DEVELOPMENT OF A SUSTAINABLE ENERGY RATING SYSTEM FOR RESIDENTIAL BUILDINGS IN SRI LANKA

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DECLARATION OF THE CANDIDATE & SUPERVISOR

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ABSTRACT

Energy rating system can be considered as a key policy instrument that will assist the government to reduce energy consumption. Energy rating includes the direct benefits such as, energy requirement and carbon dioxide emission reduction, cost reduction for the users, increase the public awareness regarding energy issues, and improve the availability of information regarding the building. The government of Sri Lanka also has identified the importance of energy performance of buildings and considers it as a strategy for the sustainable energy development of the country. Existing rating systems in the world only considered limited factors related to energy consumption and to provide more accurate rating system it is proposed that a more sustainable energy rating system should be developed considering all the criteria. This research is aimed at identifying the existing rating systems, investigate the existing systems, to identify the parameters required for determining the energy performance of residential buildings, to develop and equation for calculating the energy score and to develop a scale for comparing the energy performance of residential buildings in hot and humid climate in Sri Lanka.

To achieve the above mentioned objectives, this research followed the concept of sustainable energy which comprises of both energy efficiency and renewable energy. The energy efficiency of a residential building needs to consider the energy efficiency due to building properties and energy efficiency of the occupants. To evaluate the energy efficiency of the building properties, the asset rating method was used where the building is modeled and the energy consumption for thermal comfort and lighting is calculated. Using 4569 different models (varying window to wall ratio, orientation, zone size, zone location, building shape and floor area), a parametric analysis was conducted to develop an optimum model which was then used as the reference value for the first sub rating (Building consumption rate). A questionnaire survey was conducted to identify the factors affecting the energy consumption of the Sri Lankan residential buildings and in total 336 filled questionnaires were used for parametric analysis. The questionnaire revealed that the number of bedrooms is not significant for energy consumption and the occupant characteristics and the equipment usage are highly significant factors. Therefore, when developing the occupancy behaviour rate, the average domestic energy consumption in Sri Lanka was used as reference, without normalising. To consider the renewable energy usage, another sub rating named energy source rate was developed and to decide whether to offset the energy consumption with renewable energy use or to use a separate index, another questionnaire survey was conducted with rooftop solar PV consumers. The results of the survey indicated

that there is a strong rebound effect due to the solar PV adoption and there are some other social and technical impacts as well. Therefore, when developing the energy source rate, a sustainability index was used and based on the percentage of contribution of the energy sources to the final energy use the final energy source rate was determined.

These three sub ratings were normalised and brought to a common scale of 0 to 100. The sub ratings were integrated using weightages which were obtained using a perception survey of engineers, architects, quantity surveyors and facility managers in the industry. The application of the rating method is explained using two actual examples. Further, a sensitivity analysis was done to reflect the effect of the changes in the parameters used in the score calculation equation using the first sample house. The rating methodology proposed in this thesis can be used over any country or any building by changing the reference values and weightages.

Keywords: Energy rating; energy efficiency; buildings; thermal comfort; renewable energy; energy labels; consumer behaviour

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TABLE OF CONTENTS

Declaration of the Candidate & Supervisor i

Abstract ii

Acknowledgement iv

Table of Contents vii

List of Figures ix

List of Tables xi

List of Abbreviations xii

1 Introduction 1
- 1.1 Energy performance assessment . . . 2
- 1.2 Energy rating systems . . . 2
- 1.3 Objectives . . . 6
- 1.4 Scope . . . 6
- 1.5 Methodology . . . 7
- 1.6 Main findings . . . 7
- 1.7 Structure and overview of the thesis . . . 8

2 Literature Review 9
- 2.1 General . . . 9
- 2.2 Existing energy rating systems . . . 9
  - 2.2.1 Parameters used for existing energy rating systems. . . . 10
  - 2.2.2 Comparability matrix . . . 12
  - 2.2.3 Existing energy rating methods . . . 12
  - 2.2.4 Research gap . . . 13
- 2.3 Thermal comfort . . . 13
  - 2.3.1 Factors affecting thermal comfort . . . 14
  - 2.3.2 Thermal comfort standards in built environment . . . 16
- 2.4 Effect of building form on the energy efficiency . . . 18
- 2.5 Effect of occupant behaviour . . . 21
- 2.6 Sustainability assessment of energy sources . . . 23
  - 2.6.1 Decision support methods for energy sources . . . 29
- 2.7 Multi criteria decision analysis . . . 30

2.7.1 Weighted sum method . . . 30
2.7.2 Analytical hierarchy process (AHP) . . . 31
2.7.3 Multiattribute utility theory (MAUT) . . . 32
2.7.4 The elimination and choice translating reality (ELECTRE) 33
2.7.5 The technique for order preference by similarity to ideal solutions (TOPSIS) . . . 33
2.7.6 Preference ranking organisation method for enrichment evaluation (PROMETHEE) . . . 34
2.8 Summary . . . 35

3 Research Methodology **37**
3.1 General . . . 37
3.2 Research approach . . . 37
3.3 BC_{rate} (Building consumption rate) calculation . . . 40
3.3.1 BC_A calculation . . . 40
3.3.2 BC_O calculation . . . 42
3.4 Analysing the effect of building shape and zones . . . 43
3.4.1 Case study models . . . 43
3.4.2 Simulation settings . . . 46
3.5 Parametric analysis of the optimal form . . . 47
3.6 Optimum building design . . . 51
3.7 OB_{rate} (Occupant behaviour rate) calculation . . . 52
3.7.1 Development of the questionnaire . . . 52
3.7.2 OB_{rate} calculation . . . 53
3.8 ES_{rate} (Energy Source rate) calculation . . . 53
3.8.1 Sustainability assessment of rooftop solar PV in residential buildings . . . 53
3.8.2 Sustainability index for energy sources . . . 54
3.9 Development of energy score and scale . . . 58
3.9.1 Deciding the weights of the rates . . . 58
3.10 Summary . . . 59

4 Results and Analysis **61**
4.1 General . . . 61
4.2 Effect of building form and zones . . . 61
4.2.1 Analysis of the effect of building shape on discomfort hours 61
4.2.2 Analysing the effect of building shape on artificial lighting 62
4.2.3 Analysing the effect of zone size and zone location . . . 63
4.2.4 Analysing the effect of WWR and orientation . . . 66
4.2.5 Discussion . . . 70
4.3 Results of the parametric analysis . . . 71
4.4 Optimum building design . . . 80
4.4.1 Calculating the total energy consumption of the optimum model . . . 83
4.4.2 Calculating the total energy consumption of the optimum air conditioned models . . . 85

4.4.3 Calculating energy consumption for actual naturally ventilated house . . . 88
4.5 Effect of occupant behaviour on energy efficiency . . . 90
4.5.1 Results of the consumer energy survey . . . 91
4.5.2 Development of OB_{rate} . . . 99
4.6 Sustainability assessment of energy sources . . . 100
4.6.1 Analysis of sustainability assessment of rooftop solar PV in residential buildings . . . 100
4.6.2 Development of Energy source rate ES_{rate} . . . 108
4.7 Development of energy score . . . 109
4.7.1 Normalising the BC_{rate} . . . 109
4.7.2 Normalising the OB_{rate} . . . 110
4.7.3 Normalising the ES_{rate} . . . 112
4.7.4 Developing the energy score . . . 112
4.8 Developing the energy rating scale . . . 113
4.9 Summary . . . 115

5 Application of the energy rating system 116
5.1 General . . . 116
5.2 Applying the rating system to actual sample houses . . . 116
5.2.1 Sample house 1 . . . 116
5.2.2 Sample house 2 . . . 120
5.3 Sensitivity Analysis . . . 124

6 Discussion 126

7 Conclusions and Recommendations 128
7.1 Recommendations and future work . . . 130

Appendix A Outdoor temperature of weather file 143

Appendix B Velocities to achieve acceptable comfort levels 145

Appendix C Energy scores calculated for hypothetical scenarios 146

Appendix D Questionnaires 153

LIST OF FIGURES

1.1 Net energy generation by energy source in the world 1
1.2 Energy performance assessment systems 3
1.3 Electricity consumption of Sri Lanka by sector 5

2.1 Acceptable operative temperature ranges in ASHRAE 55 (2017) . 18
2.2 Renewable energy sources: decision making 26

3.1 Parameter categorisation 38
3.2 Overall methodology of the research 39
3.3 Samples of case study house models 44
3.4 Staircase positions of the house models and the seven cases 45
3.5 The different phases in the MIVES method 55

4.1 Discomfort hours of model houses 62
4.2 Lighting electricity of model houses 63
4.3 Variation of thermal comfort and lighting based on zone size . . . 64
4.4 Variation of thermal comfort and lighting in square shape 65
4.5 Variation of thermal comfort and lighting in rectangular shape . . 66
4.6 Variation of thermal comfort and lighting in L shape 67
4.7 Thermal comfort of the cases for various WWR 69
4.8 Lighting electricity of the cases for various WWR 69
4.9 Thermal comfort of the cases for various orientations 70
4.10 Lighting electricity of the cases for various orientations 70
4.11 Regression plots of significant variables I 77
4.12 Regression plots of significant variables II 78
4.13 Regression plots of significant variables III 79
4.14 Initial model prepared for optimal model 81
4.15 Plan views of the initial model 81
4.16 Optimum house model 82
4.17 Decision process for cooling energy calculation 89
4.18 Decision process for cooling energy calculation for Katunayake . . 90
4.19 Number of occupants in age categories 92
4.20 Number of occupants in employment categories 92
4.21 Number of households based on number of occupants in households 93
4.22 Number of households based on number of floors 93
4.23 Number of households based on number of bedrooms 93
4.24 Average electricity consumption of the households 94
4.25 Ventilation and cooling methods of respondents 94

4.26 Occupancy schedule - Time of leaving home 95
4.27 Occupancy schedule - Time of returning home 95
4.28 Average door opening schedules 96
4.29 Average window opening schedules 96
4.30 Average lighting schedules of the respondents 97
4.31 Electricity consumption before and after solar PV installation . . 101
4.32 Percentage change in electricity consumption compared to the electricity consumption before installation 101
4.33 Equipment used before PV installation and purchased after installation 102
4.34 Reasons for increase in total electricity consumption 103
4.35 Excess units supplied to the main grid by the respondents 103
4.36 Motivation for installing rooftop solar PV system 105
4.37 Utilization of the saved money from lower electricity bill 105
4.38 Electricity consumption compared to GDP 106
4.39 Electricity generation by various sources 107
4.40 Change in daily load curves from 2007 to 2014 107
4.41 Distribution of the energy score 114
4.42 Energy rating scale with standard deviations 114
4.43 Energy rating scale 114

5.1 Sample house 1 117
5.2 Sample house 2 121

6.1 Graphical representation of the final model 127

LIST OF TABLES

2.1 Principle criteria for sustainability assessment 24
2.2 Sustainability principles and sustainability assessment indicators . 25
2.3 Sustainable energy technologies and assessment 27
2.4 Classification of sustainability assessment criteria 28
2.5 Value of importance in AHP fundamental scale 32

3.1 Descriptive Statistics of the pilot survey (N=120) 44
3.2 Minimum internal dimensions of the zones 45
3.3 Material details of the construction components 46
3.4 Objectives and design variables of the optimisation 47
3.5 Internal dimensions as per regulations 51
3.6 Unobstructed area of openings 51
3.7 The requirement tree of the model with the weights 57
3.8 Sustainability index values 58

4.1 Floor areas in three zone size categories 65
4.2 Discomfort hours for various orientations 68
4.3 Best orientations 69
4.4 Parametric analysis - first run results 72
4.5 Parametric analysis - second run results 74
4.6 Parametric analysis - third run results 76
4.7 Increase in acceptable operative temperature 82
4.8 Calculated acceptable operative temperature limits 83
4.9 Air velocities and fan power at different fan speeds 84
4.10 Number of hours in operative temperature categories 85
4.11 Hours in operative temperature categories in AC case 1 86
4.12 Hours in operative temperature categories in AC case 2 86
4.13 Hours in operative temperature categories in AC case 3 86
4.14 Hours in operative temperature categories in AC case 4 86
4.15 Hours in operative temperature categories in AC case 5 87
4.16 Hours in operative temperature categories in AC case 6 87
4.17 Energy consumption of optimum air conditioned cases 87
4.18 Distribution of the respondents 91
4.19 Parametric analysis of consumer survey: first run results 98
4.20 Parametric analysis of consumer survey: second run results 98
4.21 Electricity consumption of Sri Lankan households 99
4.22 Basic Information of the respondents 100
4.23 Basic information on PV installation 100

4.24 Installation related decisions 104
4.25 Sustainability index values for energy mix 108
4.26 Sustainability index values for energy generation scenarios 109
4.27 Percentage of scores received for the three factors 112
4.28 Percentage of scores received for the three factors 113
4.29 Values used for hypothetical scenarios 113

5.1 Hours in operative temperature categories in sample house 1 . . . 118
5.2 Total energy consumption in sample house 1 118
5.3 Hours in operative temperature categories in sample house 2 . . . 122
5.4 Total energy consumption in sample house 2 122
5.5 Sensitivity analysis 125

A.1 Monthly average temperatures in weather file 143
A.2 Monthly average temperatures in weather file 144

B.1 Required velocities to achieve acceptable comfort levels 145

C.1 Values used for hypothetical scenarios 147
C.2 Values used for hypothetical scenarios Cont.. 148
C.3 Values used for hypothetical scenarios Cont.. 149
C.4 Values used for hypothetical scenarios Cont.. 150
C.5 Values used for hypothetical scenarios Cont.. 151
C.6 Values used for hypothetical scenarios Cont.. 152

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BC_{rate}	Building Consumption Rate
CBA	Cost Benefit Analysis
ELECTRE	Elimination and Choice Translating Reality
ES_{rate}	Energy Source Rate
IRR	Internal Rate of Return
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LPD	Lighting Power Density
MAUT	Multi Attribute Utility Therory
MCDA	Multi Criteria Decision Aid
MIVES	Modelo Integrado de Valor para una Evaluacion Sostenible
NDCs	Nationally Determined Contributions
NPV	Net Present Value
OB_{rate}	Occupancy Behaviour Rate
PER	Primary Energy Ratio
PMV	Predicted Mean Vote
PPD	Predited Percentage Dissatisfied
PROMETHEE	Preference Ranking Organisation Method for Enrichment Evaluation

SDGs	Sustainable Development Goals
SI	Sustainablity Index
SOS	System Of Systems
TOPSIS	Technique for Order Preference by Similarity to Ideal Solutions
WWR	Window to Wall Ratio