# Table of Contents

**Thesis Title**

“Assessment of Building Energy Performance for Energy Efficiency Measures in Selected Commercial Buildings of India”

Declaration by Candidate ................................................................. i
Certificate from Supervisor ............................................................. ii
Acknowledgement ........................................................................... iii
Table of Contents ........................................................................... iv
List of Figures ............................................................................... ix
List of Tables ................................................................................ xiv
Abbreviations ............................................................................... xvii
Abstract ....................................................................................... xix

## Chapter – 1 Introduction

1.1 Background ........................................................................... 2
1.2 Energy production and consumption in India ......................... 4
1.3 Energy use and need for conservation .................................... 6
1.4 Importance of energy efficiency in commercial buildings ........ 10
1.5 Motivation of study .............................................................. 11
1.6 Statement of research problem .............................................. 12
1.7 Significance of study ............................................................. 14
1.8 Objectives of study ............................................................... 15
1.9 Hypotheses of study ............................................................. 16
1.10 Research methodology ......................................................... 17
   1.10.1 Phases of research ......................................................... 23
1.11 General description of buildings .......................................... 25
1.12 Reason and criteria for selection of buildings ....................... 27
Chapter – 2 Literature Review

2.1 Energy and buildings

2.2 Energy efficiency in commercial buildings
   2.2.1 Energy conservation in India
   2.2.2 Global perspective of energy conservation
   2.2.3 Design of buildings for energy efficiency
   2.2.4 Building envelope
   2.2.5 HVAC system
   2.2.6 Types of HVAC system
   2.2.7 Chillers
   2.2.8 Lighting system

2.3 Thermal comfort in commercial buildings
   2.3.1 ASHRAE standard for thermal comfort
   2.3.2 Factors affecting thermal comfort

2.4 Energy efficiency techniques for HVAC system
   2.4.1 Operational techniques for energy efficiency
   2.4.2 Design techniques for energy efficiency

2.5 Building energy simulation technique
   2.5.1 Building energy simulation tools
   2.5.2 Assessment of building energy performance using simulation tools
   2.5.3 Comparing different tools in perspective
   2.5.4 Selection of tool for energy performance evaluation
   2.5.5 Energy simulation software eQUEST-3.63b
   2.5.6 Weather data for energy simulation program

2.6 Research and case studies
Chapter – 3 Research Methodology

3.1 Introduction to research
3.2 Description of buildings
3.3 Climate zones of India
3.4 Energy star portfolio manager
3.5 Benchmarking with portfolio manager
3.6 Sampling
  3.6.1 Sample design
3.7 Secondary data collection
3.8 Primary data collection
  3.8.1 Questionnaire design
  3.8.2 Questionnaire pre-testing
  3.8.3 Questionnaire survey
  3.8.4 Outlines of questionnaire survey form
3.9 Analysis of the questionnaire data
  3.9.1 General information
  3.9.2 Envelope characteristics
  3.9.3 HVAC system and lighting
  3.9.4 Base case formulation process
3.10 eQUEST building energy modeling and simulation
  3.10.1 Modeling and simulation method
3.11 Energy efficiency measures
  3.11.1 Energy efficient building envelop
  3.11.2 Energy efficient HVAC system
  3.11.3 Energy efficient lighting
Chapter – 4  Analysis of Building Energy Performance

4.1 Introduction
4.2 Energy analysis using simulation methods and techniques
4.3 Energy modeling and simulation of buildings
  4.3.1 Analysis through building energy simulation
  4.3.2 Base case formulation
  4.3.3 Input data
  4.3.4 Buildings thermal zoning
  4.3.5 Baseline case energy modeling and simulation
  4.3.6 Performance of base case models simulation
4.4 Input data and techniques of energy efficiency measures
4.5 EEMs impact on building energy efficiency
4.6 Implementation of appropriate EEMs
4.7 Evaluation of EEMs simulation results

Chapter – 5  Facts and Findings

5.1 Introduction
5.2 Energy saving calculation
5.3 Findings of building energy performance assessment
  5.3.1 Low payback period energy efficiency measures
  5.3.2 Medium payback period energy efficiency measures
  5.3.3 High payback period energy efficiency measures
5.4 Buildings energy efficiency patterns
5.5 Energy efficient HVAC system
5.6 Cost benefit analysis of EEMs for payback period

Chapter – 6  Conclusion and Recommendations

6.1 Conclusion
6.2 Recommendations of EEMs in commercial buildings of India
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3</td>
<td>Guidelines for building envelope design in commercial buildings of India</td>
<td>219</td>
</tr>
<tr>
<td>6.4</td>
<td>Guidelines for HVAC system design and operation in commercial buildings of India</td>
<td>220</td>
</tr>
<tr>
<td>6.5</td>
<td>Guidelines for lighting system in commercial buildings of India</td>
<td>222</td>
</tr>
<tr>
<td>6.6</td>
<td>Future scope of research</td>
<td>223</td>
</tr>
<tr>
<td></td>
<td>Bibliography</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>Annexure</td>
<td></td>
</tr>
<tr>
<td>Annexure: A</td>
<td>Questionnaire</td>
<td>236</td>
</tr>
<tr>
<td>Annexure: B</td>
<td>Charts and Tables</td>
<td>244</td>
</tr>
<tr>
<td>Annexure: C</td>
<td>List of Publications</td>
<td>280</td>
</tr>
<tr>
<td>Annexure: D</td>
<td>Research paper titled “Analysis and evaluation of energy conservation potential in an Indian commercial building – A case study in Jaipur” published in international journal</td>
<td>282</td>
</tr>
<tr>
<td>Annexure: E</td>
<td>Research paper titled “Energy performance and energy EEMs of a commercial building in warm and humid climate zone of India” published in international journal</td>
<td>297</td>
</tr>
</tbody>
</table>