, risk, uncertainty

## 1. SUSTAINABLE BUILDING INVESTMENT

Sustainable building investment is not a new concept, it has been around for more than a decade in the United States and longer in Europe. However, with all of the concerns about climate change, global warming, and rising energy costs in recent years, sustainability investment becomes a mainstream consideration in planning and design of most building development, both new construction and retrofit.

Substantial evidence suggests that demand for sustainable buildings has increased over the past several years. Owners, government regulators, investors and designers are the primary drivers in this shift in attitude toward sustainability. Many space users have indicated that they are prepared to pay more for rent or for purchasing sustainable buildings with the expectation to reap the benefits, such as operational cost savings, improved corporate reputation, and health and productivity. Most investors and owners of existing buildings have declared that they would not undertake a retrofit of a building without considering investment in at least some sustainable features. These professionals

believe that the benefits of sustainable building investment will increase in coming years; and therefore, they are not only concerned about today's market demand, but also about the possible growing future demand. "The decision for real estate investors and developers today is not whether new projects should be green, but rather how green they should be" (Smith, 2007, p. 1). Even during the recession, owners that fail to adapt quickly to the new standards may find their viability jeopardized" (Nelson, 2009).

### 1.1. New Responsibilities of Design Professionals Regarding Sustainable Buildings

There are two groups of decision makers who are involved in the development process of a building: design professionals, who are involved in technical decision making processes, and property professionals, who are involved in financial or investment decision making processes. Design professionals include architects, engineers, etc. Property professionals include real estate investors, developers, valuers, lenders, etc.





**Figure 1:** Communication between Design and Property Professionals

As illustrated in Figure 1, design professionals would generally propose design alternatives and provide property professionals with information concerning the impacts of their design suggestions (costs and benefits) on building performance. Property professionals process the cost-benefit information with their own decision-making techniques, and make the final decision about whether or not to proceed with investing in those proposed alternatives. Essentially, property professionals make their investment decisions based on their predictions of value, both revenue and risk. Private investors need to ensure that the projects they are investing in will generate a reasonable and competitive rate of return in the market with the lowest possible risk; they need to know if the risks associated with their investment are adequately compensated by expected returns generated—risk and revenue trade off.

It is important to note that the sustainable building investment procedure is not essentially different from that of a typical property investment analysis from risk and return perspectives. In fact, a thorough communication of value, both revenue and risk, is much more critical when analyzing a sustainable building / feature investment opportunity, due to insufficient market data, and limited knowledge and experience with sustainability investment of property professionals. Real estate investors/owners need to fully understand how sustainable building features affect the value of their investments. They must recognize the financial return they might have received above the amount they would receive when not investing in these features. Thus, a clear, comprehensive, and reliable presentation of value of sustainable buildings in the way that property professionals could understand and apply in their decision making process is vital. *This will add a new task for design professionals involved in sustainable buildings planning and design to not only thoroughly evaluate the building performance but also communicate the added value to the decision makers.*

It is the responsibility of design professionals to communicate the full scope of costs and benefits of sustainable features to property professionals. Designers should be able to explain how their sustainable design alternatives impact the building performance and how those impacts could affect the property value. This information, if presented in a reliable and understandable language, will enable real estate investors/owners to make more informed decisions about sustainable building investment. Regarding the new assignments and business activities of architects and engineers, Lützkendorf and Lorenz (2005) have also

stated that “in the future, clients will ask about the effects of these design and planning solutions on overall building [financial] performance. This creates a new client need that the design team can fulfil by providing building related information relevant to valuation and rating purposes” (p. 231).

Currently, design professionals do not report the true value of sustainable building to their clients, due to their incomplete or unreliable evaluation methods and lack of their knowledge of the investment decision making process. *Communicating the financial performance of sustainable buildings reliably requires performing more sophisticated financial and statistical analyses than what designers traditionally do.*

In order to better communicate to owners and investors, it is necessary for design professionals, particularly architects, to understand how property professionals value their investment choices, what techniques traditionally they use to evaluate their alternatives, and how they account for risk and uncertainty in their investment decision making process. Having knowledge of the investment decision making will enable designers to better organize and align their technical ideas and suggestions with the owners/investors goals. According to the USGBC (2008), “without consistent and reliable documentation of benefits, it is difficult for many building owners to commit to appropriate high-performance building. Without robust financial tools that address sustainability issues, financial institutions can not readily meet their fiduciary and statutory obligations in funding innovative and transformative technologies” (p. 16).

This paper will introduce appropriate financial, risk, and uncertainty methods that are used by investment communities for analyzing investment decisions.

## 1.2. Sustainable Development and Buildings

It is generally accepted that sustainable development has three categories of benefits including environmental, social and economic. Buildings that have the potential to contribute to sustainable development simultaneously provide all three benefits to a lesser or greater extent. A growing body of evidence suggests that the building industry has become mature enough to recognize that all three areas of benefit, particularly those improving health and productivity, could have positive impacts on property value. Health and productivity are known as central parts of the social benefits of sustainability. Until recently, health and productivity have received less attention among the private investors because there are substantial risks and uncertainties involved in the quantification of their benefits and investors are not able



to account for them in their costs-benefits analysis. However, these professionals have now realized that social aspects of sustainable development, such as adaptability, functionality, health and productivity, could significantly influence total real estate costs and users demand, and therefore, should be taken into account in the costs-benefits analysis of sustainable buildings. Muldavin (2010) has argued that from a financial perspective, sustainable property is what regulators, potential space users, and investors in the subject property defined as a sustainable property. "Proper financial analysis of a property requires explicit consideration of the potential benefits that will accrue through meeting regulator, user, and investor thresholds for sustainability" (p. 17). Thus, simultaneous consideration of all the sustainability benefits that might impact users' satisfaction is critical in understanding the full scope of costs and benefits, and therefore, the true value of sustainable buildings.

### **1.3. Costs, Benefits, Risks and Uncertainties associated with Sustainable Building Investment**

"The benefits [of sustainable buildings] range from being fairly predictable (energy and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy" (Kats, 2003, p. v). Unfortunately, the majority of current sustainable building investment decisions are solely made based on tangible cost savings, while full costs and benefits of sustainability are beyond cost savings. For example, improved worker health and productivity in an office building may contribute to significant cost savings for employers because of lower absenteeism and recruiting costs. Achieving sustainability certification, such as LEED, would increase the reputation and marketability of the subject building, which would lead to higher absorption rates and higher value.

Risk is a significantly important component of the costs-benefits analysis. No assessment of a sustainable property value would be completed without a full assessment of risks, both positive and negative. The positive risks may increase the potential benefits and negative risks may increase the potential costs. "Reduced risk is perhaps the most significant benefit of sustainable property investment" (Muldavin, 2009, p. 126). Later in this paper, it is explained that there is also uncertainty inherent in each step of sustainable buildings valuation. A clear and well-supported presentation of risk and uncertainty of achieving the expected value of sustainable buildings is critical in preventing underestimation or overestimation the value of sustainable building. If designers ignore risk and uncertainty of sustainable building investments in their analyses, they might mislead their clients. This would result in destroying their reputation and jeopardizing their consulting business.

Some of the potential benefits associated with sustainable building investments that are often ignored in current analysis procedures include: access to state or federal government incentives; tax and insurance benefits; better financing options; contributing to achieving green certifications; reduce the carbon emission; improve indoor air quality, daylighting and thermal comfort (environmental benefits); increase adaptability, serviceability, and functionality; improve health and productivity (social benefits); increase property reputation and marketability; and increase asset value or revenue due to improved appeal to regulators, space users and investors, which would lead to higher rent, higher occupancy, lower turnover, etc.

Potential risks inherent in sustainable buildings investment include: reduce the risk of losing value due to functional, economic or physical obsolescence; reduce the risk of losing users and investors due to availability of sustainable buildings in future markets; reduce the risk of inaccuracy of projected building performance; reduce energy consumption volatility; reduced liquidity risk; and reduced legislative risk (Bozorgi & James, 2010a).

Consequently, both tangible and intangible benefits could contribute to the financial value of sustainable buildings in the way that investors are interested in. *Without a simultaneous consideration of the full scope of costs, benefits, risk and uncertainty associated with sustainable building investment, understanding their true value of is not possible.*

## **2. CURRENT SUSTAINABLE BUILDINGS ASSESSMENT METHODS**

Tools and techniques that are currently widely used for assessing building performance are categorized in the following four types. The results of these methods are typically accepted as the basis for making technical and investment decisions by both design and property professionals. In this section, it is explained that why none of these tools on their own are sufficient to rely upon for making major high-quality investment decisions at the property level.

### **2.1. Green Building Certifications**

Current Green Building Certifications and Energy Rating Systems, such as LEED, BREEM, and EnergyStar are very often used as a basis for comparing the performance of sustainable buildings. However, these certifications cannot be the sole basis for defining sustainability for the purposes of major investment decision-making because of the following issues:

First, they have been designed to measure the environmental impact of sustainability, and therefore, due to their environmental outcomes rather than financial outcomes, are not able to communicate the overall performance of sustainable building to the investment decision-makers. Second, they do not provide any detail about the sustainable features employed in the building and many of the sustainable features that have contributed in achieving the

certification may not have a significant direct impact on property performance from a financial perspective. And finally, many buildings might have employed valuable sustainable attributes that could influence their market value but are not certified; therefore, relying upon certification may ignore the impact of those sustainable features on financial performance and may lead to undervaluation. “That suggests that something more granular than Energy-Star or LEED is needed to capture the green design elements that contribute to enhanced environmental, economical, and social performance which in turn link to building value” (Scott R. Muldavin, 2008, p. 9). However, it is very important to consider these elements in the financial analyses as many studies have shown that they made a positive contribution to the overall market value of a sustainable property because of their impact on reputation and marketability.

## 2.2. Building Simulation Programs

There are many Building Simulation Programs (BSPs), such as DOE 2, Energy-Plus, Radiance, Computational Fluid Dynamics (CFD), etc. developed to evaluate building performance indicators such as energy consumption, daylighting, and indoor air quality. These programs are typically used to provide supporting data for achieving certification to perform simple cost-based financial analyses. The primary issues with directly using the results of these programs for making major investment decisions are as follows:

First, these tools are primarily designed to forecast impacts of design decisions on environmental performance indicators and do not take into account other aspects of sustainable building performance/benefits. Second, their outcomes are typically described in technical terms rather than financial. Most of these tools are well developed to evaluate building performance, but fail to properly link indicators to financial performance and do not translate the technical details to a more understandable language. According to Lorch, Lützkendorf, & Lorenz (2007), “the largely technocratic approach is, on its own, not enough to bring about the necessary change. What is needed is to encourage dialogue and learning between the construction community and practitioners from the property, finance, insurance and banking industries” (p. 1). And finally, the simple financial analyses that these tools perform are based on simple estimation of cost savings, payback period and simple return on investment (Bozorgi & James, 2010b).

## 2.3. Simple Financial Methods

The financial analysis techniques traditionally used by real estate investors, owners and lenders for assessing the financial performance of sustainable buildings include: Simple Payback (PB), Simple Return On Investment (ROI), Energy-Star financial tools, etc. These approaches primarily focus on initial development cost and operational cost savings, and ignore the full scope of costs and benefits.

The full costs and benefits of sustainability—environmental and social issues along with financial

return—are beyond cost savings and traditional sustainability analysis (Muldavin, 2010); and ignoring them, may undervalue the sustainable investments and exclude many profitable investment opportunities from consideration, which ultimately would lead to underinvestment in sustainability. Nevertheless, because of their simplicity, these types of simple analysis are used very often; they might be good enough to address minor investment decisions, such as minor, but are not sufficient for major retrofits or acquisition decisions.

## 2.4. Building Performance-Based Methods

Building Performance-Based Methods such as Life Cycle Costing (LCC), Life Cycle Assessment (LCA), General Cost-Benefit Analysis (CBA), or Value Engineering (VE), are widely used by decision makers, both technical and financial, to evaluate the performance of a sustainable building over its life. The primary problem with most of these methods such as LCC or VE is the cost-based nature of their financial analysis, which would lead to the ignorance of other non-cost benefits of sustainability investment. LCA-based techniques are recognized as one of the best approaches for evaluating the environmental and some of the social aspects of sustainability. They are well developed to incorporate building performance over its entire life cycle. While LCA “takes the issue of occupant health into consideration, there is less focus on occupant satisfaction, functional fit and productivity” (Lützkendorf & Lorenz, 2005, p. 224). Therefore, to date, performance-based approaches are unable to deal with all aspects of sustainability simultaneously. Furthermore, they are not well suited to account for sustainability investment value, risks, and uncertainties simultaneously in their evaluation process in the way that investors require.

*In summary, current assessment methods and analytics do not simultaneously incorporate all of the costs, benefits, risks and uncertainties of sustainability investment, nor represent them in the way that assists investors to make informed investment decisions. Design professionals need new assessment methodologies to consider all impacts of sustainability on property market value as well as their associated uncertainty and communicate the added-value in appropriate terms to be understood and utilized in the investment decision-making process. This approach requires more sophisticated financial/valuation techniques for estimating the property value and more sophisticated statistical techniques for incorporating uncertainties of a sustainable building valuation.*

## 3. PROPERTY VALUATION

Property valuation is the practice of developing an opinion of the market value or worth of a real property. “The purpose of a valuation is to forecast the future benefits of a property and calculate this into a current price. The accuracy of that valuation will depend on the ability and skill of the valuer in understanding the factors that determine values, and the weight that those factors hold” (Bowman & Wills, 2008, p. 12). Below, three basic

approaches that are traditionally used by property professionals to determine market value are presented. All three approaches may not be applicable for all situations or may not result in accurate estimates for market value. Valuers must select the most appropriate approach based on type of property investment (new or existing property) and available data, in order to provide the most accurate indication of market value.

1) Cost Approach: This method estimates the value of a property based on the sum of the cost of the land and depreciated (present value) cost of reproduction and replacement of existing improvements. This approach could be appropriate when costs data is available and market conditions are stable. As Chappell and Corps (2009) stated, given limited national cost estimating database for sustainable buildings, this approach would likely prove less dependable and accurate, particularly for an older, existing property. (p. 14).

2) Sales Comparison Approach: This method estimates the value by comparing the subject property with transaction data (sales data) of similar properties in the surrounding or comparable data. This approach could be most useful when sufficient empirical data of similar properties is available. This approach is not yet appropriate for sustainable building valuation due to current insufficient market data for comparison. Often, sustainable buildings are compared based on their certification level. The challenge with this approach is that sustainability can be achieved through a variety of different features. Even two LEED certified buildings with the same level rating might have employed different systems and design strategies in achieving a certification. They might have different building performance and financial performance, and therefore,

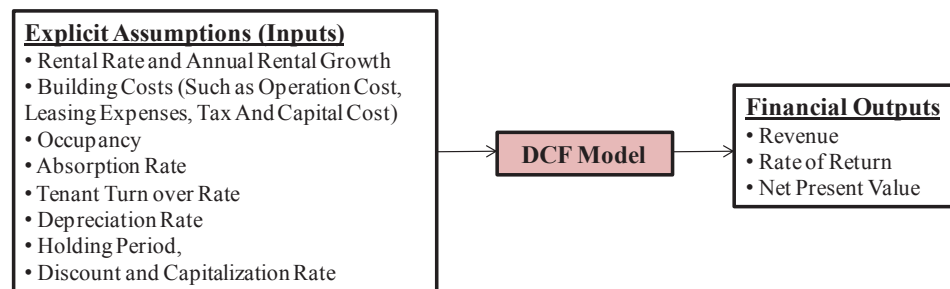
should not be considered comparable. Until more time passes and more market evidence are generated, this approach remains inappropriate for sustainable building valuation.

3) Income Capitalization Approach: This approach estimates value based on the present value of the income stream produced by the subject property. This is the primary valuation method for income producing property such as office or multi-family buildings. The methods used under the income approach primarily fall into the three categories: direct capitalization, discounted cash flow, and gross income multiplier. The discounted cash flow model, as the most common technique, is described below:

### 3.1 Traditional Discounted Cash Flow (DCF) Method

One of the powerful valuation methods currently used in real estate investment is the DCF method. This technique evaluates the present value of the projected future cash inflow and outflow over a holding period. The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate its related expenses, revenues, and risks simultaneously.

As shown in Figure 2, the DCF model takes the explicit assumptions on future rents, occupancy rate, operation costs, etc. as inputs and estimate the financial outputs such as revenue, rate of return, or net present value. These financial outcomes are the metrics that investors use for evaluating investment options. The more accurate DCF inputs would results in the more accurate financial outputs. It is the responsibility of valuers to do as much market research as possible and forecast the DCF assumptions.



**Figure 2:** DCF Model Inputs and Outputs

For example, one of the most important assumptions in a DCF model is the discount rate that is used to calculate the present value of all future cash flow streams. The discount rate reflects the risk associated with receiving the projected cash flows. The greater discounted rate will be selected for riskier project while the lower discounted rate will be selected for the projects with lower level of investment risk.

This approach currently is viewed as the most appropriate approach to provide a more reliable indication of market value of sustainable property. *We encourage design professionals to utilize the concept of*

*the DCF approach in lieu of simple PB, simple ROI, or LCC for estimating the financial performance of sustainable buildings.* With the DCF method, potential direct and indirect costs, benefits and risks associated with sustainability investment, stated previously, could be considered in generating the investment's revenue. Consideration of both revenues and risks in the valuation process will allow designers to provide their clients with the true value of sustainable buildings. It should be noted that using the concept of DCF approach requires sufficient market data upon which to rely for determining DCF inputs, such as future rents, occupancy, etc. With

the absence of sufficient market evidence for sustainable buildings, there is a substantial uncertainty associated with predicting DCF inputs. However, even with current limited hard data, DCF approach gives the users a proper financial method to acknowledge and consider factors that have impacts on future property value, rather than ignoring them in the assessment process and misleading the final decision makers.

#### 4. UNCERTAINTY

##### 4.1. Definition of Risk and Uncertainty

Risk is known as a situation in which alternative outcomes and their probability of occurrence are known, where as uncertainty is a situation where information about future outcomes and their probability are not known. "Uncertainty is anything that is not known about the outcome of a valuation at the date of the valuation, whereas risk is the measurement of the value not being as estimated" (French & Gabrielli, 2005, p. 81).

Probability distributions are the primary quantitative vehicle used for explaining risk in the risk management analysis methods. The probability distribution describes a range of possible values and the probability of any value within any subset of that range. All variables that are uncertain could be represented with probability distribution, and their associated risks could be estimated using statistical approaches based on specifications of a range of most likely values (means) or extreme values. The variability of the expected return about its mean is used as a description of risk, and standard deviation is commonly used as a measure for spread of probability distribution. As shown in Figure 3, the tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and high level of confidence in achieving the expected outcome (mean). Flat distribution with large standard deviation denotes the great degree of risk and uncertainty and low level of confidence (Bozorgi & James, 2010b, p. 3:25)

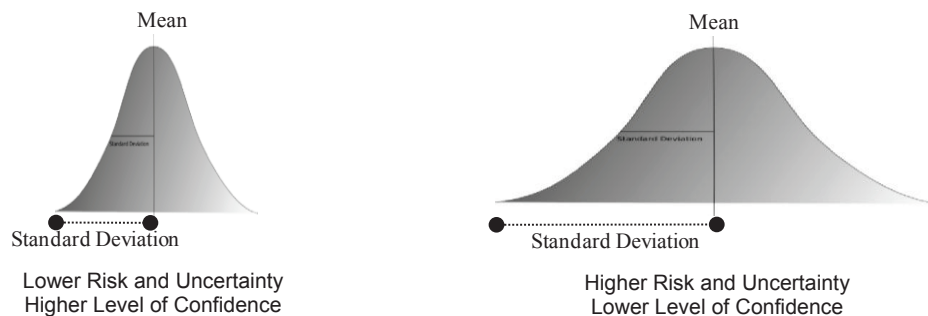


Figure 3: General Interpretation of Shapes of Normal Distribution (Bozorgi & James, 2010b, p. 3:25)

##### 4.2. Uncertainty in Property Valuation

There is general agreement that there are risks and uncertainties associated with property valuation procedures that need to be identified, assessed, and reported in a way that can be understood and analyzed by investors or end users. For example, the uncertainty of DCF inputs (explicit assumptions about future factors) or the risk of not achieving value or rate of return as predicted in DCF (estimation of DCF outputs). Acknowledgement of uncertainty inherent in the valuation process would provide investors with useful information about the level of confidence in receiving their expected return and therefore insight

*Considering uncertainty involved in sustainable buildings valuation, it is vital that design professionals account for uncertainty when analyzing the value of a sustainable building; otherwise, the outcomes of the valuation process may be underestimated or even overestimated, and may lead to inappropriate investment decisions. In the DCF model, the inputs are included as single point estimates and therefore, the uncertainties of the DCF assumptions are not taken into account. Inability of the traditional DCF model to deal with uncertainty in the valuation process requires a more sophisticated approach to explicitly account for uncertainty.*

##### 4.3. Monte Carlo Simulation (MCS)

"Monte Carlo analysis is a widely used numerical computational analysis tool that draws information from input probability distributions, applies the data in a process, and generates an outcome distribution" (Jackson, 2008, p. 137). This technique is able to account for uncertainties by allowing for a range for each input and its correlations at the same time, perform a random probabilistic sensitivity analysis and model a range of possible outcomes. In the MCS, simulation data is processed and ranges of final outputs are estimated through the base model which describes the relationship between inputs and outputs. The results allow decision makers to better analyze and interpret uncertainty and provide them with more reliable information than a few discrete scenarios. This method is also suggested to include various uncertainties of valuation by describing the range of possible values instead of a single-point estimate of value in the DCF model.

We encourage design professionals to use the MCS for modelling uncertainty and estimating the final financial performance indicators of sustainable building. The base model for this simulation, which describes the relationship between inputs and outputs, is built based on the DCF approach. This probabilistic model takes and analyzes the same DCF inputs and outputs but replaces

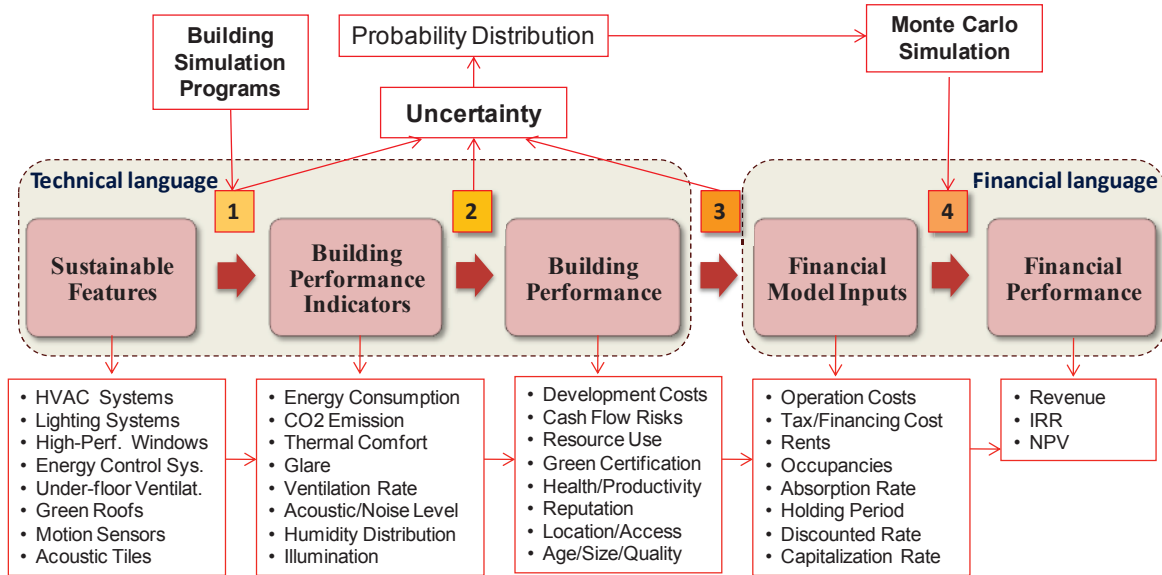


single estimate points with appropriate ranges and probability distributions. *The MCS incorporates the uncertainties of achieving the DCF inputs and articulates the risks related to receiving these outcomes.*

## 5. NEW ASSESSMENT PROCESS

We propose a new assessment approach to estimate the true value of sustainable building. Unlike the current sustainable building assessment process, this new process explicitly connects performance estimates from the design professionals to the property valuation

techniques to communicate to property professionals in a common language. With this new approach, designers could also better understand the impact of their design decisions on financial performance of a sustainable building at the design stage, which would result in more viable designs. In development of this process emphasis has been placed first, on the simultaneous consideration of environmental, social, and economic benefits in context of value, and second, on the explicit consideration and articulation of valuation uncertainties. The process is illustrated in Figure 4:



**Figure 4:** A Process for the Valuation of Sustainable Buildings

The process begins with taking the sustainable features and estimating their related building performance indicators through the appropriate BPSs. For each selected system, certain building performance indicators can be determined, for example, energy consumption as an indicator of energy performance, or ventilation rate and pollution as indicators for indoor air quality. Then, depending on the system and its performance indicators, the selected systems would be modeled through the appropriate BPS. It might be necessary to model a particular sustainable feature with multiple BPSs as most of the sustainable features have impacts on more than one building performance indicators which directly or indirectly contribute to the value of building. For example, using an energy efficiency HVAC system reduces operational costs but at the same time may improve indoor air quality which may improve health and productivity.

*It is very important that designers realize that any building performance indicator that is of interest to occupants could play a role in the financial performance of a building; therefore, a thorough evaluation of all performance indicators that might be influenced by a sustainable feature is required.*

Second is to determine the building performance in terms of both sustainable and non-sustainable factors. Factors related to sustainable features include development costs, occupant satisfaction, and health and productivity, contribution sustainable certifications, achievable incentives, marketability, risks, etc. Non-sustainable building performance, which are not related to sustainable features but critical in valuation of a property, include location, access, age, size, etc. When evaluating a sustainable building, some sustainable factors such as costs, possibility of achieving certification or incentives, can be estimated relatively easily based on available data, guidelines, regulations and BPSs outcomes. However, factors such as users' satisfaction, and health and productivity are more difficult to measure precisely.

Third is to select key financial model inputs based on building performance estimates, which includes all costs, benefits and risks associated with the sustainable building investment. This is the translation step from technical to financial language. The traditional DCF approach is suggested as a base model for estimating the true value of sustainable buildings. Valuers consider all sustainable and non-sustainable factors, determined

in the previous steps, simultaneously, assess the market responses (regulators, space users and investors' demand) and forecast the DCF model inputs. Last is to calculate the value based on the DCF model inputs. Monte Carlo simulation with a base case built upon the DCF approach is suggested to estimate the final financial performance indicators while modeling uncertainties.

### **5.1. Considering Uncertainties Inherent in Sustainable Buildings Valuation**

As stated previously, there is a certain amount of uncertainty associated with measuring the outcomes of each step in the valuation process. Some of these uncertainties include:

uncertainty associated with forecasting building performance indicators by building simulation programs; uncertainty associated with achieving any certification or energy label; uncertainty inherent in determining the building performance, such as health and productivity based on projected outcomes; uncertainty associated with future energy price escalation, interest rates, or inflation; uncertainty associated with forecasting the financial model inputs, such as future rents.

These types of uncertainty need to be considered in order to communicate reliable outputs to final decision-makers. *Specifying a probability distribution for each uncertain variable, involved in the process, is suggested in order to incorporate and articulate their uncertainty.*

It should be noted that this paper is not intended to provide information about estimating and collecting data required for each step for the proposed process. A thorough discussion about incorporating the various

factors in the process will be presented in future publications by the authors.

## **CONCLUSION**

Design professionals are not able to estimate and communicate reliable financial performance data for sustainable buildings if they solely rely on their current approaches and knowledge. They need to utilize more sophisticated financial/valuation and statistical techniques in order to present the true value of sustainable buildings to property professionals. While designers are not expected to perform a thorough market analysis and predict accurate financial model inputs, they are expected to provide comprehensive, reliable and understandable information to their clients and assist them in making investment decisions. They are expected to acknowledge that benefits of sustainable building investment are beyond cost savings and to consider full costs, benefits, risks and uncertainties in their analysis. The suggested methods, DCF and MCS, are examples of such techniques that would enable designer to do the above.

Therefore, the authors believe educating the design professionals, particularly architects, about property valuation and the investment decision-making process, and providing them with a defined procedure to follow to understand the impact of their design decisions on those factors that are important for the property professionals, could be helpful toward communicating the true value of sustainable buildings and driving their market.

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# **Improving the Quality of Energy Retrofits Investment Decisions by Including Uncertainty in Energy Modeling Process – A Case Study**

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## **Abstract**

Currently, many investment decisions concerning energy retrofits are made directly based on the outcomes of energy simulations. However, there are various uncertainties inherent in the energy retrofit assessment process, both at the energy simulation and life cycle cost analysis (LCCA) levels, which can result in inaccuracy of energy performance forecasts and therefore, inappropriate investment decisions.

Through a case study, this paper presents a procedure for deriving and including the uncertainty associated with various factors in energy retrofit option assessment and clearly demonstrates how to generate probability distributions for final outcomes. These distributions provide decision makers with more insight into the risks associated with achieving the expected outcomes. The simulation process proposed in this paper could be used by modelers to improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions concerning energy retrofit.

An existing office building is selected and multiple calibrated energy base models are developed to evaluate a combination of lighting controls as a new energy retrofit option. The paper demonstrates the calibration process of the base models and a LCCA of the lighting controls package. A sub-analysis was conducted to examine how evaluating retrofit options with multiple base models could impact the financial outcomes and improve the final investment decisions. The financial metrics are compared with the results of modeling using a single base model. The results show that this approach could have the potential to and may alter a retrofit decision from 'no go' to 'go'.

It should be noted that the goal in this paper is not to generate the most accurate outcomes but to demonstrate a procedure to include risk and uncertainty in the energy modeling process of green retrofit technologies.

## **Introduction**

As summarized by Bozorgi and Jones (2010), evidence suggests that there is inaccuracy/error associated with energy modeling forecasts and in some cases the models are not a good predictor of project energy performance (pp. 3/15-13/16). The accuracy of model prediction is greatly dependable on the accuracy of inputs. In the context of existing buildings, the level of uncertainty associated with simulation inputs is typically higher, because the systems may not be performed as they are specified or designed. Therefore, there is always some uncertainty associated with projecting the energy use based on design assumptions. It is critical for decision makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building energy performance when making decisions based on the predicted performance [1].

In this analysis, ranges and probability distributions are suggested to be used instead of single-point estimates in order to introduce various sources of uncertainty and articulate the risks associated with achieving the expected energy performance outcomes. Probability distributions are the primary quantitative vehicle used for explaining risk and uncertainty in the risk management analysis methods. All variables that are uncertain could be represented with probability distribution, and their associated risks could be estimated using statistical approaches based on specifications of a range of most likely values or extreme values. The variability of the expected return about its mean is used as a description of risk, and standard deviation is commonly used as a measure for spread of probability

distribution. By providing more insight into risk, the proposed process will improve the reliability of energy modeling outcomes and also the confidence level of decision-makers in their decision-making process. As a result, the quality of investment decisions concerning energy retrofit options will increase [2].

Calibration of a base model is a critical part of the simulation process of existing buildings for the purpose of evaluating energy retrofit options. Existing buildings are typically modeled based on the necessary data and information obtained from available plans and construction details, specification books, and operating schedules. The results of initial simulations usually indicate that despite the careful attention in creating the models, the actual measured energy use is different from what was projected by models. This discrepancy is primarily due to the significant uncertainty or error associated with the simulation inputs, which this study attempts to explicitly consider in the simulation process. Mechanisms that are typically used to identify the errors and update the inputs include: using the most accurate as-built information, site visits, surveys and interviews with building operation managers and occupants, on-site measurement, such as outside air flow, temperature or light levels measurement, and checking the utility bills data, such as electricity bills and gas bills [3]&[4].

Accordingly, through conducting a case study on an existing office building, this paper aims to derive the various sources of uncertainty inherent in the energy retrofit analysis and numerically demonstrate a procedure for including those uncertainty factors into the modeling process in order to communicate more reliable outcomes to the decision-makers. The analysis shows how various potential risk and uncertainty might impact the final financial outcomes, and therefore, the investment decisions. The paper present a calibration process and explains how to create a reliable model to serve as a base case for evaluating the energy performance and generating distributions of energy performance indicators, resulting from selecting a new retrofit option—lighting controls package. It also describes a LCCA process of the selected retrofit option and demonstrates how to generate distributions of financial performance indicators such Net Present Value (NPV) and Internal Rate of Return (IRR).

Unlike the common practice of calibration, this study developed multiple acceptable base models for evaluating the selected energy retrofit option to account for inaccuracy of base models in generating the distribution of outcomes. Energy retrofit options are typically evaluated based on a calibrated energy base model. The acceptability of these base models are determined based on their forecasts error indicators. However, there might be several base models within the acceptable ranges that have different inputs, outputs, and error indicators. These base models could produce different outcomes when evaluating the performance of new retrofit options due to interactive modeling effects of retrofit options inputs. Thus, a sub-analysis was conducted to compare the estimated financial outcomes with the results of modeling using a single base model. The hypothesis here is that considering the inaccuracy of a base model could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. This analysis tests this hypothesis towards the broader goal of assisting decision-makers to make more informed decisions about investing in green retrofits. The results explain whether or not the impacts of modeling new retrofit options using different base models are significant enough to encourage modelers to put extra time and effort into running additional simulations.

It is important to note that this paper is mainly concerned with demonstrating the process of calibration and generation of distributions of outcomes and not the accuracy of final numeric results. The accuracy of outcomes is limited to the quality of assumptions and information that was obtained through literature, researcher's professional judgments, expert interview, and questionnaires.

## **Energy Simulation and Calibration Process**

As mentioned earlier, a thorough calibration process requires on-site measurements, surveys and interviews with occupants, etc. However, in this case study, the model was made as reliable as possible based on the available drawings and interviews with the owner representative and the property manager. No measurement or experimental study was performed for collecting the actual data other than actual utility records. The subsequent steps were followed in order to arrive at a reliable model:

- 1) The initial model was set up in eQuest (QUick Energy Simulation Tool) based on the data collected from the architectural and mechanical drawings, construction details, researcher's visit, pictures, and interview with the owner representative who was also an occupant in the building. The annual and

monthly electricity consumptions were calculated based on the initial model. The building is all electric and there is no gas usage. A Typical Meteorological Year (TMY) file was used in the simulation process and not the actual weather file of 2009 for which the modeled consumptions was compared with. This could be one of the sources of inaccuracy associated with modeling outputs.

2) The actual annual and monthly electricity usage (KWh) was gathered by looking at 12 months of electricity bills in 2009. Adjustments were then made to those estimates in order to correspond to the calendar months. Utility records are not normally first of the month to last of the month, the simulation outcomes from energy modeling, however, are first of the month to last of the month. Two possible procedures for dealing with this include: if available, sum the daily simulation values to correspond to the measured records; or normalize the measured records to correspond to the simulated monthly values (weighted average approaches). This could be another potential source of inaccuracy associated with the modeling outputs. In this case, the weighted averages of actual electricity records were estimated to correspond to the calendar months.

3) The actual weighted average electricity usages were compared with those predicted by the simulation model, and the annual and monthly Mean Bias Error (EER) % and Coefficient of Variation of the Root-Mean-Squared Error (CV RMSE)—error indicators—were calculated by formulas presented in Equation 1:

$$ERR_{\text{month}} (\%) = \left[ \frac{(M - S)_{\text{month}}}{M_{\text{month}}} \right] \times 100\% \quad (1)$$

$$ERR_{\text{year}} (\%) = \sum_{\text{year}} \left[ \frac{ERR_{\text{month}}}{N_{\text{month}}} \right] \quad (2)$$

**Equation 1: EER and RSME formulas [4]**

where *M*: measured electricity (kWh) or fuel consumption; *S*: simulated electricity (kWh) or fuel consumption; *N<sub>month</sub>*: number of utility bills in the year.

$$CV (RSME_{\text{month}}) (\%) = \left[ \frac{RSME_{\text{month}}}{A_{\text{month}}} \right] \times 100\%$$

$$RSME_{\text{month}} = \left\{ \frac{\left[ \sum_{\text{month}} (M - S)_{\text{month}}^2 \right]}{N_{\text{month}}} \right\}^{1/2}$$

$$A_{\text{month}} = \left[ \frac{\sum (M_{\text{month}})}{N_{\text{month}}} \right]$$

where RMSE: root-mean-squared monthly error; *A<sub>month</sub>*: mean of the monthly utility bills.

The calculated EER% and CV RMSE% were checked to see if they fall in any of the three accepted tolerances for data calibration suggested by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 14, International Performance Measurement and Verification Protocol (IPMVP), and Federal Energy Management Program (FEMP) (presented in Table 1)

**Table 1: Acceptable tolerance for monthly data calibration**

Index	ASHREA 14 (%)	IPMVP (%)	FEMP (%)
ERR month	±5	±20	±15
ERR year	-	-	±10
CV (RMSE month)	±15	±5	±10

Source: Pan, et al., 2007

The error percentages of the initial model did not agree well with the above acceptable ranges, and therefore, the initial model was not appropriate for evaluating the new retrofit options.

4) Further investigation was performed to collect more updated information about the inputs that might have higher impacts on the energy consumption and/or were not clear from the drawings—Information about current Heating, Ventilation, and Air-Conditioning (HVAC) and lighting systems including: types of cooling source; Roof Top Units (RTUs) zoning; HVAC schedule; thermostat set points for summer, winter, occupied, and unoccupied times; cold deck resets type and temperature; economizer system; lighting plans; desk lamps; and exterior lights and their schedules. Through a survey and a follow up interview with the property manager, most of the needed information was obtained and possible input changes were identified. For example, for thermostat set points which

have significant impacts on energy consumption, the property manager could not provide exact values. She indicated that this has varied significantly in the past.

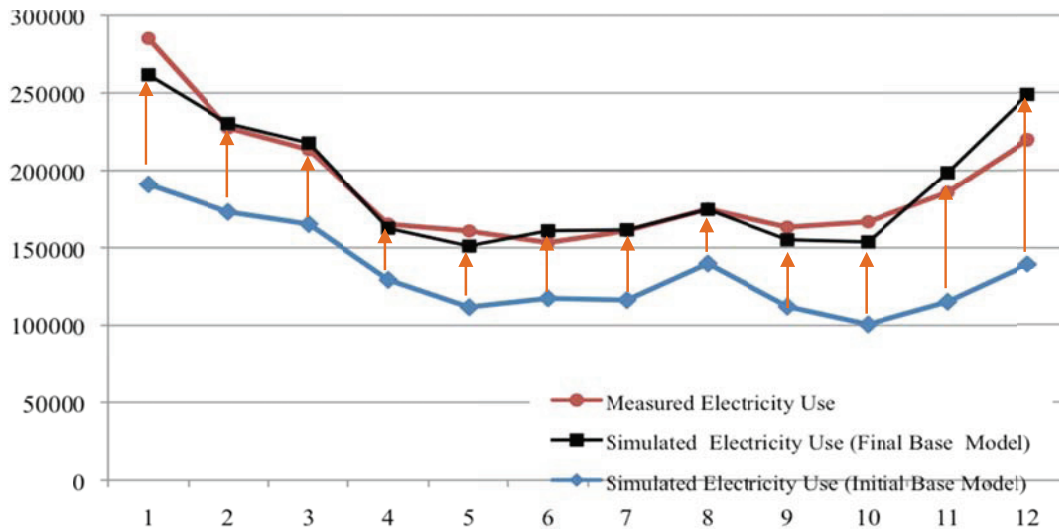
5) The initial model was calibrated and updated based on the new information from the property manager. The new modeling outputs (KWh) were compared with the actual usages by calculating error indicators—monthly and yearly EER as well as CV (RMSE). The new estimates were much closer to the acceptable ranges suggested by the aforementioned guidelines; however, they were still not within acceptable ranges.

6) The calibration process continued by varying the inputs, which were more uncertain based on our interviews and on-site visits, over reasonable ranges. The input changes included thermostat set points, lighting power density, task lighting and equipment power density, cold deck reset temperature, energy efficiency ratio (EER), minimum air flow, etc. More than 80 models were created and their calculated error indicators were compared with those suggested in Table 1. A model with error indicators that complied with the ranges suggested by FEMP and were very close to those suggested by ASHRAE 14 and IPMVP was selected as the best model. This calibrated model was thought to be sufficiently accurate to serve as a reliable base case for evaluating the new retrofit options. Table 2 shows the comparison of the energy consumptions predicted by this model and actual usages as well as related error indicators:

**Table 2: Final Calibrated Model Error Indicators in Compare to Actual Electricity Usages**

	Max	Min	Average
Measured 2009 Monthly Energy Use KWh	285181	153264	189703
Simulated Monthly Electric Use KWh	261700	151000	189708
EER month	8.23%	-13.32%	0.00%
Measured Total 2009 Energy Use KWh	2,276,431		
Simulated yearly Electric Use KWh	2,276,500		
EER year	0.00%		
CV (RMSE m)	6.79%		

Figure 1 shows the monthly electricity use as predicted by both the initial and final models. Through an iterative calibration process (creating and testing more than 80 models) the model was improved until they closely matched the actual consumptions. The  $EER_{year}$  of the best model was zero.



**Figure 1: The eQuest Model prediction vs. actual consumption**

7) The next step of the process was to model the retrofit option—lighting control systems—using the calibrated base model. The lighting control systems modeling, LCCA, and a procedure for generating the distribution of final financial outcomes are discussed in the following sections:

### Final Distribution of Energy Savings and Interaction of Base Models

In current practice and literature, typically, a model that falls in any of the three accepted tolerances for data calibration stated in Table 1 and matches more closely with actual consumption—overall lowest monthly and yearly EER as well as  $CV_{RMSE}$ —will be used as a base model for existing buildings. New retrofit options will then be entered to this base model to be assessed and compared. However, base models themselves often involve a certain level of inaccuracy as they are typically calibrated based on the final modeling outputs, *which could be results of different inputs*. For example, the predicted energy consumption (KWh) of an energy model with certain assumptions about air conditioner Energy Efficiency Ratio (EER) and lighting power density could be very close to the one with a lower EER but a higher lighting power density assumptions. And both base models might be qualified as acceptable models, based on the aforementioned guidelines, due to their close predicted energy consumptions. In fact, this is very common in the calibration process as selecting a certain/accurate value for some inputs can be difficult in existing buildings.

Therefore, there might be several base models within the acceptable ranges that have different inputs, outputs, and error indicators. *A model with lowest error indicators is not necessarily the one that replicates the actual performance most accurately*, due to the uncertainty associated with inputs. Furthermore, selecting the lowest error indicators sometimes is not very straightforward, because a model might have a lower  $EER_{month}$  for most of the months, but have a higher  $EER_{year}$  or  $CV_{RMSE}$ . It is very important to note that while the final outputs (KWh) of acceptable models might be very close, they could produce different outcomes when evaluating the performance of new retrofit options. This is primarily due to interactive modeling effects of new retrofit options inputs with the base models. Therefore, ignoring the impacts of the variability of inputs for the base models on the outcomes might result in different investment decisions when comparing different retrofit options.

In summary, there are two factors that could influence the distribution/variance of savings associated with new retrofit options in the simulation of existing buildings: 1) ranges of assumptions for new retrofit options and 2) the inaccuracy of base models. In other word, as shown in Figure 2, the final simulation output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy of base models, is often ignored.

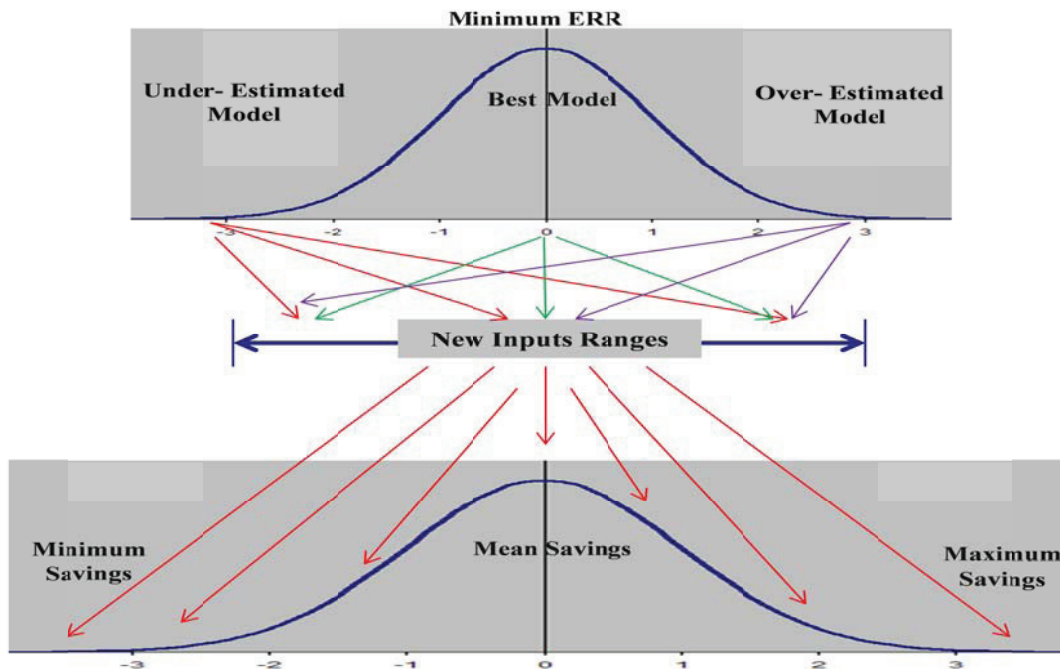


Figure 2: Interaction of base model inaccuracy in generating the final simulation outcomes



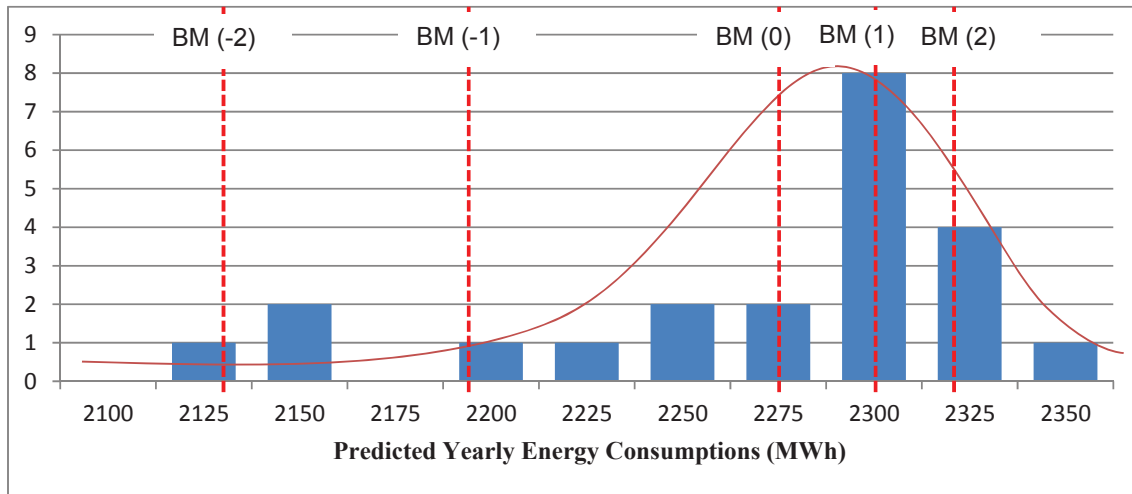
In this paper, lighting control systems were modeled with multiple base models to generate the distribution of energy savings and assess the potential impacts of different base models on simulation outcomes. The objective of this analysis was to understand how this approach could improve the final decisions about retrofit options investment and if the results were worth the effort of running additional scenarios. Might this approach alter the final investment decisions? This is one of the questions that this paper aims to address.

### Creating Multiple Base Cases for Evaluating a New Retrofit Option

In order to create a more acceptable model, the seven inputs were selected to be varied over reasonable ranges. These inputs include: four thermostat set points (occupied cooling, occupied heating, unoccupied cooling, and unoccupied heating), cold deck reset temperature, EER of HVAC systems, and Variable Air Volume (VAV) minimum flow.

These factors were selected because, based on the interview with the property manager and researchers' professional judgments, they might involve a higher level of uncertainty. For example, relative to thermostat set points, the property manager indicated that set points have been varied significantly in the past. Thus, the set points values were selected as the inputs to be varied for creating other acceptable base models. Based on the mechanical drawings of the building, the EER values for two RTU units should be 15 and 14. However, this building was built in 2000, and it is likely that HVAC systems do not currently perform as efficiently as what they were designed for. Therefore, the EER values for two systems were varied in ranges of 12-15 and 11-14.

Several base models were created in addition to those built previously and their error indicators were calculated to ensure that they meet the acceptability conditions by the aforementioned guidelines. 22 models were within the acceptable tolerances. Figure 3 shows the distribution of the predicted yearly energy usages of the 22 base models:



**Figure 3: The Distribution of Predicted Energy Use (MWh) of 22 Base Models**

As the distribution of energy consumptions shows, there are some base models (towards the left side) that under-predicted the energy consumption, compared to 2,276.5 MWh consumption of the best base model, and there are others (towards the right side) that over-predicted the consumption. The best model with  $EER_{year}$  of 0%, which is presented in Table 3, is close to the mean of the above distribution. Five base models (BM) were then selected from 22 models to be used for evaluating the lighting control option and generating the savings distributions. The five base models, BM (-2), BM (-1), BM (0), BM (+1), and BM (+2), are shown in Figure 3 by dash lines. BM (-2) denotes the base model with lowest predicted energy use, BM (0) the medium, and BM (2) the highest energy use. Their related assumptions, savings, and error indicators are presented in Table 3:

**Table 3: Five base models assumptions, savings and error indicators**

	<b>BM (-2): Lowest prediction</b>	<b>BM (-1): Lower prediction</b>	<b>BM (0): Best Model</b>	<b>BM (+1): Higher prediction</b>	<b>BM (+2): Highest prediction</b>
Yearly energy use prediction (MWh)	2,130.90	2,181.60	2,276.50	2,291.50	2,315.60
EER month	-4.1% to +14.3%	-8.7% to +11.6%	-13.3% to +8.2%	-14.3% to +6.9%	-13.8% to +7.7%
EER year	6.24%	4.06%	0.00%	-0.62%	-1.70%
CV (RMSE m)	9.03%	8.09%	6.79%	6.84%	7.14%

### Accounting for Risks Associated with the Systems Performance - Five Cases for Lighting Control Systems Option

According to a principal at CQI Associate, energy models do not replicate the real world situation, “because those models do not take into account the true investment and cost issues and as well as experience-related issues about them. We have never seen the savings that high [as predicted by model].” There is a certain level of uncertainty associated with each technology which depends on the current level of knowledge of designers or contractors. How innovative is the technology? What is the proven and what is not proven? What are the standard practices versus more advanced practices?”

As mentioned previously, the primary goal of this paper is to present a procedure for including the uncertainty associated with various factors associated with lighting control systems into the modeling process and accounting for those inherent experience-related risk issues in the modeling outcomes. The result of the analysis shows how various potential risk and uncertainty might impact the final financial outcomes, and therefore, the investment decisions. There are several risks associated with the actual performance of lighting control systems. Daylight sensors need to be well calibrated to perform as they are designed, otherwise there might be no savings and low satisfaction by occupants. Occupancy sensors may not be as effective as they are expected to be, if not located properly to cover the area under their control. There is always a risk of poor quality of installation or workmanship—the contractors’ risk. Therefore, in order to demonstrate a process of accounting for the potential risks associated with the performance of the lighting retrofit option in the modeling process, five different cases were developed. Seven factors/variables related to lighting controls performance were identified and their values were varied over defined ranges for creating the five lighting retrofit cases. Case 1 was the best case, case 3 was the most-likely, and case 5 was the worst case. Defining a range for each variable would help to account for some of the risks associated with the option’s performance. If a retrofit option is an innovative technology that the market does not have much experience with, the wider ranges might be defined for its uncertain variables. If it is a proven technology, like the lighting retrofit option in this case, the ranges could be narrower accordingly. Table 4 shows the variables and their values for each lighting control system case:

**Table 4 : Variables and Range for Creating Five Lighting Controls Cases**

<b>Variables</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>	<b>Case 4</b>	<b>Case 5</b>
Minimum Light Level – Daylight Sensors	5%	5%	10%	10%	20%
Occupancy Sensors (Schedule)	Low	Low-Medium	Medium	Medium-High	High
High End Tuning Strategy	21.0%	20.5%	20.0%	19.5%	19.0%
Personal Dimming Control	17.0%	16.0%	15.0%	14.0%	13.0%
Lighting Power Density (W/Sq.Ft)	1.1	1.3	1.5	1.5	1.6
Demand (KW) Prediction Adjustment Factor	0.8	0.86	0.92	0.96	1

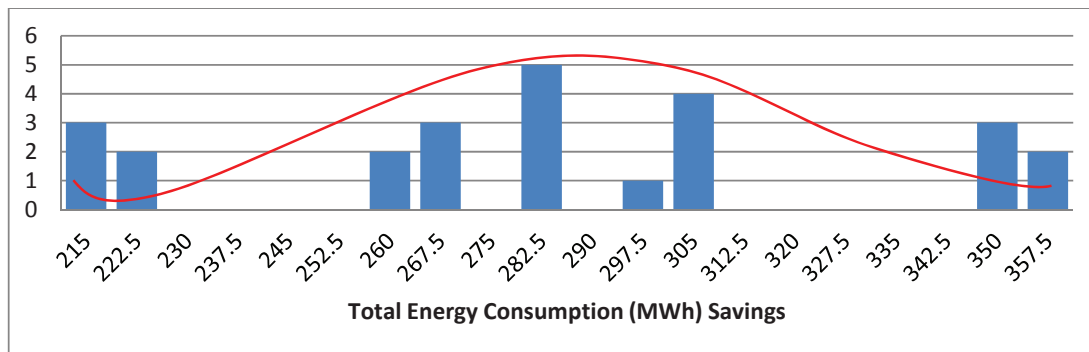
The minimum lighting level or the minimum output fraction for continuous control type, which is the lowest lighting output that the lighting system can dim down to, is expressed as a fraction of maximum light output. This is the fractional light output that the system produces at a minimum input power. Lutron Electronics claims that their sensors could dim down to 1%, however, daylighting was modeled

with systems with minimum lighting level of 5%, 10%, and 20% to account for the potential risks, mentioned above. Occupancy sensors are modeled with different occupancy schedules, low to high. In the high end tuning strategy, typically the digital ballasts would be set to trim 20% on top of the lighting output. Therefore, a range of 19%-21% trimming was considered. Studies by Lutron Electronics showed a 15% lighting energy savings when personal dimming controls were employed. A saving range of 13%-17% was considered for personal dimming controls to account for uncertainty associated with its related savings. Lighting power density is one of the factors that could have a significant impact on the outcomes of lighting control systems. Also, it could vary significantly based on the occupants' behavior. Since no tests were conducted in this case study to measure the actual lighting power density, a range of 1.1-1.6 (W/Sq.Ft) was considered to account for this variance. Demand reduction is one of the important benefits of lighting control systems such as daylight sensors. The demand peak (KW) reduction of this option was estimated through eQuest. As described previously, the energy based models in this study were calibrated based on KWh consumptions, so that the predicted KWh matches the actual KWh. They were not calibrated based on their KW prediction. The predicted KW of the best base model (BM0) was compared to the actual values. The  $EER_{year}$  was 13.61%. This indicates that the BM0 was over-predicting the annual demand peak by 13.61%. Therefore, in order to account for this inaccuracy in energy models, a multiplier, in a range of 0.8-1, was considered to adjust the KW prediction in each case.

The five lighting retrofit cases, described in Table 4, were modeled using the five base models, explained in Table 3 through eQuest, which result in a total of 25 energy models/savings estimates. These 25 estimates are used to generate the distributions of energy savings and related financial performance indicators. An excel-based model, a Lighting Control Systems Analytics (LCSA) was then developed for estimating the final lighting controls energy savings and performing economic analyses for each case. This is an analytic tool that could take the KWh and KW estimates from energy models as inputs, and perform a comprehensive analysis to estimate energy savings and financial performance indicators such as simple payback, simple ROI, NPV and IRR as outputs. The assumptions for creating the five lighting cases are primarily based on the researcher's professional judgment and experts' interview. They may not be the most accurate assumptions as no measurement tests or tenants interviews are performed in this case study. As mentioned previously, the goal is not to generate the most accurate outcomes but to demonstrate a procedure to include risk and uncertainty in the energy modeling process of green retrofit technologies.

### Distributions of Energy Performance Indicators and Total Energy Cost Savings

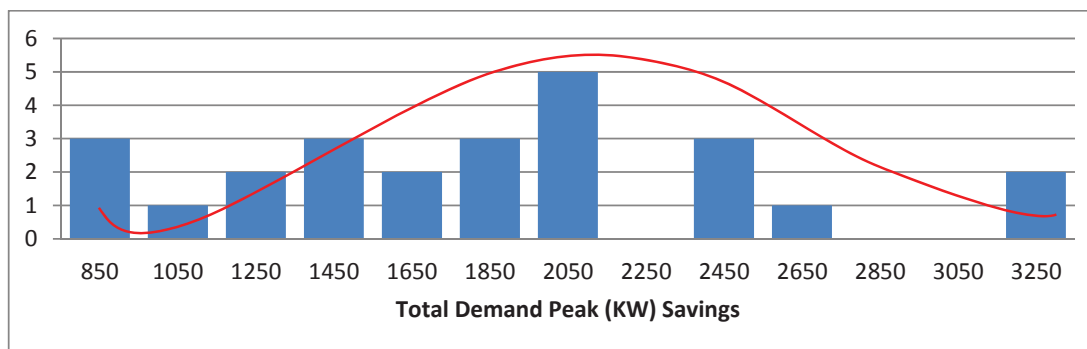
In order to estimate the distributions of energy performance indicators, 1) the impacts of daylight harvesting, occupancy sensors, and different lighting power density on energy savings were first calculated by modeling the 25 cases (five cases by five base models) in eQuest; 2) The outputs, including KWh and KW estimates for both lighting and whole building, were taken to the LCSA; 3) The impacts of high-end trimming<sup>1</sup>, personal dimming control, and demand peak adjustment factors were then estimated and incorporated through the LCSA; and 4) The distributions of energy performance indicators, KWh savings and KW savings, were generated based on the 25 saving estimates. Figure 4 and Figure 5 show the distributions of total MWh and KW savings:



**Figure 4: The Distribution of Energy Consumption Savings (MWh)**

<sup>1</sup> High-end trimming/tuning: sets the maximum light level based on customer requirements in each space.





**Figure 5: The Distribution of Peak Demand Savings (KW)**

Based on the annual KWh and KW savings and electricity costs per KWh and KW, the total cost savings were estimated for the 25 cases. The summary of statistics of total costs savings are presented in Table 7.

## Financial Analysis

### Simple Cost-Based Analysis

The entire capital costs data for lighting control systems including equipment and installation costs were obtained from Lutron Electronics. Capital costs could vary significantly based on the building characteristics, number of existing lighting fixtures, users' expectations, lighting contractors, etc. For the purpose of this analysis, five capital cost estimates were developed for the lighting retrofit cases 1-5 to account for the potential uncertainty associated with cost approximation suggested by Lutron Electronics. The utility provider for the building provides incentives for lighting equipment replacements / retrofits and lighting control systems. It pays all incentives four weeks after the project completion and verification. Thus, the total incentives for the lighting control systems were estimated for the five cases based on assumed ranges for numbers of sensors and ballasts and amount of the incentives for each installation.

Since the incentives are more likely to be paid in the same year that lighting retrofits occur, the total investment/development costs of the lighting retrofit option were then estimated by subtracting the incentives from the total capital costs. Table 5 shows the capital costs, the total utility incentives, and the total investment costs for the five cases.

**Table 5: Capital Costs, Utility Incentive, and Investment Costs**

Descriptions	Case 1	Case 2	Case 3	Case 4	Case 5
Total capital costs	\$329,430	\$342,785	\$356,140	\$365,044	\$373,947
Total utility incentive	\$50,824	\$54,487	\$63,172	\$75,402	\$93,487
Total Investment/Development Costs	\$278,605	\$288,298	\$292,968	\$289,642	\$280,460

Simple paybacks and simple Return On Investment (ROI) were estimated using the total investment/development costs and total cost savings, and their distributions were generated based on the 25 savings cases. The summary of statistics are presented in Table 7

### Life Cycle Cost Analysis (LCCA)

Cash flows for a period of 20 years were developed. NPVs and IRRs were estimated over four time horizons of 5, 10, 15, and 20 years to show the financial performance of the lighting retrofit over various life cycles. The costs of lighting replacements at the end of their useful life cycle were included in the cash flows for two conditions. The two conditions are 1) When a lighting retrofit option is undertaken and new control systems are installed—the replacement costs can negatively impact the cash flow at the end of the new systems useful life 2) When no lighting retrofit is undertaken and existing lighting fixtures will be replaced with similar models—the costs can positively impact the cash

flow at the end of the remaining useful life of the existing lighting fixtures. Table 6 shows the certain assumptions that are made for performing the LCCA:

**Table 6: Assumptions for LCCA**

	Case 1	Case 2	Case 3	Case 4	Case 5
Discount Rate for LCCA	7.0%	7.5%	8.0%	8.5%	9.0%
Reduction in maintenance cost for first X years (until the end of UL)	\$1,000	\$900	\$800	\$700	\$600
Remaining useful life (UL) of current lighting fixture	3	4	5	6	7
Total cost of upgrade current non-efficient fixture at the end of UL/Sq.Ft	\$0.80	\$0.90	\$1.00	\$1.10	\$1.20
Capital cost for replacing the current lighting fixture at the end of their UL	\$71,228	\$80,132	\$89,035	\$97,939	\$106,842
Useful life of new lighting control systems and fixtures from Lutron	15	14	13	12	11
Capital costs of upgrading new lighting systems after the first useful life (first 10-15 years)	\$160,263	\$169,167	\$178,070	\$186,974	\$191,425

Distributions of NPVs and IRRs over various periods of 5, 10, 15, and 20 years were generated. Table 7 shows the minimum, maximum, mean, and standard deviation of financial outcomes:

**Table 7: Min, Max, Mean, and Standard Deviation of Financial Outcomes**

Financial Metrics	Min	Max	Average	Standard Deviation
Total \$ Savings	\$26,975	\$49,829	\$38,163	\$6,656
Simple Paybacks	5.6	10.4	7.7	1.4
Simple ROI	9.62%	17.89%	13.35%	2.41%
5-Year NPV	(\$152,667)	\$22,199	(\$78,550)	\$61,199
10-Year NPV	(\$28,430)	\$225,171	\$97,429	\$68,462
15-Year NPV	(\$3,390)	\$334,067	\$150,239	\$101,059
20-Year NPV	\$53,661	\$478,213	\$249,254	\$129,192
5-Year IRR	-23%	11%	-8%	12%
10-Year IRR	9%	27%	17%	5%
15-Year IRR	9%	29%	18%	6%
20-Year IRR	12%	30%	20%	5%

## Interpretation of Distributions of Final Outputs

Probability distributions provide information about the probability of achieving the estimated outcomes. Based on the empirical rule if a distribution is approximately normal then the probability is about 68.26 percent of the estimates will lie within one standard deviation of the mean (mathematically,  $\mu \pm \sigma$ , where  $\mu$  is the arithmetic mean), about 95.44 percent will be within two standard deviations ( $\mu \pm 2\sigma$ ), and about 99.74 percent will lie within three standard deviations ( $\mu \pm 3\sigma$ ) [3].

The distributions of NPVs in this scenario are approximately normal, and therefore, the following information could be understood from the distribution of average 5-year NVP:

- There is about 68% chance that the 5-year NVP falls between -\$139,749 and -\$17,351.
- There is about 95% chance that the 5-year NVP falls between -\$200,948 and +\$43,848.
- There is about 99.5% chance that the 5-year NVP falls between -\$262,147 and +\$105,047.
- There is less than 13% chance that the 5-year NVP is positive.

- There is about 84% chance that the 5-year NVP is not less than -\$17,351.
- There is about 2% that that the 5-year NVP is higher than +\$43,848

The above information provides investment decision-makers with more insight into risk associated with achieving the expected financial outcomes. As a result, decision-makers would be able to make more informed decisions concerning investing in green retrofit options.

## Discussion on Using Multiple Base Models for Simulating Retrofit Options

The hypothesis here is that considering the inaccuracy of a base model in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. This sub-analytic attempts to test this hypothesis towards the broader goal of assisting decision-makers to make more informed decisions about investing in green retrofits.

In order to measure the impacts of simulation with multiple base models on financial outcomes, the low-end and high-end impacts were estimated by comparing the minimum and maximum of each financial outcome to related average value of the best model (BM0). The assumption was that the retrofit options would be modeled using the best model (BM0), if multiple base models would not be used. Table 8 shows the impacts, both absolute values and percentages, on different financial indicators:

**Table 8: Impacts of simulating by multiple base models on financial outcomes**

Financial Indicator	(Min - BM0)	(Max - BM0)	Low-End Impact	High-End Impact
Total \$ Savings	-\$744	\$3,563	-2%	13%
Simple Paybacks	-1.2	0.2	-12%	2%
Simple ROI	-0.3%	1.3%	-2%	13%
5-Year NPV	-\$3,596	\$16,625	-38%	136%
10-Year NPV	\$0	\$65,771	0%	253%
15-Year NPV	-\$9,181	\$39,206	-334%	2708%
20-Year NPV	-\$11,334	\$46,742	-10%	79%
5-Year IRR	-1%	4%	-17%	74%
10-Year IRR	-1%	2%	-3%	25%
15-Year IRR	-1%	3%	-4%	32%
20-Year IRR	-1%	2%	-2%	20%

Therefore, if the lighting controls option was only modeled using one calibrated base model:

- The total savings could have been underestimated by 13% (\$3,563) or overestimated by 2% (\$744).
- The Simple Payback could have been underestimated by 2% (0.2 year) or overestimated by 12% (1.2 years).
- The 5-year NPV could have been underestimated by 136% (\$16,625) or overestimated by 38% (\$3,596).
- The 5-year IRR could have been underestimated by 74% (4%) or overestimated by 1% (17%).

The results of the analysis show that including inaccuracy of base models could have the potential to impact the financial outcomes and influence the investment decisions. There were few conditions in the NPV analyses, 10-year and 15-year NPV, where one case has a negative NPV with the best case (BM0) but positive NPVs with other base models. Thus, if an investor bases her/his decision on the result of modeling with a single base model, she/he would not agree to invest in the lighting controls option. The 4% increase in a 5-year IRR or \$16,625 in a 5-year NPV could alter an investment decision from 'no go' to 'go'.

It should be noted that many factors might play roles in the magnitude of impacts. Factors include level of calibration, type of retrofit options, investors return' horizons, building characteristics, or nature/level of analysis. Accordingly, the inaccuracy of base models could potentially impact the investment decisions at the property level, when selecting the retrofit options. It could alter an investment decision from 'no go' to 'go'.

## Conclusion

Decision-makers often rely on the results of the energy simulation when making investment decisions about energy retrofit options. Thus, it is important for modelers/consultants to examine potential strategies to improve the reliability and level of confidence associated with simulation outcomes to ultimately enhance the quality of investment decisions. Towards achieving this objective, this paper presents how to define and include ranges for uncertain factors in the energy retrofit assessment process and explains how to generate distributions of outcomes to communicate risk associated with achieving the expected outcome. The proposed process is numerically demonstrated through a case study on evaluating a combination of lighting controls package for an existing office building.

When simulating a new retrofit option in an existing building, there are two factors that could influence the distribution/variance of savings associated with the retrofit option: 1) ranges of assumptions for new retrofit options and 2) the inaccuracy of base models. The final simulation output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy of base models, is often ignored. The analysis shows that considering the inaccuracy of a base model in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. It could alter an investment decision from 'no go' to 'go'. However, the result of this single analysis cannot be generalized. Therefore, depending on the level of analysis, modelers are encouraged to consider the inaccuracy of a base model in addition to the uncertainties associated with each retrofit option when making investment recommendations about green retrofits to decision-makers.

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**26<sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech – Poster**



# A New Process for Assessing the Financial Performance and Uncertainty Associated with Implementing Energy Efficiency Systems and Strategies

## 1. Introduction

In the United States buildings account for over 30 percent of energy consumption and by some estimates nearly 50 percent of greenhouse gas emissions. With the growing concerns for climate change, global warming and interest in sustainability, property owners, investors, and developers are increasingly interested in investing in energy efficiency systems and strategies (EESS).



**No precise answer for:**

- Does EESS pay off and if so, by how much?
- How does energy efficiency impact the properties' financial value?
- What is the most profitable EESS option?
- What is the true return on investment (ROI)?
- Are benefits sufficient to take the risk?
- How confident investors could be in achieving the expected ROI?

Energy Simulation Programs (ESPs) are the primary tools that are used by design professionals to project building energy performance. These models help decision makers to explore the potential savings, compare the various EESS, and select the most cost-effective options. Currently, many energy efficiency investment decisions are made based on the results of these ESPs.

## 2. Problem Statement

The financial outcomes of ESPs on their own are incomplete, unreliable and inappropriate for making high-quality investment decisions. They may undervalue EESS investment, exclude many profitable opportunities from consideration, and lead to poor decisions about implementation of EESS. Two major problems are:

### ❑ Communication between technical and financial decision makers:

- Focus on assessment of systems and building performance outcomes
- Fail to properly link energy to financial performance

### ❑ Simplistic cost-based financial analysis:

- Focus on initial costs and operational cost savings and estimate
- Estimate simple payback (PB), simple (ROI) or life cycle cost (LCC) as indicators of financial performance
- Ignore many potential benefits, risks and uncertainties of EESS investment
- Fail to estimate the true financial value added by EESS investment

## 3. Research Objectives

- ❑ Development of a systematic process for a more holistic financial assessment of EESS, while explicitly addressing the inherent risks and uncertainties to assist users to make more informed decisions about investing in EESS.
- ❑ Linking ESPs outcomes to more sophisticated financial / statistical methods used by the investment community for evaluating investment decisions.
- ❑ Create a single integrated platform to bridge the gap between the design and investment communities and translate the technical language to financial language to communicate more reliable and understandable information regarding EESS implementation's ROI and its associated uncertainty.

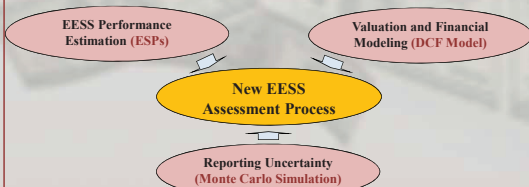


Fig. 2: Three major area considered in the development of the process

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## 4. New Assessment Process

The four-step translation process is a robust valuation process that takes EESS, uses current EPSs to forecast estimates of their energy efficiency outcomes, links their outcomes to key financial variables to be included in a Discounted Cash Flow (DCF) model, and uses a Monte Carlo simulation technique to derive distributions of their financial performances. It is a roadmap that decision makers could follow to better understand the true value added by EESS as well as the risk and uncertainty of achieving their possible additional ROI.

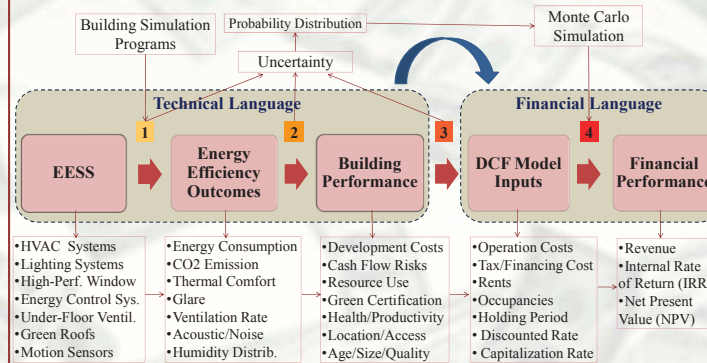


Fig. 3: A process for deriving the financial performance of EESS

### 1 Step 1: Building Modeling

- Inaccuracy/error inherent in forecasting the energy performance outcomes needs to be considered.
- It is not just energy cost savings that matters.
- EESS needs to be modeled with more than one simulation program for a thorough valuation.

### 2 Step 2: Building Performance Forecasting

- Green Performance Factors should be estimated based on the results of simulation programs, available data, guidelines and regulations.
- The effect of energy efficiency outcomes on health and productivity may be roughly estimated in the absence of sufficient data to support more specific claims.

### 3 Step 3: DCF Model Inputs Determining

- The concept of the DCF approach is suggested to be used as the base model in lieu of simple PB, simple ROI, and LCC for estimating the financial performance of EESS.
- With the DCF method, potential direct and indirect costs, benefits and risks associated with energy efficiency investment could be considered in generating the investment's revenue.

### 4 Step 4: Uncertainty Modeling and Financial Performance Estimating

- A probability distribution should be specified for all variables that are uncertain in each step.
- The Monte Carlo simulation, with a base model built based on a DCF approach, is suggested to take the range of each DCF input, perform a random sensitivity analysis and generate the distribution of the final DCF outcomes such as NPV and IRR.
- The Monte Carlo analysis is able to measure and express various risks and uncertainties in the process by ascribing the range of possible values instead of a single-point estimate of value in the DCF model.

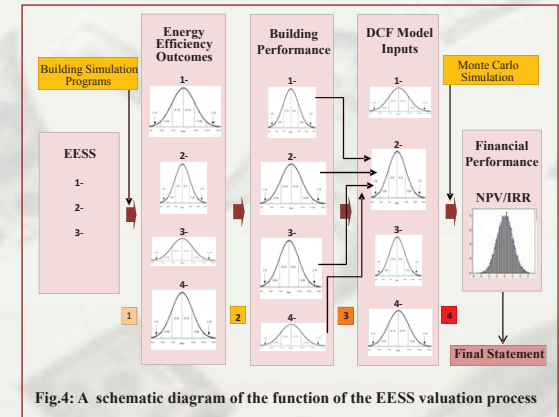
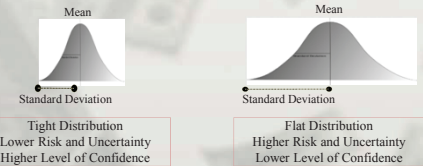


Fig.4: A schematic diagram of the function of the EESS valuation process

## 5. Results of the Process

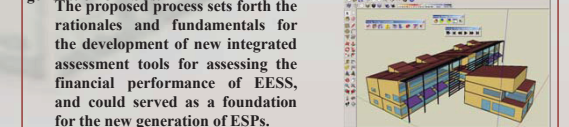
The resulting ranges and the shape of distributions would provide useful information about the uncertainty related to the estimation of DCF inputs and would articulate the risks related to achieving DCF outputs. It provide a much more comprehensive view of financial performance of EESS, as opposed to single-point estimates of traditional analysis.



## 6. Benefits of the Process and the Next Step

- ❑ By applying the proposed process, traditional simple cost-based methods could be replaced in the decision-making analysis, and therefore, many new opportunities for EESS investments may emerge.
- ❑ The outcomes will communicate with property professionals and benefit them in making informed decisions with a higher level of confidence regarding:
  - Whether or not to proceed with a particular EESS investment**
  - Implementing the best possible EESS options in new or existing building**
- ❑ The outcomes will help design professionals to understand the true financial performance of their design decisions and its impact on selection of EESS at the pre-development stage, resulting in more holistic and viable design.

The proposed process sets forth the rationales and fundamentals for the development of new integrated assessment tools for assessing the financial performance of EESS, and could served as a foundation for the new generation of ESPs.



**27<sup>th</sup> GSA Research Symposium and Exposition at Virginia Tech – Poster**

# The Next Generation of Building Energy Simulation Programs: A New Eight-Step Procedure for Deriving the Financial Value and Risk of Energy Retrofit Options

## 1. Introduction

In the United States, more than 90% of the entire stock of commercial buildings represent existing buildings, which 75% of them were built before 1990. Typically, these buildings have a larger energy consumption due to the inefficiency of their systems and construction. The potential market for energy retrofit in the US:

- \$15 billion by 2014 (McGraw-Hill Construction)
- \$18 billion per year (Johnson Control)
- \$400 billion over the coming years (Pike research)

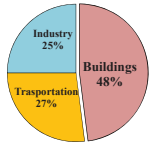


Fig.1: The US Energy Consumption

However, despite the highly compelling potential of energy efficiency retrofits, and increased awareness of property professionals of positive financial performance and prediction of future growing demand, the magnitude of energy efficiency investment is much lower than what it was expected to be. Why?!!!

One of the primary reasons is the inability of current tools and techniques in providing appropriate outcomes for making high-quality investment decisions.

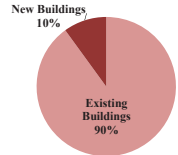


Fig.2 : New vs. Existing Buildings



## 2. Problem Statement

Energy Simulation Programs (ESPs) are the primary tools that are used by design professionals to project building energy performance. The financial outcomes of ESPs may undervalue EESS investment, exclude many profitable opportunities from consideration, and lead to poor decisions about implementation of EESS. Three major problems are:

- 1. Understandable- Communication between technical and financial decision makers:**
  - Focus on assessment of systems and building performance outcomes
  - Fail to properly link energy to financial performance
- 2. Comprehensive- Simplistic cost-based financial analysis:**
  - Focus on initial costs and operational cost savings
  - Ignore many potential benefits, risks and uncertainties
- 3. Reliable- Inability to Deal with Risk and Uncertainty**
  - They only take single point estimates of inputs and ignore their variance

## 3. Research Objectives

The broader goal is to create a new integrated assessment approach to assist decision makers to capture this huge potential of energy retrofits in commercial building market

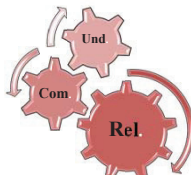
- 1) Impact the 90% of 48% of energy consumption in the US
- 2) Increase the use of green technologies in building retrofit business.

□ Bridging the gap between the design and investment communities and translate the technical language to financial language - **Understandable**

□ Considering full scope of costs and benefits and risks associated with EROs, both tangible and intangible - **Comprehensive**

□ Developing a procedure for identifying, quantifying, and presenting uncertainties inherent in both energy performance and financial performance to address the risk associated with expected financial outcomes - **Reliable**

□ Linking ESPs outcomes to more sophisticated financial /statistical methods used by the investment community for evaluating investment decisions to address value and risk in the way that investors require - **Understandable & Reliable**



## Alireza Bozorgi\* and Dr. Jim Jones\*\*

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\*\*Professor of Architecture  
College of Architecture and Urban Design

## 4. A New Eight-Step Procedure

1. Set up the Initial Base Model and calculate the monthly electricity and gas usage
2. Observe the actual performance indicators and Compare them with Models' Projection
3. Identify the suspected inputs, Modify the Inputs and Calibrate the Base Model
4. Perform Sensitivity Analysis on New Energy Retrofit Options (EROs)
5. Determine Ranges or Distributions for new Building Performance Factors
6. Provide a Comprehensive Building Performance Statement
7. Utilize the Concept of Discounted Cash Flow (DCF) Methods and Determine Ranges or Distributions for the DCF Inputs
8. Estimate the Financial Performance Indicators through Monte Carlo Simulation

Technical Tools  
Used by Design  
Professionals for  
Building  
Performance  
Assessment

Linking

Financial Methods  
Used by Property  
Professionals for  
Investment  
Analysis

$$\text{New Green Building Performance} + \text{Non-Green performance Information} + \text{Historic Financial Data} = \text{Statement of Building Performance}$$

Fig.3: A Comprehensive Building Performance Statement

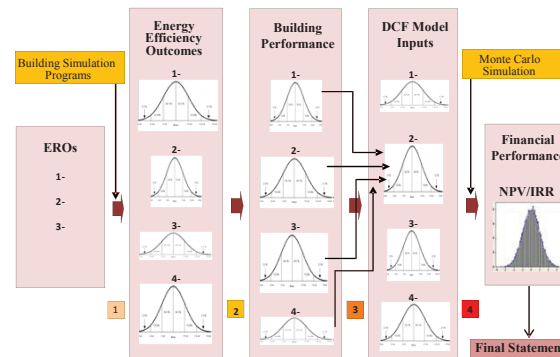
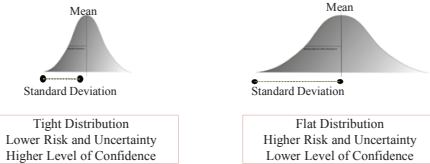


Fig.4: A schematic diagram of the function of the EROs valuation process

## 5. Results of the Process

The shape of distributions would provide useful information about the uncertainty related to the estimation of DCF inputs and would articulate the risks related to achieving DCF outputs. It provide a much more comprehensive view of financial performance of EROs, as opposed to single-point estimates of traditional analysis.

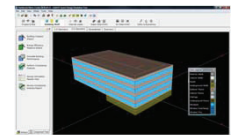


## 6. Benefits of the Procedure

- By applying the proposed procedure, traditional simple cost-based methods could be replaced in the decision-making analysis, and therefore, many new investment opportunities may emerge.
- The outcomes will communicate with property professionals and benefit them in making more informed decisions with higher level of confidence
- Property professionals will be able to integrate energy efficiency into investment decisions and therefore, will be encouraged to consider more green technologies when making retrofit investment decision.
- The outcomes will help design professionals to understand the true financial performance of their design decisions and its impact on selection of ERO, resulting in more holistic and viable design.

## 7. New Generation of ESPs and the next step

The proposed procedure sets forth the rationales and fundamentals for the development of new integrated assessment tools for assessing the financial performance of energy efficiency, and could served as a foundation for the new generation of ESPs.



□ Should Utilize the More Sophisticated Financial & Statistical Techniques—DCF & MCS in lieu of SPB & LCC

□ Should Have the Ability to Take Inputs From Real Estate Experts

## 8. Validation through Case Studies



Existing Non-Green Office Buildings

- Survey 1: Environmental Building Systems Modeling Experts
- Survey 2: Green Building Consultants
- Survey 3: Healthcare Practitioners and Productivity Experts
- Survey 4: Real Estate Valuation/Development Experts
- Final Survey: Validation

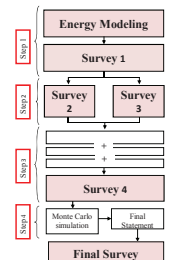


Fig.5: The data collection process



**Integrating Value and Uncertainty in Sustainable Options Analysis in Real Estate Investment**

**Purpose** - The main purpose of this paper is to set forth the rationales and foundations for the development of new integrated tools to include risk and uncertainty for assessing the financial performance/value of sustainable options investment in existing income-producing properties.

**Design/methodology/approach** - In the development of the new assessment process, this study looks at the three following domains simultaneously and brings them all together into a single integrated platform to evaluate the possible sustainable options.

- Sustainable options and their performance projections – Building Simulation Programs;
- Sustainable property valuation - Discounted Cash Flow Model;
- Communicating the uncertainty of a valuation process- Monte Carlo Simulation.

**Findings** - The outcome of this paper is a systematic valuation process to assess a set of sustainable options while clearly articulating the risk and uncertainty inherent in the valuation process in a way that can be utilized for making high-quality decisions about green retrofits investment.

**Practical implications** - The suggested process in this paper will provide such a methodology and roadmap that helps to identify, measure, and consider various uncertainties associated with sustainable options evaluation. The outcomes of this process assist the users in making more informed decisions when evaluating greening their existing properties.

**Originality/value** - The paper proposes a functional analytical method to bridge the gap between the design and investment communities by linking the current technical tools to traditional financial techniques. It provides both design and property professional with a new approach to think about financial assessment of sustainable options in the context of value.

**Keywords** – Sustainable Options/Properties, Green Retrofit Investment, Building Performance, Property Valuation, Risks, Uncertainties

## **A Three-Level Analysis Approach for Deriving the True Financial Performance of Energy Retrofit Options**

**Keywords:** energy retrofit options, true financial assessment, value-based analysis, Non-cost savings benefits of energy efficiency investment

Decisions for investing in Energy Efficiency in existing buildings are often made based on the energy cost savings and simple cost-based analysis. However, the true financial performance of energy efficiency is beyond the energy cost savings. The non-cost benefits, which are more difficult to quantify, are often ignored when evaluating an energy retrofit option. This paper suggests a three-level analysis approach for estimating the true financial performance of energy retrofit options in existing buildings. The energy benefits that are examined for assessing the true financial performance include: 1) Energy-Related Factors: factors that have impact on energy savings, including capital costs, operation and maintenance costs, and incentives. 2) Non-Energy Factors: the benefits that are not related to energy savings but could contribute to cost savings, including health and productivity. 3) Non-Cost Savings Factors: the benefits that may not contribute to energy and cost savings, including improved occupant's comfort/satisfaction, improved safety and security, and contribution to energy or green certification.

The paper looks at all factors simultaneously and presents a holistic assessment process for capturing those benefits in the financial assessment. An existing office building and a typical energy retrofit option are selected to conduct a case study for demonstrating the numeric application of the proposed assessment process. The three-level financial analysis, proposed in the paper, includes: A) Cost-based level-1, where only energy related costs savings are considered. B) Cost-based level-2, where the non-energy cost savings, including health and productivity, are considered in addition to the items in level A. C) Value-based level, where the value implications of the green retrofit option are considered in addition to items in levels A and B. The financial implications of non-cost benefits, which are difficult to include in cost-based analyses, could also be captured at this level. The new holistic approach enables decision-makers to better evaluate the energy retrofits option and make more informed decisions about investing in energy retrofit option.

**APPENDIX H: IRB Approval Letter**



**MEMORANDUM**

**DATE:** December 2, 2011

**TO:** James R. Jones, Alireza Bozorgi

**FROM:** Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

**PROTOCOL TITLE:** Integrating Value and Uncertainty in Sustainable Options Analysis in Real Estate Investment

**IRB NUMBER:** 11-971

Effective December 1, 2011, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the new protocol for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at <http://www.irb.vt.edu/pages/responsibilities.htm> (please review before the commencement of your research).

**PROTOCOL INFORMATION:**

Approved as: **Expedited, under 45 CFR 46.110 category(ies) 6, 7**

Protocol Approval Date: **12/1/2011**

Protocol Expiration Date: **11/30/2012**

Continuing Review Due Date\*: **11/16/2012**

\*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

**FEDERALLY FUNDED RESEARCH REQUIREMENTS:**

Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

\*Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office ([irbadmin@vt.edu](mailto:irbadmin@vt.edu)) immediately.

cc: File

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