THE POETICS AND PRAGMATICS IN GLENN MURCUTT’S HOUSES.

The Ball-Eastaway and Marika-Alderton house.

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ABSTRACT

Glenn Murcutt is nowadays recognized as a master and one of the most influential environmental architects of the century. His awareness, life experiences and deep analysis of the Australian landscape, climate and vernacular architecture, have led him to become one of leaders of critical regionalism in the world. Murcutt's work symbolises the equilibrium between the manmade and natural realm. Murcutt's designs aim to not only protect the inhabitant from the exterior elements (e.g. sunlight, rain and wind), but to lower the energy consumption; they are responsive, adaptable and more importantly, they continuously remind us the significance of nature.

Murcutt’s work has been well documented and published since 1985, when Philip Drew wrote Leaves of Iron.

Among Drew, other researchers (e.g. Fromonot, Pallasmaa and Beck and Cooper, among others) have extensively studied and described Glenn Murcutt's designs. Throughout these publications, the authors have grasped the essence of his work and fully described the theory behind his designs, nevertheless and surprisingly, his work has not received much academic attention.

The aim of this dissertation is to explore and critically review his design philosophy through an in-depth analysis on the performance, (both visually and spatially) of two of his built houses: the Ball-Eastaway house, in Glenorie, New South Wales and the Marika-Alderton house, in Eastern Arnhem Land, Northern Territory. It is intended to holistically fill the void in the knowledge gap of Glenn Murcutt's buildings, his contribution to architecture and its intricate relationship with the environment. To analyse these projects, sketches, drawings, photography and computer aided models and simulations were used as support and evidence to improve the understanding behind Murcutt's design intentions.

The findings of this study show how Murcutt's design philosophy has evolved throughout his career. His work praises the horizontality of the Australian landscape, while constantly recalling the past. His designs are based on a deep contextual and climatological analysis, yielding an architecture that specifically belongs to the Australian background. Through the use and refinement of elements and construction techniques derived from vernacular architecture, Murcutt skilfully orchestrates shapes, materials and the environmental conditions to produce responsive and delightful spaces, continuously allowing the inhabitant to manipulate the light, breeze, sounds and views according to their needs.

Murcutt’s work does not only represent the balance between man and nature, moreover his work epitomizes the equilibrium between poetics and pragmatics; between art and science.

Keywords: Glenn Murcutt, Australia, Critical regionalism, Comfort, Housing, Free-running buildings.
Table of Contents

ACKNOWLEDGMENTS .................................................................................................................. 2
ABSTRACT ..................................................................................................................................... 3
LIST OF FIGURES .......................................................................................................................... 6
LIST OF TABLES ............................................................................................................................. 8

1. INTRODUCTION ....................................................................................................................... 9
   1.1. Background: The spirituality of Glenn Murcutt’s work ......................................................... 9
   1.2. Research Objective .............................................................................................................. 10
   1.3. Research Questions ............................................................................................................ 11
   1.4. Significance of the Research ............................................................................................... 11
   1.5. Methodology ...................................................................................................................... 11

2. LITERATURE REVIEW ............................................................................................................ 14
   2.1. The poetics of daylight and space in modern housing ....................................................... 14
   2.2. Glenn Murcutt: Life and Architecture .............................................................................. 17
   2.2.1. Simplicity, Landscape and Climate: The Architecture of Glenn Murcutt ....................... 20
   2.2.2. Glenn Murcutt: A Journey through Houses ................................................................ 22
   2.3. Environmental design for modern housing .................................................................... 29
   2.3.1. Comfort requirements in Australia .............................................................................. 32

3. THE BALL-EASTWAY HOUSE ............................................................................................. 34
   3.1. Background ....................................................................................................................... 34
   3.2. Architectural promenade .................................................................................................. 37
   3.3. Microclimate analysis: Glenorie, NSW ............................................................................ 41
   3.4. Orientation, sun, wind and form: Rules of thumb design analysis .................................. 44
   3.5. Visual environment and daylighting performance analysis ............................................. 53
   3.5.1. Visual performance study under sunny sky conditions: Illuminance ......................... 56
   3.5.2. Visual comfort study: Luminance ratio study ............................................................. 58
   3.6. Thermal Environment ...................................................................................................... 61
   3.6.1. Thermal simulation and results .................................................................................... 62
   3.7. The Ball-Eastaway house: Summary .............................................................................. 67

4. THE MARIKA-ALDERTON HOUSE ....................................................................................... 68
   4.1. Background ....................................................................................................................... 68
   4.2. Architectural promenade .................................................................................................. 71
   4.3. Microclimate analysis: Eastern Arnhem Land, NT ............................................................ 75
   4.4. Orientation, sun, wind and form: Rules of thumb design analysis .................................. 78
   4.5. Visual environment and daylighting performance analysis ............................................. 87
   4.5.1. Visual performance study under sunny sky conditions: Illuminance ......................... 90
   4.5.2. Visual comfort study: Luminance ratio study ............................................................. 92
   4.6. Thermal Environment ...................................................................................................... 94
   4.6.1. Thermal simulation and results .................................................................................... 95
   4.7. The Marika-Alderton house: Summary ......................................................................... 99

5. COMPARATIVE ANALYSIS .................................................................................................... 101

6. CONCLUSIONS ....................................................................................................................... 106

7. LIMITATIONS AND FURTHER RESEARCH ...................................................................... 108

8. BIBLIOGRAPHY and references ............................................................................................ 109

9. APPENDIX ............................................................................................................................... 112
List of Acronyms

ABCB: Australian Building Codes Board

AIA: American Institute of Architects

ASHRAE: American Society of Heating, Refrigerating and Air Conditioning Engineers

BASIX: Building Sustainability Index

BCA: Building Code of Australia

BSI: British Standards Institution

BOM: Australian Bureau of Meteorology

CIBSE: Chartered Institution of Building Services Engineers

CLEAR: Comfort and Low Energy Architecture

DF: Daylight Factor

EDSL: Environmental Design Solutions Limited

EPFL: École Polytechnique Fédérale de Lausanne

HVAC: Heating, ventilation and air conditioning

NCC: National Code of Construction

NatHERS: The Nationwide House Energy Rating Scheme

NSW: New South Wales

NT: Northern Territory
List of Figures

Figure 1. Villa Savoye by Le Corbusier. Photography by: Jean-Christophe Ballot. Source: Giordano (2012) 16
Figure 2. Tugendhat House by Mies van der Rohe. Photography by: David Zidlicky. Source: The Guardian (2014) 16
Figure 3. Farnsworth House (Mies van der Rohe). Photography by: Prodan (2013) 18
Figure 4. Top: Author's sketch based on Murcutt's basic site analysis sketch. Bottom: Basic design principles: orientation, sunlight and prevailing wind access. Sketches by: Author. Source: Heath (2009). 20
Figure 6. Horizontality in the Australian landscape. Old Currango Hut, New South Wales. Photography by: Bonwell (2014) 22
Figure 7. Angophora costata: leaves and shadows. Photography by: McHugh (2013) 22
Figure 8. Angophora costata (Sydney Red Gum tree) shedding skin during spring. Photography by: Noosa (2014) 22
Figure 9. Glenn Murcutt: Location of key housing projects. Source: Author (2014) 23
Figure 10. Glenn Murcutt's timeline: Main projects. Illustrations: Author. Photography: As detailed 24
Figure 11. Glenn Murcutt's typological grouping of main projects: Mass tectonic vs. light-weighted 26
Figure 12. Architectural portrayal of selected projects to assess. Source: El Croquis (2012) 27
Figure 13. Minimum average daylight factor in dwellings. Source: BSI (2008) 30
Figure 14. Acceptable operative temperature ranges for naturally conditioned spaces. By ASHRAE (2004). 31
Figure 15. Australia's sixty-nine climate zones for housing design. Location of East Arnhem Land (NT) and Glenorie (NSW). Source: NatHERS (2014) 33
Figure 16. Left: Ball-Eastaway house, exterior view. Photography by: Max Dupain. Right: Conceptual sketch by Glenn Murcutt. Source: El Croquis (2013) 34
Figure 17. Left: Conceptual sketches showing the axial layout of the house. Right: Conceptual sketches showing initial studies of the house's form and connection with the site. Sketches by: Glenn Murcutt. 35
Figure 18. Ball-Eastaway section showing the relationship between the wide gutters and the configuration of the interior space of the house. Drawing by Glenn Murcutt. Source: El Croquis (2013) 35
Figure 19. Ball-Eastaway interior space and finishes. Photography by Anthony Browell. (El Croquis, 2013) 36
Figure 20. Ball-Eastaway 3D view. Detail of the 'feathering' in the edges of the verandah's floor. Source: Author (2014) 36
Figure 21. Ball-Eastaway exterior view (bridge, facade and main entrance). Photography by Anthony Browell. 37
Figure 22. Ball-Eastaway floor plan and spatial arrangement. Location of first view on the architectural promenade. Source: Author (2014) 37
Figure 23. Ball-Eastaway interior view from living space towards the gallery/corridor. Photography by Anthony Browell. Source: El Croquis (2013) 38
Figure 24. View of the northern verandah - a space for meditation and tranquillity. Photography by Reiner Bl unc. Source: EPFL (2005) 39
Figure 25. Interior view of the main living space. An open plan combines the kitchen, dining and living rooms, while offering direct contact with the exterior. Photography by Anthony Browell. Source: El Croquis (2013) 39
Figure 26. View from the living room towards the verandah, which fuses with the tree canopy and views. Photography by: Reiner Bl unc (2005). Source: Velux (2014) 40
Figure 27. Exterior view of the main verandah. The space is surrounded wholly by nature; the direction of both ceiling and flooring constantly points the viewer's gaze outwards. Photography by Anthony Browell. Source: El Croquis (2013) 40
Figure 28. Ball-Eastaway house: Location and coordinates. Source: Author (2014) 41
Figure 29. Monthly Diurnal Averages. Weather data for Richmond, NSW. Source: NatHERS (2014) 41
Figure 30. Total annual rainfall for New South Wales, Australia. Richmond, experiences a considerable annual rainfall, ranging between 900 mm to 1800 mm annually. Source: BOM (2014) 42
Figure 31. Annual sky conditions for Richmond, NSW. Left: Median cloud cover. Right: Cloud cover types. Source: Weatherspark (2014) 42
Figure 32. Wind frequency and direction for Richmond, NSW. Left: annual frequency. 43
Figure 33. Ball-Eastaway's orientation vs. Optimum orientation for Richmond, NSW. Source: NatHERS and Ecotect's weather tool (2014) 43
Figure 34. Floor plan and orientation. Source: Author (2014) 43
Figure 35. Solar access and spatial arrangement. Floor plan is over layered by the sun path diagram during summer solstice and winter solstice. Source: Author (2014) 45
Figure 36. Sun and space: solar access and shadow cut away sections during noon. Source: Author (2014) 47
Figure 37. Sun and space: solar access and shadow cut away sections at 4pm. Source: Author (2014) 48
Figure 38. Ball-Eastaway section and solar access at noon. Left: Summer solstice - Middle: Equinox - Right: Winter solstice. Source: Author (2014) 49
Figure 39. Ball-Eastaway section and solar access at noon during winter solstice. Source: Author (2014) 50
Figure 40. Ball-Eastaway section. Detail on the structure and building materials in the living space, no insulation protecting the flooring is included. Section by Glenn Murcutt. Source: El Croquis (2012) ................................................. 51
Figure 41. Rule of thumb calculation for cross-ventilation in the living space. Source: Author (2014) ................. 51
Figure 42. Rule of thumb calculation for single-sided ventilation in the bedrooms. The large area of glazed louvres and the spatial geometry will allow natural ventilation to cool down the spaces. Source: Author (2014) 52
Figure 43. Daylight factor plot, uniformity ratios and light journey in the Ball-Eastaway house. ......................... 53
Figure 44. Light journey’s views showing the spatial daylighting variation. Source: Author (2014) ................. 54
Figure 45. Daylighting section, showing the effect the building’s geometry has on the daylight distribution in the living space. Source: Author (2014) ........................................................................................................ 55
Figure 46. Illuminance mapping (using Radiance) of living space and bedroom under overcast and sunny sky conditions. Source: Author (2014) ........................................................................................................ 57
Figure 47. Visual range to establish the visual task (5’), immediate surroundings (30’) and far surroundings (60’). Diagram from author, based on image by Hopkinson (1966). ................................. 58
Figure 48. Brightness contrast study of living space and bedroom under sunny and overcast sky conditions. Source: Author (2014) ........................................................................................................ 59
Figure 49. Adaptive thermal comfort range for Richmond, NSW. Source: Author (2014) ................................. 60
Figure 50. Living space monthly percentage of hours in comfort zone vs. average monthly temperatures. .... 63
Figure 51. Living space seasonal thermal performance vs. average exterior and resultant temperatures. Source: Author (2014) ........................................................................................................ 64
Figure 52. Bedroom monthly percentage of hours in comfort zone vs. average monthly temperatures. Source: Author (2014) ........................................................................................................ 65
Figure 53. Bedrooms seasonal thermal performance vs. average exterior and resultant temperatures. Source: Author (2014) ........................................................................................................ 66
Figure 54. Exterior view – Southern facade - of the Marika-Alderton house. Photography by Reiner Blunck. Source: El Croquis (2012) ........................................................................................................ 68
Figure 55. Illustration of the New Guinea traditional longhouse. Unknown author. Source: Jane (2011) .... 69
Figure 56. Conceptual sketches showing the spatial and environmental relationship between the plan and section. Sketches by Glenn Murcutt. Source: El Croquis (2012). ................................. 69
Figure 57. Section of the Marika-Alderton house, showing the relationship between shape, materiality and a responsive envelope. Drawing by Glenn Murcutt. Source: El Croquis (2012) ................................................. 70
Figure 59. Exterior view of the house’s main entrance. Details on the slatted operable openings and tilting plywood panels which continually fuse the interior of the house with the landscape. Photography by Reiner Blunck. Source: El Croquis (2012) ........................................................................................................ 72
Figure 60. Interior views from the living space. A realm of steel and wood - the materialization of a balanced world between manmade and nature. Photography by Reiner Blunck. Source: El Croquis (2012) ........................................................................................................ 73
Figure 61. Interior view of the children's bedrooms. A floating bed, and operable slatted shutters continually frame nature. Photography by Reiner Blunck. Source: El Croquis (2012) ........................................................................................................ 74
Figure 62. Interior view from the master bedroom. Detail on the sitting area and operable openings which always link interior with exterior. Photography by Reiner Blunck. Source: El Croquis (2012) ........................................................................................................ 74
Figure 63. Marika-Alderton house: Location and coordinates. Source: Author (2014) ......................................... 75
Figure 64. Monthly Diurnal Averages. Weather data for Darwin, NT. Source: NathHERS (2014) ................. 75
Figure 65. Total annual rainfall for Northern Territory, Australia. Eastern Arnhem Land experiences a considerable annual rainfall, ranging between 1200 mm to 1800 mm annually. Source: BOM (2014) ........................................................................................................ 76
Figure 66. Annual sky conditions for Darwin, NT. Left: Median cloud cover. Right: Cloud cover types. ........................................................................................................ 76
Figure 67. Wind frequency and direction for Darwin, NT. Left: Annual frequency. Middle: Wet season prevailing wind frequencies. Right: Dry season prevailing wind. Diagrams by Weather Tool (ECOTECT). ........................................................................................................ 77
Figure 68. Marika-Alderton house orientation vs. Optimum orientation for Darwin, NT. Source: NathHERS and Ecotect's weather tool (2014) ........................................................................................................ 77
Figure 69. Floor plan and orientation. Source: Author (2014) ........................................................................................................ 78
Figure 70. Solar access and spatial arrangement. Floor plan is over layered by the sun path diagram during summer solstice and winter solstice. Source: Author (2014) ........................................................................................................ 79
Figure 71. Sun and space: solar access and shadow cut-away sections at 8 a.m. Source: Author (2014) .... 81
Figure 72. Sun and space: solar access and shadow cut-away sections at noon. Source: Author (2014) .... 82
Figure 73. Marika-Alderton section and solar access at noon. Left: Summer solstice - Right: Winter solstice. Source: Author (2014) ........................................................................................................ 83
Figure 74. Marika-Alderton section and solar access at noon during Winter solstice. Source: Author (2014) 84
Figure 75. Rule of thumb calculation for cross-ventilation in the living space. Natural ventilation is continually encouraged through the operable slatted openings, tilted plywood panels or flooring. Source: Author (2014) .... 85
Figure 76. Cross-ventilation and Venturi effect produced by Windworkers. Air movement is continually encouraged in order to decrease the interior temperatures. Source: Author (2014) ........................................................................................................ 85
Figure 77. Daylight factor plot, uniformity ratios and light journey in the Marika-Alderton house. Source: Author (2014) ........................................................................................................ 87
Figure 78. Light journey’s views showing the spatial daylighting variation. Source: Author (2014) ................. 88
Figure 79. Daylighting sections, showing the effect the building’s geometry has on the daylight distribution. 89
Figure 80. Illuminance mapping (using Radiance) of living space and bedrooms under overcast and sunny sky conditions. Source: Author (2014)................................................................. 91
Figure 81. Luminance mapping (using Radiance) of living space and bedrooms under overcast and sunny sky conditions. Source: Author (2014)........................................................................... 93
Figure 82. Monthly adaptive thermal comfortable range for Darwin, NT. Source: Author (2014)........................ 94
Figure 83. Living space monthly percentage of hours in comfort zone vs. average monthly temperatures...... 96
Figure 84. Living space seasonal thermal performance vs. average exterior and resultant temperatures...... 96
Figure 86. Bedrooms seasonal thermal performance vs. average exterior and resultant temperatures........... 98
Figure 85. Bedrooms monthly percentage of hours in comfort zone vs. average monthly temperatures........ 98
Figure 87. Architectural and spatial comparative analysis. Source: Author (2014) ........................................ 103
Figure 88. Daylighting performance and comfort comparative analysis. Source: Author (2014)................. 104
Figure 89. Ventilation and thermal performative comparative analysis. Source: Author (2014)............... 105

List of Tables

Table 1. Summary of thermal cases examined in Glenn Murcutt’s houses. Source: Author (2014).............. 13
Table 2. Recommended lighting design criteria by CIBSE (2006)............................................................ 32
Table 3. Recommended criteria for thermal comfort by CIBSE (2006)....................................................... 33
Table 4. Approximate reflectance of typical building finishes. Source: CIBSE (1994)............................... 53
Table 5. Monthly average temperature vs optimal temperature for comfort in Richmond, NSW. Source: Author (2014).............................................................................................................. 61
Table 6. Typical thermal properties of common building and insulating materials. Table by Author based on Appendix 1 by Kyle (1999)................................................................................... 62
Table 7. Ball-Eastaway description of thermal simulation cases. Source: Author (2014)......................... 62
Table 8. Summary of internal conditions and assumptions considered during thermal simulation. Source: Author (2014).............................................................................................................. 63
Table 9. Monthly average temperature vs optimal temperature for comfort in Darwin, NT. Source: Author (2014).............................................................................................................. 94
Table 10. Typical thermal properties of common building materials found in the Marika-Alderton house. Table by Author based on Appendix 1 by Kyle (1999).................................................. 95
Table 11. Marika-Alderton description of thermal simulation cases. Source: Author (2014).................... 95
Table 12. Summary of internal conditions and assumptions considered during thermal simulation. Source: Author (2014).............................................................................................................. 95

List of Equations

Equation 1: Optimal temperature for comfort by ASHRAE........................................................................ 13
1. INTRODUCTION

The central design issues are humans – their history and culture; space; light; how things are put together; and responsibly to the land [...]. Design is a chess game, and from rationalism and the aesthetic expression of building construction you can perhaps derive poetry.

Glenn Murcutt (Beck, Cooper and Murcutt, 2002, p.17)

1.1. Background: The spirituality of Glenn Murcutt’s work.

The aesthetical and philosophical influence that modernist architects such as, Le Corbusier, Mies and Aalto had on Murcutt’s work is undeniable. Each one’s attempts (whether environmentally successful or not), to develop and transform the significance of housing – as the essential space for human well-being during the first half of the twentieth century -, set the design principles that years later Murcutt will reinterpret in his work. The residential projects (e.g. Villa Savoye, Farnsworth House or Villa Mairea) designed by these masters represent a turning point in modern housing design.

Today, Le Corbusier’s (2008) famous phrase of designing houses as living ‘machines’ resonates in Murcutt’s own words and design philosophies; nevertheless, with another dye. Murcutt reinterpreted the form and materiality of modern architecture while trying to solve the environmental impact that these fully glazed, enclosed and machined conditioned buildings implied. Once Murcutt realised the environmental significance that shifting from this appalling model would bring to the environment, he unequivocally decided that all his designs would be free-running buildings.

It is essential to comprehend that Murcutt’s work is derived from a combination of factors, or experiences throughout his life. While the influence of modern architecture (with its strengths and weaknesses) is undeniable, three other aspects finally shaped Murcutt’s architectural language. The combination between Thoreau’s (2012) life principles, (i.e. of living an unpretentious life in permanent contact with nature, while shaping the perfect austere shelter) plus the profound observation of Australia’s vernacular architecture and most importantly, its landscape and climate, have shaped his architecture; one, that has established Murcutt’s status of ‘a living legend, an architect totally focused on shelter and the environment’, as Huxtable (as cited by The Hyatt Foundation, 2002) commented during the announcement of Murcutt’s Pritzker prize ceremony.

According to Farrelly (1993), Murcutt’s work is ‘inspirational and forbiddingly simple’, nevertheless, full of contradictions. For instance, Farrelly questions how Murcutt’s designs are considered universal, when they are developed site specifically? Or how, through his geometrical designs and building materials - which seemingly disassociate with nature -, his buildings become a natural fragment of the landscape? According to Murcutt (as cited in El Croquis, 2012), his work is far from contradictory, as it
is through the permanent confrontation between man and nature that his projects harmonize and merge within the Australian context.

Murcutt’s life has been a continuous confrontation between what society expects, and what his beliefs dictate. This same conflict, has yielded in a very successful singular architectural practice, focused primarily in housing design. Paradoxically, when he was awarded the Pritzker prize, to the surprise of many, Murcutt’s modest housing designs were the reason behind it. At this point Farrelly’s questionings echo more strongly; what is the significance of Glenn Murcutt’s work? And even more importantly, how has Murcutt transformed the unpretentious concept of a house, into a spiritual haven?

It is in Murcutt’s profound observation of nature and his craftsmanship, in which clues to his responsive architecture are found. Every element designed plays an important role in this orchestra-like architecture. His buildings are designed to allow the inhabitants to easily adapt their spaces, while adjusting the daylighting, ventilation and connection with the exterior.

His projects are praised by their weightlessness, large operable openings, deep overhangs and verandahs, which in addition to permeable skins, natural ventilation and daylighting is controlled; moreover, his work is celebrated for being responsive to climate, culture and history.

Throughout his career, Murcutt’s work has been extensively published, nevertheless it has not received enough academic attention, so this study aims to explore and grasp the poetics and pragmatics implicit in Glenn Murcutt’s timeless, honest and inspiring simple architecture.

1.2. Research Objective

The main focus of this study is to holistically fill the gap in the existing knowledge in Murcutt’s work. As mentioned, although there are various publications which have described in detail his oeuvre, there is a fundamental insufficiency of critical analysis in the performative aspect of his buildings.

Through this investigation, not only will the architect’s design philosophies be analysed, but more importantly, their effect on the visual and thermal environments of his houses. Specifically, the study will focus on the environmental and atmospheric qualities of two of Murcutt’s most celebrated projects, the Ball-Eastaway house (in NSW) and the Marika-Alderton house, located in NT. The main idea is to compare not only their overall performance, but to grasp their design similarities and differences and how they respond to the context. Both houses are not only found in two very distant settings, but more importantly, each one is found within a particular climate zone in Australia, allowing a profound analysis of how Murcutt’s design philosophies respond to different conditions.

It is crucial to consider that this investigation intends to wholly assess the intricate relationship between the house’s spatial quality, materiality and environmental design strategies, in order to provide evidence on their performance and comfort levels conveyed.
1.3. Research Questions

Besides the main objective described previously, this investigation will focus on the following enquiries, which will be used as a guide for the analysis of both projects:

- How light and space design influences the spatial and environmental delight in Glenn Murcutt’s houses?
- Are the key living spaces (i.e. bedrooms and living rooms) as designed, capable of performing and yielding a comfortable atmosphere and thermal delight?

1.4. Significance of the Research

Glenn Murcutt’s work has received most of the prestigious awards in the architectural sphere, evidencing the importance and influence of his oeuvre for contemporary architecture. Murcutt has been awarded with the Australian Institute of Architects Gold Medal, the Alvar Aalto Medal, the Pritzker Architecture Prize (2002) and finally the AIA Gold Medal.

Despite the significance these awards infer on Murcutt’s work, the insufficiency of critical analysis and factual evidence available, as Farrelly (2002) demands, is necessary to further support his reputation.

The importance of this research to the field is very important as through new knowledge and evidence, Murcutt’s work will be analysed yielding in a more accurate and critical perception of his work, and more importantly, how his buildings perform as designed. Additionally, this study expects to increase the interest in Murcutt’s work for further research; not in vain, Murcutt is considered an ‘innovative architectural technician who is capable of turning his sensitivity to the environment and to locality into forthright, totally honest, non-showy works of art’, as recognised by Brown (as cited by The Hyatt Foundation, 2002).

1.5. Methodology

In order to accomplish the previously mentioned objectives and to have accurate results, the following methodology was adopted throughout the study:

As the investigation seeks to have a complete understanding of Murcutt’s design philosophies, and their impact on the energetic performance and comfort provided by the Ball-Eastaway and Marika-Alderton houses, a detailed literature review was the initial phase. This opening stage included information regarding the evolution of the intricate relationship between light and space (with a particular focus on early housing design and its significance), and how throughout history, one has sculpted the other; additionally, this phase included an extensive study on Murcutt’s work in order to understand how his life experiences have influenced his design philosophies. It is important to emphasize that during
this stage, his extensive work was analysed and categorized in order to explain the selection of the projects assessed (See Section 2.5).

Additionally, an attentive review on daylighting and thermal comfort considered in order to have a better understanding on how one affects the other, and how through careful design, both can produce delightful and comfortable spaces. Basic recommendations provided by specialized organizations (e.g. CIBSE, BSI and ASHRAE) were considered to appropriately assess the visual and thermal environments of Murcutt’s houses.

The following step was the qualitative analysis of both houses; the history behind them was considered, in search of Murcutt’s design intentions, as well as to understand the initial environmental strategies pursued. An analysis of the spaces and their relationship with orientation, programme and climate was performed; additionally, an architectural promenade supported by images provided a better depiction of the spatial qualities, proportions and materials selected by Murcutt. Once this initial analysis was completed, 3D models were built to complete further daylighting and thermal studies.

As Murcutt’s architecture is intended to respond entirely to the site-specific climate, a detailed microclimate analysis was done in Darwin, NT and Richmond, NSW (as the closest points to the original locations) based on the weather data from NatHERS. Through this analysis, the relationship between Murcutt’s architecture and the sun, wind and rain becomes clearer, improving the basic understanding of Murcutt’s buildings and how they respond to climate as free-running buildings.

In terms of quantitative analysis, both projects were simulated in Autodesk’s Ecotect and EDSL TAS, allowing further analysis on the luminous and thermal environments. Through these analyses, a more complete perspective on the energetic performance and comfort levels achieved by each can be assessed and critically studied.

In Autodesk’s Ecotect, based on NatHERS’ weather data and RADIANCE output, daylighting simulations were performed under overcast and sunny skies conditions to have a general understanding of the visual performance and comfort provided annually. In more detail, daylight distribution was investigated considering the daylight factor under overcast skies as the worst case scenario; following, the illuminance and luminance levels were studied under both sky conditions during summer solstice (21st December), equinox (22nd March) and winter solstice (21st June) at noon to have a broader perspective of the building’s daylighting conditions. Additionally, uniformity ratios and brightness-contrast studies were performed; all results were analysed and compared against the recommended daylighting guidelines by CIBSE (1994).

To analyse the thermal performance, both houses were simulated using EDSL TAS, considering their different building materials. Accordingly to their site-specific climates, three simulation cases (Table 1) were established to test the resultant temperatures in the interior spaces, allowing a general understanding of the monthly and seasonal performances of the buildings as designed.
Table 1. Summary of thermal cases examined in Glenn Murcutt’s houses. Source: Author (2014)

<table>
<thead>
<tr>
<th>Cases</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal conditions</td>
<td>Presence (Yes / No)</td>
<td>Presence (Yes / No)</td>
<td>Presence (Yes / No)</td>
</tr>
<tr>
<td>Ball-Eastaway house</td>
<td>Infiltration rate</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Internal heat gains</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Chimney heat gains</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Natural ventilation</td>
<td>NO</td>
<td>YES* (30%)</td>
</tr>
<tr>
<td>Marika-Alderton house</td>
<td>Infiltration rate</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Internal heat gains</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Natural ventilation</td>
<td>YES (Partial)</td>
<td>YES (Partial)</td>
</tr>
</tbody>
</table>

* Natural ventilation in the Ball-Eastaway house was simulated throughout the year, except during winter.

In order to have consistent outcomes from simulations, particular assumptions were considered depending on their site-specific climate necessities as well as, their form and materiality. Nevertheless, all internal heat gains are applied during the occupancy schedules and no other heat gains are included, nor is any mechanical ventilation, cooling or heating included.

Once all the output from these simulations was analysed, the objective was to determine the percentage of hours - both monthly and annually - that resultant interior temperatures in living spaces and bedrooms remained within the comfort zone.

In order to define a comfort zone for each building, all monthly average temperatures were used as a base to calculate the optimal temperature for comfort (i.e. $T_{comf}$) in Richmond, NSW and Darwin, NT based on the Adaptive Model by Nicol, Humphreys and Roaf (2012). To set an acceptable comfortable range for naturally conditioned, the following ASHRAE equation was applied:

\[ T_{comf} = 0,31T_o + 17,8 \]

Where:

- $T_{comf}$ = is the optimal temperature for comfort
- $T_o$ = is the mean outdoor temperature

To the each month’s $T_{comf}$, a ±2 °C was applied in order to expand the comfortable thermal range for each month, resulting into broader acceptable upper and lower limit bands. Once the simulated data was analysed, the results were compared against the adaptive comfort zones in order to establish the performance of each house.

Lastly, once all the qualitative and quantitative results were obtained for both houses, a comparative analysis between them established any similarities and differences in terms of the design principles and environmental strategies applied by Glenn Murcutt in his work, and their impact on the designs. Based on this comparison, key findings and conclusions of the study were summarized in the last section.
2. **LITERATURE REVIEW**

2.1. The poetics of daylight and space in modern housing.

> ‘Space can no longer be understood apart from time, and that reality includes a fourth dimension, a temporal one in which light and time are one and the same.’ Plummer (2012)

Light and space have an intertwined relationship recorded since ancient times. In Vitruvius (2003) treatise of architecture - *De Architectura* -, he reminds us how through the discovery of fire, as a source of light and warmth, the origin of dwellings is found. Once fire was discovered, ancient men gathered around it, realizing the benefits - physical and psychological - that fire conveyed. This process generated the creation of primitive shelters, as spaces for sharing and protecting themselves from the sun, rain and winds.

In accordance to Vitruvius (2003), all buildings should be designed and built under the premises of *firmitas, utilitas* and *venustas*. *Firmitas* refers to the strength, quality and durability of the structure on which any building is raised; *utilitas* refers to the usefulness and ability of a space to fulfil its purpose, while *venustas*, denotes the aesthetical qualities of spaces in order to delight and raise people’s spirits.

Whereas *firmitas* and *utilitas* have a practical nature, *venustas* has a poetic essence, as it not only refers to the aesthetic qualities of a building, but it also comprises the intangible qualities which allows a building to trigger emotional reactions on the observer.

Throughout human history, daylight has been associated with life, truth, wisdom and more importantly divine presence. As both Hyatt (2007) and Plumber (2012) coincide, the most significant spaces dealing with daylight are religious and ceremonial buildings, as they are designed to welcome light and transform the spatial atmosphere and human experience into a sacred one. It is through a careful design (considering scale, proportion, materiality, openings and correct treatment of chiaroscuro), that these buildings convey a dramatic, mysterious or calm atmospheres, inducing an emotional response to light.

In architecture, daylight has always been considered an essential aspect of design regardless of the style; nevertheless, initially the restrained development of new building techniques and materials available – mostly stone, wood and glass -, represented a constraint on the opening sizes and interior illumination. The industrialization period (during the late eighteenth and mid-nineteenth centuries), carried technological changes, (i.e. development of new building materials such as iron and steel) that greatly reduced these constraints. As Baker and Steemers (2002) describe, the ‘striking’ impact that iron structures had on the loadbearing of traditional walls, allowed designers to increase the opening sizes, resulting on an increase in transparency and therefore luminosity.
The technological leap which led to the development of electric lighting and air conditioning (early twentieth century), was supposed to liberate buildings from climate, through controlled environments. With the extended use of steel and glass, some Modern architects (e.g. Gropius and Mies) designed fully glazed and enclosed buildings with the intention of providing higher levels of daylight. Paradoxically, the results obtained were diametrically opposed to those expected, as these ‘glass cages’ as Wright called them, suffered from ‘increased glare, excessive solar gains and heat loses, and a lack of privacy’, as Baker and Steemers (2002) explain, triggering not only the energetic consumption of buildings, but also, the loss of the intangible force of arousing emotions in architecture.

With the beginning of the twentieth century, the environmental concern was growing and modern architecture turned its gaze to its origins (i.e. nature and climate), as a way of integrating daylight and space with the neglected exterior world. Natural light prevailed once again and modern masters, (e.g. Wright, Le Corbusier, Asplund and Aalto) became increasingly interested not only in the visual effects that daylight would convey to sculpture spaces, furthermore, they pursued to return the emotional qualities and connection lost with nature. The significance of daylight in design can be comprehended in Le Corbusier’s words, ‘architecture is the masterly, correct and magnificent play of volumes brought together in light….I compose with light….Light is the key to well-being’, as cited by Plummer (2013).

Given the importance that daylight had during the first half of the twentieth-century, it would be expected to easily find significant information on the impact of daylight on housing; nevertheless, most of the work available refers to the predominant spaces (i.e. religious buildings, libraries or museums) designed by these masters of light. It is crucial at this point to consider Hyatt’s (2007) debate on the idea that despite housing representing the most intimate and appealing design opportunity for architects, often both the task and its relationship with daylight are undervalued. This argument is made unmistakeable when Hyatt questions why, if the positive effects that correct daylighting has proven on the health of employees in offices, they have not been applied with the same thoroughness in housing design?

Le Corbusier’s and van der Rohe’s work was fundamental to innovate the relationship between light, space and environment in modern housing. In Villa Savoye (1929), as shown in Figure 2, Le Corbusier intended to design the house as a ‘machine for living’ (Le Corbusier, 2008), based on the experience of movement, yet its orientation and sun’s path yielded in a free open plan, that through ribbon windows and pilotis maintained a continuous relation between interior and exterior, making it possible for the house to have an appropriate luminous environment. On the other hand, in the Tugendhat House (1930) shown in Figure 3, Mies also carefully studied the context, and similarly as Le Corbusier, the orientation and sun’s path shaped a house whose main spaces were designed to open and face the sun, while adapting visually and physically to the existing slope. Despite the lavish design (due to the expensive
building materials and techniques), Mies proficiently designed an extraordinary heating and cooling system to respond to climate, making the house not only aesthetically appealing, but comfortable.

Both Villa Savoye and the Tugendhat House, represent a prominent leap forward for modern housing, as they not only reinvented the aesthetics of traditional housing, but through daylight, Le Corbusier and Mies skilfully sculpted these houses, offering spaces orchestrated by movement, colour and poetics, while remaining functional. It is important to note that despite Mies’ shortcomings regarding the environmental design approach, as Hawkes (2008) stresses, Mies believed that ‘we should strive to bring nature, houses, and people together into a higher unity.’

Figure 1. Villa Savoye by Le Corbusier. Photography by: Jean-Christophe Ballot. Source: Giordano (2012)

Figure 2. Tugendhat House by Mies van der Rohe. Photography by: David Zidlicky. Source: The Guardian (2014)
2.2. Glenn Murcutt: Life and Architecture

Endeavouring to comprehend Murcutt’s work unquestionably implies understanding the man behind the architect, and how his life experiences have greatly influenced his work. Murcutt was born in London in 1936, but raised in an isolated zone within the untamed New Guinea and the Murcutt family recognised the constant threats that living in an isolated place - in contact with aborigines and nature - conveyed, while also experiencing the beauty and freedom that this wild environment carried. Undoubtedly, his childhood years in New Guinea taught Murcutt that surviving meant observing and learning from the environment, but furthermore importantly, adapting and working alongside with it.

Arguably, and as Drew (1992) suggests, it was in New Guinea where Murcutt had his first contact with the ‘primitive hut’ (or the New Guinea longhouse), which accordingly to Drew, it is one of Murcutt’s most influential stimuli; it is in this image – of the aboriginal shelter -, were the allegory between their primitive form and materiality (i.e. bark), was translated by Murcutt into the use of corrugated iron; interestingly enough, Murcutt disproves these ideas as Godsell recalls Murcutt words, (as cited in Levene et al. 2012) assuring that ‘there was not a single longhouse in my childhood.’

Nevertheless, and as Pallasmaa believes (as cited in Levene et al. 2012), Murcutt's childhood in New Guinea certainly shaped his character, sensibilities and interests. Moreover, he believes that the experiences lived there gave rise to his ‘independence, self-assurance and inventiveness’.

As most of the studies on Murcutt's life assert, nature was not Murcutt's only continuous influence; Arthur Murcutt (his father) was his sturdiest one. According to Drew (1992), Arthur Murcutt, raised his children in an strict and unconventional way, pursuing to instil the values of work ethics and resolving problems on their own, while remaining humble and always doing ‘ordinary things, extraordinarily well’, as cited in Fromonot (2003). Additionally, Farrelly (2002) amply describes Arthur Murcutt as a ‘philosopher, inventor, timber-miller, naturalist, disciplinarian…and tireless designer and builder of houses’.

One of Arthur’s Murcutt most significant influences on his family was undoubtedly in the rational way of living and thinking. According to Godsell (Levene et al. 2012), ‘finding [the] lowest common denominator’ helps him strive for simplicity, allowing to discover and reveal the essential. This strive for simplicity lies in Arthur’s Murcutt profound faith in the doctrines of Thoreau. As Farrelly (2002) assures, a ‘profound osmotic influence’ of Thoreau’s philosophy grew within the family; their way of living and thinking was profoundly based on his beliefs, Thoreau (as Farrelly explains) believed that ‘individual conscience was a higher authority than law…and that the practice of economy and simplicity, in life as much as in aesthetic endeavours, was almost a moral duty’.
Arthur Murcutt not only designed his own houses, but he built them. Career-wise and since childhood, Glenn Murcutt was exposed to his father’s fascination in architecture, and particularly in van der Rohe’s, Farnsworth House (Figure 3). The effect modern architecture would have in Murcutt’s work became materialized once Murcutt started his practice, and as Drew (1992) proposes, Murcutt adopted the architectural language of the modern glass pavilion, (i.e. its elongated form, the use of stilts to separate the building off the ground, its open plan and glazed openings), and superimposed it with the vernacular language of the aboriginal hut. This blend according to Drew (1992), would later be the base to Murcutt’s ‘long-roofed hut type’ houses.

During his first years in practice, as Fromonot (2003) observes, van der Rohe’s influence in Murcutt’s work was undeniable, nevertheless as a foreign language, didn’t respond to the Australian context. When Murcutt realized this, he shifted his gaze towards Australian vernacular architecture and indigenous life in search of answers. Additionally, and as Drew (1992) emphasizes, Murcutt had the opportunity to travel around the world, and during these journeys he observed and became deeply stimulated by the simplicity of Greek vernacular architecture and how spaces were chiselled through light, topography, colour and texture in order to create what he considered a spiritual atmosphere.

Throughout these journeys, Murcutt was profoundly impacted by Aalto’s work; the permanent connection between Aalto’s spaces with the Finnish landscape, as well as his skilful use of daylight to sculpt and dramatize spaces captivated and inspired Murcutt. According to Drew (1992), ‘Aaltos’ work suggested to Murcutt the importance of letting the Australian landscape to contribute to the definition of ‘an Australian form’.

Figure 3. Farnsworth House (Mies van der Rohe). Photography by: Prodan (2013)
Many of the assertions recognised in Murcutt's publications, identify him as the *true* Australian architect, nevertheless Murcutt claims that he has ‘never set to produce this – as it will result in a *cliché*’, as cited by Godsell (Levene et al. 2012). According to Godsell, Murcutt assures that the deep observance of the Australian landscape, its climate and the close relationship between them and aboriginal lifestyle, have firmly anchored Murcutt’s work to the Australian collective memory and cultural identity, ‘making [Murcutt’s work] part of the place’.

In relation to Godsell’s observation, Beck et al. (2002) coincide on the nature of Murcutt’s work, reassuring that his buildings grow from the land and offer ‘view to contemplate, breezes to refresh, angles to welcome or block the sunlight when needed the most’. Additionally, an emphasis on how Murcutt’s spaces are humanized and designed not only to be aesthetically pleasant, or to enhance the relationship between man and nature, but as Heath (2009) notes, Murcutt's work is ‘designed so it can literally be tuned like an instrument to respond to seasonal cycles […] it is choreographed to interpret the most beneficial characteristics of the natural environment.’ This metaphor is accentuated by Murcutt, as Godsell (Levene et al. 2012) explains, ‘to Murcutt, his buildings are like ‘static’ musical instruments, that once in contact with wind, sun, water and flora – they become alive, they become an orchestra of nature.’

The nature of Glenn Murcutt’s life is that of contemplation, silence and deep connection with the landscape. Through nature, Murcutt is able to transform his life experiences and deepest beliefs, into fascinating spaces that can be appreciated as living machines, merging and translating Le Corbusier’s and Thoreau’s ideals of the perfect house into his own.

According to Pallasmaa (as cited in Levene et al. 2012), Murcutt’s work is born from the distinctiveness of each place. Additionally, Pallasmaa concludes that Murcutt's buildings ‘possess an indisputable prestige and beauty of causality and reason. His houses are instruments for inhabiting the landscape and the elements.’

When most of Murcutt’s publications are analyzed, there seems to be a common linearity of concepts and opinions towards his work. This section has shown that Glenn Murcutt - the man and the architect - are inherently intertwined; by understanding his life, we are able to understand his work, and when both are analysed, his celebrated phrase of touching ‘this Earth lightly’ regains deeper sense.

Finally, it is important to underline that while all studies have the same appreciation and value towards the significance of Glenn Murcutt’s work (as a pioneer of environmental design), only Farrelly (2002) seems to question why despite Murcutt been considered Australia’s most celebrated architect, ‘surprisingly little [of what] has been written about him…attempts any serious analysis.’

Through Murcutt's work and life philosophies, it is clear that his work is more than inspirational and transcendental, as it revitalizes the importance of vernacular architecture, through simple, yet honest solutions which decrease energy consumption and enhance the environment.
2.2.1. Simplicity, Landscape and Climate: The Architecture of Glenn Murcutt.

As perceived in the previous section, Murcutt’s practice is very distinctive from others. He decided to work alone and to only develop his work within Australia, as the only place where he masters its climate and landscape. Only within the Australian continent - as Pallasmaa stresses (as cited in Levene et al. 2012), does Murcutt feels confident enough to work, allowing him to personally control every detail throughout the design and building stages. This work method has produced several design principles which he has skilfully repeated and readapted to his designs.

Among these principles, orientation (commonly due north) can be considered essential, as it defines the access to sunlight and prevailing winds. Additionally, Murcutt closely studies the site’s geomorphology and views in order to make a confident decision of where to set the building. (Figure 4).

![Diagram](image.png)

Figure 4. Top: Author’s sketch based on Murcutt’s basic site analysis sketch. Bottom: Basic design principles: orientation, sunlight and prevailing wind access. Sketches by: Author. Source: Heath (2009).
Murcutt studies solar angles and rainfall to determine the roofing’s shape and dimensions; he favours to design slim spaces with a standard height (typically 2.10 m) and permeable, lightweight skins to facilitate natural ventilation. In his designs, vernacular elements such as: verandahs, clerestory windows, glazing louvres and blinds are included to enhance the inhabitant’s experience, allowing them to regulate the internal space accordingly to their needs.

Many of these principles seem to be adopted and reinterpreted from Australian vernacular architecture, aboriginal shelters (Figure 5) and the modern glass pavilion. The metaphoric resemblance of his buildings - in terms of form, function and materiality -, to these archetypes seem to have a common root. These design principles are vital not only for aesthetic reasons, but more importantly, for their significance towards designing spaces which not only protect and enhance the quality of life of its occupants, but decrease their environmental impact.

Despite the significance on the plan for Murcutt, and as Pallasmaa argues (as cited in Levene et al. 2012), ‘Murcutt’s architecture is primarily an architecture of the section’. It is through the section that Murcutt is able to fully analyse and comprehend the design implications of the sun’s path, prevailing wind direction, views, and topography; in Murcutt’s sections, key elements such as the roofs are shaped and therefore their typology (i.e. symmetrical, asymmetrical or single pitched).

During the design process, and as Farrelly (2002) indicates, it is important to notice that in Murcutt’s work, simple geometry and material of his buildings intentionally ‘dissociate themselves from the natural world’. But it is through this confrontation (of natural space vs. manmade) that Murcutt creates an essential and deliberate harmony, not through ‘sameness, but through disparateness’, as Godsell (as cited in Levene et al. 2012) echoes Murcutt’s own words; nature and manmade space are one.
2.2.2. Glenn Murcutt: A Journey through Houses.

Murcutt’s work is comprised mainly by small, modest, yet impressively detailed houses. As previously mentioned, Murcutt is an environmentalist and draws inspiration from observing the vast Australian landscape; he, seeks to design and built spaces ‘to serve human ends’ (Beck, Cooper and Murcutt, 2002), while minimizing the inexorable consequences that human occupation has on the environment. As mentioned earlier, Murcutt designs and builds only within Australia; it is here where his pragmatic mind translates, as Drew (1985) mentions, the poetry and sacredness of the Australian landscape (Figure 9) - and specially its native trees (Figures 10 and 11) -, into spaces that just like them, provide shelter and shade, while varying their skins according to the climate.

Figure 6. Horizontality in the Australian landscape. Old Currango Hut, New South Wales. Photography by: Boniwell (2014)

Figure 7. Angophora costata: leaves and shadows. Photography by: McHugh (2013)

Figure 8. Angophora costata (Sydney Red Gum tree) shedding skin during spring. Photography by: Noosa (2014)
When some of his most celebrated housing projects are positioned within Australia's map (Figure 9), there seems to be a strong connection between his home state (i.e. NSW) and the development of his career.

In order to emphasize the importance and evolution of the section in Glenn Murcutt’s work, the following timeline (Figure 10) will position the projects described in Figure 9 in time, starting from his early ‘Miesian’ styled houses, to his most recent projects, known to belong into the ‘Critical Regionalist’ style by Heath (2009). It is fundamental to understand that a key aspect of a Murcutt house is that it evolved from pure – and not functional – modernism, into a geometry that grows from the land as Drew (1985) states, while responding to the sun, winds, rain and above all, the breath-taking Australian landscape.
GLENN MURCUTT:
Houses timeline

Mosman, Sydney

Belrose, Sydney

Laurie Short House (1972 – 1973)
Terry Hills, Sydney

Greenfell, Sydney

Marie Short House* (1972-1974)
Kempsey, New South Wales

Ockens House (1977-1978)
Sydney, New South Wales

Ball-Eastaway House (1980)
Sydney, New South Wales

Fredericks House (1981)
Jamberoo (NSW)

Magney House (1982)
Bringie Bringie (NSW)

Figure 10. Glenn Murcutt’s timeline: Main projects. Illustrations: Author. Photography: As detailed.
Source: Author (2014)
GLENN MURCUTT: Houses timeline

Magney House (1986 - 1990)
Sydney (NSW)

Done House (1988 - 1999)
Sydney (NSW)

Meagher House (1988 - 1992)
Bowral (NSW)

Mount Wilson (NSW)

Eastern Arnhem Land
(Northern Territory)

Kangaroo Valley House (2003 - 2005)
Kangaroo Valley (NSW)

House in Mount Wilson (2005 - 2008)
Blue Mountains (NSW)

Figure 10 continues. Glenn Murcutt's timeline: Main projects. Illustrations: Author. Photography: As detailed.

Source: Author (2014)
GLENN MURCUTT: Typological grouping

- Mass tectonic architecture in Glenn Murcutt’s portfolio is not very common. Most of his most praised and consummate works are praised due to their lightness; therefore, this study will focus on the light weighted projects, in order to assess the quality of light, shadow, materiality and space in them.

SELECTED PROJECTS

ON THE GROUND

- Armstrong House
- Magney House
- Meagher House
- Kangaroo Valley House

OFF THE GROUND

- Ball-Eastaway House
- Fredericks House
- Simpson-Lee House
- Manka-Alderton House
- House in Mount Wilson

Figure 11. Glenn Murcutt’s typological grouping of main projects: Mass tectonic vs. light-weighted

Source: Author (2014)
Figure 12. Architectural portrayal of selected projects to assess. Source: El Croquis (2012)
When Murcutt’s sections are analysed, the roofing and openings typologies evidently stand out. It’s necessary to stress that as Figures 10 to 12 reveal, Murcutt initiated his career designing flat-roofed houses (e.g. Laurie Short house), referring to the strong influence that modern architecture had on him. Nevertheless, once Murcutt realized the issues linked to heavy rainfall and sunlight, he realized the modern house will not perform or yield comfortable spaces.

The section helps Murcutt to overlay the climate’s elements with geometry, in order to understand how one would affect the other. Sun angles, prevailing winds, views and natural features became his designing tools. Murcutt’s designs are mainly symmetrical or asymmetrical, mostly light-weighted and raised off the ground, or heavy-weighted and on the ground; to Murcutt each design is unique, and as such will respond entirely different depending on its location.

Mucutt’s work is mainly praised for its light-weightiness and environmental responsibility. He designs layered free-running buildings which respond to the climate passively without requiring additional energy.

The selected projects offered a unique opportunity to study how Murcutt’s design principles were applied to buildings with the same typology, (i.e. light-weight, off the ground and symmetrical) nonetheless located in very different climate zones. As Figure 12 shows, both formally and conceptually, these houses were designed considering specific needs, and as such should perform and respond in different ways, yet always allowing the inhabitant to control their environments, and therefore their comfort.
2.3. Environmental design for modern housing.

‘The significant environmental propositions in architecture rest upon acts of imagination in which technics are brought to bear in the service of poetic ends.’ Hawkes (2008)

As shown in the previous section, the environmental problematic caused by architecture occurred when the relationship between space and environment was neglected. Despite what Hawkes (2008) refers to as the ‘environmental imagination’, the design strategies and technologies shaped by innovators like Le Corbusier, Aalto or Kahn (to decrease the reliance of buildings on electricity for lighting, heating and cooling) although remarkable, seem to have been overlooked for most of the second half of the twentieth century.

The significant environmental impact that the built environment has generated in the last four decades, as Glasson et al. (2012) assert, has remarkably increased the interest in environmental matters including design. As both Hawkes (2008) and Kopec et al. (2012) concur, the fundamental element which will improve not only the energetic performance of buildings, but their ambiance, lies in understanding the science behind climatic conditions, and how these can impact design. Evidence based design is nowadays essential in order for the designer to make informed choices; by providing scientific evidence a design can be justified.

Daylighting will vary according to location, therefore taking into the account the latitude and longitude of the site will make it possible to study in depth the relationship between the site’s context and the sun’s path. Additionally, daylight will vary accordingly to the space’s function, as well as its form, openings, interior finishes and furniture; taking this into account and as Hyatt (2007) questions, what does it mean to design a well-lit space?

Accordingly to Bossley (cited in Hyatt 2007), a well-lit space is one which is designed to balance between ‘summer’s shading and winter’s welcoming of daylight and heat gains’, furthermore he stresses that the significance of daylighting is been present at the right time and place. To this argument it is necessary to correlate that correct daylighting will not only translate to a reduction in energy consumption, but as Lippmann (cited in Hyatt 2007) concludes, through correct access to daylight - and therefore an intimate link between interior and exterior -, the spaces’ atmospheres will be exalted, carrying not only benefits for our daily activities, but conveying vital benefits to our body and mind.

When scrutinising the basic daylight requirements for households, due to the fact that normally no specialized tasks are performed within a household, it has to be clarified that lighting has to satisfy three basic human needs such as, visual comfort, visual performance and safety. According to BSI (2008) and Raynham et al. (2012), the following principles should be achieved in order to attain well-lit spaces:
• Average daylight factor: Ensuring that spaces are well-lit and will not depend on supplementary artificial lighting; the average daylight value should be between two and five percent. (Figure 13)

Figure 13. Minimum average daylight factor in dwellings. Source: BSI (2008)

• Uniformity ratio: In order to achieve a correct distribution of reflected interior lighting, the required ratio varies between 0.4 and 0.8 (the ratio of minimum to average illumination), being 0.8 for critical tasks, and 0.4 adequate for circulation areas.

• Luminance ratio study: In order to provide visual comfort, glare (high contrast) between the task and its immediate and general surroundings should be in the ratio of 10:3:1, according to CIBSE (1994). Inside a room, glare can be controlled by the use of blinds, curtains, shading devices or varying the reflectance of materials.

• Reflectance of materials. To create a balanced distribution of light within a space, the luminance of surfaces will be determined by the illuminance and reflectance of the surface. The recommended reflectance of interior surfaces according to Raynham et al. (2012) are:
  o Ceiling: 0.7 to 0.9;
  o Walls: 0.5. to 0.8;
  o Floor: 0.2 to 0.4
  o Furniture and machinery: 0.2 to 0.7

However important are the poetics inherent in daylight, an equally significant aspect is the warmth transmitted through light. Light is energy, and once it falls on a surface it will be transformed into heat, therefore, daylight is not only related to the visual experience and comfort within a space, but to its thermal qualities and effects. As Hyatt (2007) assured, ‘in the well-designed house the correct play of light warms a space when required and can be mediated to permit illumination with minimal heat gain’.

According to ASHRAE (2004), thermal comfort can be described as the ‘condition of mind which expresses satisfaction with the thermal environment’. Nevertheless, due to uncontrollable climatic factors (e.g. air temperature, relative humidity and air speed) as well as, varying environmental elements (amongst people) such as clothing, activity and the subjectivity of what might be considered warm or cold, makes thermal comfort very difficult to be attained for every person within a space.

Studying thermal performance within a space is not only related to health and air quality; as Parsons (2003) suggests, thermal conditions within a space will have a direct impact on the comfort of occupants, leading to a significant effect in the ‘person’s mood and behaviour.’
When analysing thermal comfort, it is essential to consider the six primary factors (i.e. metabolic rate, clothing insulation, air temperature, radiant temperature, air speed and humidity), which will affect the perception of thermal comfort within a space; also it is important to stress the variations that seasonal changes will infer on people’s needs, both physiological as psychological. Considering the subjectivity around achieving thermal comfort, how an acceptable thermal condition be determined?

In order to target an acceptable thermal condition for naturally conditioned spaces, Figure 14 (based on an adaptive model for thermal comfort), will provide the necessary information to make an informed decision.


Addressing thermal comfort in housing is essential, as it represents one of the spaces where individuals spend most time. It is known that human health and comfort are mainly influenced by changes in airflow and thermal comfort, therefore optimizing airflow and internal conditions, will not only positively affect the life quality of inhabitants, but it will also translate into a drop in energy consumption, and therefore on the building’s environmental impact.

As it has been showed, the intricate relationship between light – as a visual enhancer -, and its thermal qualities is indissoluble. In order to successfully achieve the delicate equilibrium between light and heat gains, as Hyatt (2007) states, the ‘correct orientation [of the building] is the key.’ Only when this balance is accomplished, will the emotional and rational qualities of daylight combine into sculpting not only a functional space, but a living machine whose ambiance will inspire; simultaneously, this space will protect and enhance the quality of life of its inhabitants through a constant symbiosis with the environment.
2.3.1. Comfort requirements in Australia.

Establishing the relationship between the projects’ locations, climate and specially its use is fundamental to identify the design criteria needed to provide spaces which offer not only shelter and protection to its inhabitants, but also, comfort.

As Race (2006) explains, in order for a space to provide comfortable levels of living to its inhabitants, three basic factors must be conveyed through design: fresh air (with the opportunity of cooling or heating it as needed), noise and odour control and good lighting. It is important to emphasize that the present investigation, despite aiming to study the general performance of both houses will focus on the visual and thermal performances, thus not considering their acoustic performance.

Visual performance mainly refers to the quality of lighting within a space. Good lighting will enable the inhabitant to work and move safely within a space and perform any task correctly, while providing an attractive atmosphere. In terms of assessing the daylighting performance, the following guideline (Table 2) suggested by CIBSE (2007) will be used to identify the minimal levels of daylighting required.

Table 2. Recommended lighting design criteria by CIBSE (2006)

<table>
<thead>
<tr>
<th>Building/room type</th>
<th>Maintained Illuminance (lux) at the appropriate working plane or height</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwellings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathrooms</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>bedrooms</td>
<td>100</td>
<td>Study bedrooms require 150 lux at desk</td>
</tr>
<tr>
<td>halls, stairs</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>kitchen</td>
<td>150-300</td>
<td></td>
</tr>
<tr>
<td>living rooms</td>
<td>50 - 300</td>
<td></td>
</tr>
</tbody>
</table>

While daylight performance and comfort are more universal, in terms of been assessed, when discussing thermal comfort this principle doesn’t apply, as it will vary according to the project’s location and climate. According to the principle of Adaptive Comfort as Nicol, Humphreys and Roaf (2012) explain, thermal comfort will vary according to each person’s age, activity, clothing and metabolic rate, therefore the main goal is to achieve a comfortable temperature for the majority of occupants.

Considering that Australia is divided in sixty-nine climate zones (Figure 15) according to NatHERS (2014), and that both projects analysed are located in very different locations, it is important to mention that despite the complex relationship between the government’s institutions, codes and tools developed (e.g. NCC, BCA, NatHERS and BASIX), regarding energy efficiency (Appendix 1), it appears to be no clear definition of the optimum levels of comfort required for each climate zone, specifically towards housing and/or naturally ventilated buildings. Instead, comfort is implied as a result of careful building
fabric design and energy efficiency. Considering this, the criteria suggested to achieve thermal comfort by CIBSE (2006), will be used as a reference (Table 3) in spite of the vast differences, and what can be considered as comfortable in each country. These guidelines will be compared with the optimal temperatures for comfort to establish any conclusions regarding the comfort levels achieved by each building.

![Map of Australia's climate zones](image)

**Figure 15.** Australia’s sixty-nine climate zones for housing design. Location of East Arnhem Land (NT) and Glenorie (NSW). Source: NatHERS (2014)

<table>
<thead>
<tr>
<th>Building/Room type</th>
<th>Winter operative range (°C)</th>
<th>Winter comfort temp. (°C) for non-air conditioning buildings</th>
<th>Suggested air supply rate l/s per person</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dwellings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathrooms</td>
<td>20 - 22</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bedrooms</td>
<td>17 - 19</td>
<td>23</td>
<td>0.4 - 1 ACH</td>
<td>Sleep may be impaired above 24 °C</td>
</tr>
<tr>
<td>halls, stairs</td>
<td>19 - 24</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kitchen</td>
<td>17 - 19</td>
<td>60</td>
<td></td>
<td>60 litres</td>
</tr>
<tr>
<td>living areas</td>
<td>22 - 23</td>
<td>25</td>
<td>0.4 - 1 ACH</td>
<td></td>
</tr>
</tbody>
</table>

In terms of overheating, CIBSE (2006) establishes that if internal temperatures rise for more than one percentage of annual occupied hours over 28 °C in living spaces and 26 °C in bedrooms, it can be considered overheating; nevertheless, again this benchmark has to be reconsidered for each location (i.e. New Arnhem, NT and Glenorie, NSW), according to their specific characteristics.
3. THE BALL-EASTAWAY HOUSE

3.1. Background

The Ball-Eastaway house (Figure 16), located in a secluded bush land in Glenorie, NSW, and was finalized in 1983. When Murcutt’s clients (a couple of painters) approached him, the house’s main intention was clear, it needed to be designed as retreat, as an escaping route from the hectic city-life into a space where serenity soothed their souls.

In Murcutt’s own words (as cited in Beck, Cooper and Murcutt, 2002), the dwelling was designed as a ‘building that has docked, put out is bridge like a ship, and is ready to go away […] the house slides just below a large shelf of sandstone.’ The metaphor of the house being a ship, is represented by the steel columns that separate the dwelling from the ground, and as Farrelly (2002) noted, this emphasizes the difference between the natural world and the man-made. Moreover than underpinning the idea of contradiction in Murcutt’s design process, as a way to blend, the main reasons for lifting the house off the ground are more practical, than romantic, through this strategy, Murcutt protects the building from fires and rainfall, while preserving the sandstone and respecting the natural path of surface runoff waters and wildlife.

Formally, the house’s axial alignment (Figure 17) as suggested by Farrelly (2012), seems to respond to the forms of the sandstone bed, which in addition to the site’s views, offered Murcutt the opportunity to develop a slim plan, whose openings were precisely orchestrated – in apparent contradiction with the openness of the natural surroundings -, just to emphasize the grandeur of nature once the occupant steps inside the house. The interior spaces are clearly defined between the private served spaces (i.e. bedrooms) positioned to the West, and the serving spaces (i.e. living space) to the
East; both spaces are linked through a corridor that was designed as a display area for a large scaled painting.

Figure 17. Left: Conceptual sketches showing the axial layout of the house. Right: Conceptual sketches showing initial studies of the house’s form and connection with the site. Sketches by: Glenn Murcutt.

Source: El Croquis (2013)

Being Murcutt an enthusiastic designer of site-specific architecture, he carefully considered the site’s microclimate and physical characteristics to establish the materiality of the house. When Murcutt considered the rainfall and trees surrounding the site, he knew that conventional gutters and pipes would block, giving him the opportunity to solve this issue through the development of the house’s section, (Figure 18) fundamental aspect that defined the house’s form.

Figure 18. Ball-Eastaway section showing the relationship between the wide gutters and the configuration of the interior space of the house. Drawing by Glenn Murcutt. Source: El Croquis (2013)

As previously mentioned, when Murcutt raises the building off the ground, he instantly makes the house float in the air. Again the image of a ship sailing away echoes, nevertheless, this light-weighted
construction, more than being a poetic resource - and in the architect's pragmatic mind-, it becomes a technique for the building to fight occasional bush-fires during summertime, while providing a simpler and less invasive building process. Once Murcutt establishes this condition as a fundamental design factor, he decided to minimize the use of timber (used only in flooring), and shape a corrugated iron and steel ship on the outside, (supported by a sprinkler system along the facades and roof to protect the building from any fires), while creating a softer interior, one that as the exterior, pursues a minimalistic aesthetic (Figure 19) through an captivating combination of bleached walls and vaulted ceilings, with warmer hardwood floorings.

Figure 19. Ball-Eastaway interior space and finishes. Photography by Anthony Browell. (El Croquis, 2013)

According to Murcutt's design intentions for a frugal design, the house lacks of any building décor element, strongly echoing the modernist influence in his work. Just as Thoreau would like to, the simplicity achieved in this house seems awe-inspiring, yet again, the design is able to convey the duality between the rational and emotional, discovering the sublime message implicit in Murcutt's architecture:

Figure 20. Ball-Eastaway 3D view. Detail of the 'feathering' in the edges of the verandah’s floor. Source: Author (2014)
the greatness of nature over mankind. This relationship is finely expressed by the architect’s ‘feathering’, a design allegory described by Beck and Copper (2002) as the refinement of the building’s edges (Figure 20), just as plants ‘fine down towards their extremities’, the edges of the man-made spaces, slowly meet the borders of the natural realm, creating a subtle distinction between both worlds, not through a harsh dialogue, but through a gentle touch.

3.2. Architectural promenade

From a distance, the corrugated iron house seems to float above the eucalyptus leaves on the ground. As the thin and diagonal wooden bridge approaches, the Ball-Eastaway house (Figure 21), can be described as a horizontal enclosed and tough-looking foreigner when compared with its natural surroundings. The house is clearly directional, its longer facades are mostly closed, while the shorter ones are completely opened framing the natural scenery.

![Figure 21. Ball-Eastaway exterior view (bridge, facade and main entrance). Photography by Anthony Browell. Source: El Croquis (2013) ](image)

![Figure 22. Ball-Eastaway floor plan and spatial arrangement. Location of first view on the architectural promenade. Source: Author (2014) ](image)
Once the bridge reaches a small puncture in the building’s façade, a simple over-head white ceiling announces a transition, a transparent door invites the inhabitant in. Once this translucent door is crossed, a striking red painting across a wooden corridor enraptures the person into the house. A white vaulted ceiling softens the rigid right-angled outlines of the house. (Figure 23).

Figure 23. Ball-Eastaway interior view from living space towards the gallery/corridor. Photography by Anthony Browell. Source: El Croquis (2013)

Turning the gaze to the left of the corridor reveals two doors, the study to the left and the bedroom to the right. Without crossing these doors, immediately the view escapes from this white man-made heaven, impacting a large tree which rests peacefully in front of these rooms. The real heaven has been discovered, these spaces were designed for man to live, work and rest alongside nature.

Walking down the corridor, two doors enclose the houses’ most sacred and private space: the meditation verandah (Figure 24). Once outside, a fully enclosed verandah frames the real canvas, the magnificent landscape. A defined line, an edge, announces the end of one world and the beginning of another; here, the space was designed with the only purpose of inviting the inhabitant to observe, to relax; to be soothed by nature.
Once inside again, the vaulted ceiling guide the inhabitant to the living space. An open plan combines the kitchen area with the dining and living room. All vertical surfaces (i.e. walls, the kitchen’s furniture and the fire place) are white and merge with the ceiling, while opposing with the timber flooring, as a reminder of the constant equilibrium pursued by Murcutt in his designs between man and nature. Three openings bring light to this open space; when standing between the dining table and the kitchen (Figure 25) the gaze focuses on the empowering image the main verandah offers, while to the left,
glazed louvres let fresh air and light into the dining area; to the right, light punctures the curved ceiling, offering a new view: the sky.

The edge of the living space, flanked by translucent panes on sliding doors indicate the end of the interior space, and the beginning of a new transitional space; the main verandah (Figure 26), is discovered once the doors are opened; the view overflows and light and fresh air embraces the viewer. Here, the timber floor carefully guides the gaze towards the omnipresence of nature. Once the gaze begins to follow the pattern and direction of the timber flooring, suddenly it finds itself lost, surrounded by nothing but the empowering landscape (Figure 27).

Figure 26. View from the living room towards the verandah, which fuses with the tree canopy and views. Photography by: Reiner Blunck (2005). Source: Velux (2014)

Figure 27. Exterior view of the main verandah. The space is surrounded wholly by nature; the direction of both ceiling and flooring constantly points the viewer’s gaze outwards. Photography by Anthony Browell. Source: El Croquis (2013)
3.3. Microclimate analysis: Glenorie, NSW.

As mentioned previously, the Ball-Eastaway house is located in Glenorie, a small suburb in the outskirts of Sydney (NSW) and according to the climate zoning of Australia by NatHERS, it is located within the 28th climate region, based on the weather data of Richmond, NSW. Due to its southern location, and conforming to BOM (2014), the climate in NSW is entirely temperate, indicating a mild climate with rare temperature extremes.

Figure 28. Ball-Eastaway house: Location and coordinates. Source: Author (2014)

Figure 29. Monthly Diurnal Averages. Weather data for Richmond, NSW. Source: NatHERS (2014)
As Figure 29 indicates, this location experiences a seasonal climate, having an annual average temperature of 17°C and a maximum and minimum temperature of 39.5°C (January) and 0°C (August), suggesting that a well insulated envelope is needed to cope with the important variation in temperatures.

According to BOM (2014), the monthly mean rainfall for Richmond ranges from 122 mm in February (summertime) to 28.5 mm in July (winter), showing that rainfall is present throughout the year and must be taken into account during the design process. Consistent with this fact, and as shown by Figure 30, the total annual rainfall is substantial.

![Total annual rainfall for New South Wales, Australia. Richmond, experiences a considerable annual rainfall, ranging between 900 mm to 1800 mm annually. Source: BOM (2014)](image)

Figure 30. Total annual rainfall for New South Wales, Australia. Richmond, experiences a considerable annual rainfall, ranging between 900 mm to 1800 mm annually. Source: BOM (2014)

Annually, the sky conditions for this zone (Figure 31), show that the median cloud cover is 87% (mostly cloudy) and does not vary substantially over the course of the year. Throughout the year, cloudy skies are substantial, nevertheless overcast skies are the most common, suggesting this type of sky as the regular condition for daylight performance and comfort analysis.

![Annual sky conditions for Richmond, NSW. Left: Median cloud cover. Right: Cloud cover types. Source: Weatherspark (2014)](image)

Figure 31. Annual sky conditions for Richmond, NSW. Left: Median cloud cover. Right: Cloud cover types. Source: Weatherspark (2014)
Murcutt’s houses are designed as free-running buildings, therefore considering the frequency and direction of the prevailing winds is fundamental to have a panorama on the impact that the combination between temperatures, radiation, rainfall and winds will have on the overall energetic performance of the building.

According to NatHERS weather data, the annual wind frequency (Figure 30), indicates that the prevailing winds direction comes from the SW and NE. Nevertheless, and to be more accurate, during summer the prevailing winds come mainly from the S, while during winter they come from the W and SW.

Figure 32. Wind frequency and direction for Richmond, NSW. Left: annual frequency – Middle: Summer frequency - Right: winter frequency   Source: NatHERS (2014)

Figure 33. Ball-Eastaway’s orientation vs. Optimum orientation for Richmond, NSW. Source: NatHERS and Ecotect’s weather tool (2014)
The building’s positioning and orientation is fundamental to have an overall balanced performance throughout the year. As shown by Figure 33, the sunpath indicates that the site will have access to long summer days, while shorter winter days, hence the orientation and access to sunlight is a key factor. According to NatHERS (2014), the optimum orientation for any building within this area implies a 357.5° compromise from North; from the sunpath and orientation analysis, it is suggested that in order for the house to perform, solar access (and heat gains) have to be maximized during winter, while balancing shade and ventilation during summer.

Taking into account all these climatic characteristics is fundamental to understand Murcutt’s design intentions and to test both the visual and environmental performance of the house. A correct orientation, plus carefully designed openings, insulation (skin thickness) and the right building material selection, will yield in a comfortable space throughout the year, as shown by the psychrometric chart (APENDIX XX).

3.4. Orientation, sun, wind and form: Rules of thumb design analysis

When analysing Murcutt’s work and design principles (Section 2.4), it is clear that orientation – due North -, is the most common orientation for his projects, denoting a careful consideration of climatic conditions to assure correct sunlight access annually. Nevertheless, and in Murcutt’s own words, (as cited in Levene and Márquez, 2012) the case for the Ball-Eastaway house seems an exception, as it is oriented to 45°, responding mainly to the site’s views (Figure 33).

Analyzing the building’s orientation and its relationship to the sunpath, will yield in a better understanding of the house’s form and spatial arrangement.
By overlaying the sunpath during summer solstice and winter solstice (Figure 35), it seems like Murcutt - based on his idea of preserving the bed stone and exploiting the views - positioned the house according to these factors, and not to his typical north orientation. Taking into account this, Murcutt gave the living space (where the inhabitants will spend most of their time), priority access to sunlight.

As the image shows, during both dates, the living space is the only space which gets direct exposure to sunlight.
As mentioned previously, Murcutt designed the long facades of the house to be almost completely blind. As Figure 32 shows, the only opening in the long facades is located in the northern façade, in the dining area; whereas the short facades are completely translucent, allowing daylight into the main spaces, the bedrooms and living space.

When a shadow analysis is performed on the house during noon (Figure 36), it shows that the roof works as designed, protecting the interior spaces from the harsh midday sunlight throughout most of the year, while allowing some sunlight into the dining room during winter. It is also important to notice how the verandah's cantilevered roof gives shading to the living space during summer, whilst during winter, it allows some direct daylight – and heat gains – into the living space.

In order to understand how the low angled sun will affect the interior spaces, the same analysis was performed at 4pm (Figure 37). From this analysis a very distinctive finding points out; considering the configuration of the facades, and their relationship with the spatial arrangement, the only opening in the northern façade allows light and fresh air into the living space, enhancing the overall atmosphere of this area; nevertheless, when the bedrooms are analysed, there seems to be a conflict. During summer, when extra heat gains should be avoided, through the bedroom openings, sunlight penetrates the spaces, whereas during winter, when the sun's warmth is desirable, the bedrooms remain overshadowed.
Figure 36. Sun and space: solar access and shadow cut away sections during noon. Source: Author (2014)
At this time, the bedrooms are completely overshadowed.

Figure 37. Sun and space: solar access and shadow cut away sections at 4pm. Source: Author (2014)
The section - as mentioned earlier -, is one Murcutt’s essential design tools. When the house’s section is overlapped with the different solar angles during summer solstice, equinox and winter solstice (at noon), the perception that this house was designed having the views as a priority, rather than orientation (and its performance implications), becomes stronger.

As Figure 38 shows, sunlight enters the living space through the tall opening in the northern façade; when the different sun’s angles (at noon) are overlapped with the section, it is clearer how during summer, the vaulted ceiling plus the wide gutters, protect the interior space from harsh daylight, nevertheless the roof light (apparently with no blinds or solar protection) allows direct sunlight into the space, bringing undesired heat gains to the interior. It is important to mention that the vaulted ceiling – more than a poetic element reminiscent of the sky’s vault -, is in fact part of Murcutt’s design strategies to have a better distribution of daylight throughout the house.

Figure 38. Ball-Eastaway section and solar access at noon. Left: Summer solstice - Middle: Equinox - Right: Winter solstice. Source: Author (2014)
When the section is analysed during winter (Figure 39), the low angled light enters deeper into the space, providing more light and heat gains during cold days; nevertheless, the roof light, which could provide direct daylighting remains as a source of indirect lighting, depicting at the same time an opportunity for heat loses to occur.

The basic rules of thumb to determine the right window sizing for daylighting a space (Appendix 2) shows that in both the living space and bedrooms, the ratio between window sizing and floor area is correct, suggesting there is good access to daylighting.

Figure 39. Ball-Eastaway section and solar access at noon during winter solstice. Source: Author (2014)
Ventilation is fundamental for the overall performance of the house and the inhabitant's health. As a free-running building, the house was designed to be cooled through natural ventilation. The house, being raised off the ground allows winds to cool down the envelope during summertime; however, and according to Murcutt's drawings (Figure 40), the timber floor rests directly over the structure, with no apparent insulation, which during winter most likely might have a reverse effect on the thermal performance of the house.

Taking into account that one of Murcutt's main design principle is to develop elongated buildings with thin plans, natural ventilation, as an environmental strategy is very likely to work. The basic rule of thumb calculation (Appendix 3) for naturally ventilated spaces indicates that while one sided ventilation might work, cross-ventilation (Figure 41) will work to cool down the interior temperatures in the living space.
space. It is very important to stress out that Murcutt designed this house to be fully operable, in terms of allowing the inhabitant to open doors, glazed louvres or roof lights according to their needs.

Analysing the single-sided ventilation strategy used by Murcutt to provide fresh air and cool down the temperature in the bedrooms (Figure 39), as fundamental spaces for the inhabitant to repose, is very important as well. According to the rule of thumb calculations (Appendix 4), both bedrooms comply with the minimum dimensions to be ventilated from one side. Nevertheless, having such a large opening area, additionally to no insulation in the flooring, might influence their energetic performance and comfort levels.

According with these basic analyses, they suggest that despite the house as designed might offer the right amount of daylighting into spaces, due to its orientation and thin skin thickness (according to Murcutt’s drawings, only the exterior walls have Insulwool as thermal insulation), might have an important impact on the building’s performance and comfort. In the following chapters both the daylighting and thermal environments will be analysed in detail, in order to draw more accurate results.
3.5. Visual environment and daylighting performance analysis

The visual environment is a fundamental factor allowing the inhabitant to carry its activities or tasks securely, through a well day-lit space, the atmosphere and comfort will be enhanced, having a positive effect on the person's health and state of mind.

Daylight is not only distributed through the space by means of its geometry; the reflectance of surfaces will also greatly help to a better distribution of natural light. According to CIBSE (1994) and to Murcutt’s selected interior finishes the values shown in Table 4, will provide a better understanding on the simulations carried out to analyse the visual environment of the house.

<table>
<thead>
<tr>
<th>Building surface</th>
<th>Reflectance</th>
<th>Material or finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceilings</td>
<td>0.8</td>
<td>White emulsion paint on plain plaster surface</td>
</tr>
<tr>
<td>Walls</td>
<td>0.8</td>
<td>White emulsion paint on plain plaster surface</td>
</tr>
<tr>
<td>Kitchen furniture</td>
<td>0.8</td>
<td>White (kitchen furniture)</td>
</tr>
<tr>
<td>Floors and furniture</td>
<td>0.25</td>
<td>Timber: oak</td>
</tr>
<tr>
<td>Glazing</td>
<td>0.6</td>
<td>Clear glass</td>
</tr>
</tbody>
</table>

Given the activities held within a household, no exceptional daylighting requirements are needed, nevertheless and to ensure that the spaces are correctly day-lit, a minimum daylight factor of two percent will be used as a guide to analyse the visual performance in overcast sky conditions. As Figure 43 shows, the average daylight factor in the main spaces is above five percent, indicating that even during an overcast sky condition, all spaces are naturally well-lit; no extra lighting from artificial sources is needed as CIBSE (1994) establishes. In Figure 44, views of the journey and daylighting conditions under overcast skies can be appreciated.

Figure 43. Daylight factor plot, uniformity ratios and light journey in the Ball-Eastaway house.

Source: Author (2014)
Figure 44. Light journey’s views showing the spatial daylighting variation. Source: Author (2014)
Additionally, CIBSE (1994) recommends that the uniformity of illuminance over task areas and their immediate surroundings should not be less than 0.8, it has to be considered that this recommendation is intended for working or learning spaces with specific tasks, and not housing design. Nonetheless, the uniformity ratios achieved show that Murcutt designed and positioned the openings intentionally to create a more relaxing atmosphere, one were daylight soothes the spirit. The daylight variation within the house can be better appreciated through a light journey (Figures 43 and 44), which provides further evidence on Murcutt’s design intentions. Despite that the house’s orientation is not the optimum, Murcutt is able to play with daylight, making a clear transition both between the living space and the bedrooms, as well as between the interior and exterior. As shown, the most dramatic change can be perceived in the main entrance, where the DF is gradually lowered, enhancing the space’s use (as a display area), while providing visual adaptation (Moore, 1991) to the inhabitant. It is also important to notice how the bedrooms have a higher DF value, which will indicate that correct daylighting values achieved, will enhance the visual acuity.

Lastly, in order to comprehend the relationship between the building’s orientation, its geometry and the location of openings and how they influence the visual performance, Figure 45 shows how the combination of the roof light, the tall opening in the dining area and the vaulted ceiling gradually decrease and distribute daylight more uniformly throughout the space.

![Daylighting section](image)

The daylighting achieved in the living space varies, from a vivacious atmosphere – near the opening, to a smoother and calmative atmosphere in the kitchen area. The variation in daylighting makes the space dynamic.

Figure 45. Daylighting section, showing the effect the building’s geometry has on the daylight distribution in the living space. Source: Author (2014)
3.5.1. Visual performance study under sunny sky conditions: Illuminance

Illuminance, as described by CIBSE (1994), is the luminous flux density that falls on a surface. In order to understand how daylight varies - and the effect it has on space -, it is essential to assess the illuminance distribution. As this analysis intends to have a rounded understanding on the daylighting performance of the building, illuminance was assessed both under overcast and sunny sky conditions, at noon time (worst case scenario), during summer and winter solstice, as well as during equinox.

According to CIBSE’s (2006) recommendations on the illuminance levels required in housing design, and according to the results seen in Figure 46, there is a significant difference in the spatial daylighting performance between sunny and overcast skies conditions. As shown, the most critical space is the dining area, whose illuminance levels under sunny skies extents higher than 500 lux, clearly exceeding from the 300 lux recommended by CIBSE. When the illuminance for this space under overcast skies is analysed, notably the illuminance level decreases, ranging between 200 – 350 lux, and therefore performing better. This difference suggest that during sunny sky conditions, external shading, or operable blinds may decrease the illuminance levels and therefore the overall visual performance, and to prevent any stress or fatigue occurring due to the high levels of light falling on surfaces.

In the case of the bedroom, the illuminance achieved under both sunny and overcast skies is significantly higher than the 100 lux level CIBSE (2006) recommends. For this space, again the combination between a thicker glazing and blinds might decrease these values and improve the overall atmosphere.
Figure 46. Illuminance mapping (using Radiance) of living space and bedroom under overcast and sunny sky conditions. Source: Author (2014)
When the different illuminance mappings on the floor plan are analysed, it proves Murcutt designed the corridor not only as a display area, but as a transition space between inside and outside. This transition is made by limiting the openings and guiding daylight towards this space from three different sides. As expected from the other spaces illuminance performance, the corridor achieves better illuminance levels under overcast skies, while during summer solstice, (when the sun’s angle is highest and light enters through the translucent main door and roof lights in the bathroom and laundry), harsh daylight falls in the display wall.

In order for these results to cling with reality, it is very important to consider that overcast skies conditions are most probable to occur throughout the year in Richmond, NSW; therefore and despite it is important to understand daylighting’s general performance, the results shown during sunny sky conditions can be considered as the worst case scenario, and very unlikely to occur. Considering this, the illuminance performance surpasses the minimum levels recommended, indicating that as designed, the interior spaces receive correct daylighting for their purpose, nevertheless the use of blinds or operable shading devices might improve the ambiance during sunny sky conditions.

3.5.2. Visual comfort study: Luminance ratio study.

Properly assessing the daylighting performance within a space is vital (as mentioned before), to assure the correct daylight access required to perform any activity safely; however, due to human being’s sensibility to brightness, the space has to be designed to assure that high brightness of the light emitted or reflected (CIBSE, 1994) is controlled to a minimum, in order to offer visual comfort too.

In order to assess the luminous intensity in the environment, the brightness contrast ratio (Hopkinson, 1966) was used to evaluate whether the house, as designed, decreases the incidence of glare issues (which may lead to visual discomfort) in main spaces. The visual range (Figure 47), was established to analyse the visual task and its near and far surroundings.

Figure 47. Visual range to establish the visual task (5°), immediate surroundings (30°) and far surroundings (60°). Diagram from author, based on image by Hopkinson (1966).
Hopkinson (1966), established that the ideal luminance ratio between the visual task, its immediate surroundings and the far surroundings is 10:3:1. This ratio was considered to analyse the luminance and potential glare issues.

It is important to clarify that luminance levels were analysed during the same period of time and spaces as the illuminance mapping, however, due to the site’s mostly overcast sky conditions, the luminance mapping was performed only during equinox under sunny sky conditions, as well as under overcast skies, in order to have a more realistic panorama.

According to the results, in all the spaces, the relationship between the visual targets and their surroundings proves that experiencing glare is unlikely to occur as the house was designed by Murcutt. Nevertheless, in the dining room the display area (i.e. painting) was chosen to be the visual task, if the visual task shifted towards the opening, other results might have risen, given the high luminance values near it. Additionally, although sunny skies during winter are very rare, the high luminance values near the opening suggest that under this condition inhabitants may suffer from glare discomfort, condition that might be improved by blinds that can partially block the low angled sun.
## II. VISUAL COMFORT ASSESSMENT:

### SUNNY SKY CONDITION

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<th>Equinox (22nd March)</th>
<th>Winter solstice (21st June)</th>
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<td><strong>Time:</strong> Noon</td>
<td><strong>Time:</strong> Noon</td>
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<tr>
<td><strong>Solar angle:</strong> 80°</td>
<td><strong>Solar angle:</strong> 56°</td>
<td><strong>Solar angle:</strong> 33°</td>
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#### LUMINANCE (cd/m²) ASSESSMENT – RADIANCE RENDERS + MEASURING POINTS

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</tbody>
</table>

Figure 48. Brightness contrast study of living space and bedroom under sunny and overcast sky conditions. Source: Author (2014)
3.6. Thermal Environment

Analysing the thermal environment of the Ball-Eastaway house is essential to have a full understanding of the building’s performance and its impact on the comfort and spatial ambiance.

Just as daylight conveys warmth into spaces, winds will affect the thermal comfort and performance of the house depending on the design of the thermal envelope. The site’s climate, additionally to the building’s orientation and its building elements, (i.e. thermal mass, insulation, window size and shading) will help to optimise the indoor comfort and energy consumption of the house.

In order to determine whether the house offers comfortable conditions as designed, a thermal simulation was done in EDSL TAS, the resultant temperatures in the living space and bedrooms were compared with the monthly acceptable comfort zone (Table 5 and Figure 49) developed for Richmond, NSW, based on the Adaptive Model for thermal comfort by Nicol, Humphreys and Roaf (2012).

Table 5. Monthly average temperature vs optimal temperature for comfort in Richmond, NSW. Source: Author (2014)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average temperature (°C)</th>
<th>Optimal temperature for comfort (T_comf) (°C)</th>
<th>Acceptable lower temp band (°C)</th>
<th>Acceptable top temp band (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>23.1</td>
<td>25.0</td>
<td>23.0</td>
<td>27.0</td>
</tr>
<tr>
<td>February</td>
<td>22.6</td>
<td>24.8</td>
<td>22.8</td>
<td>26.8</td>
</tr>
<tr>
<td>March</td>
<td>23.1</td>
<td>24.3</td>
<td>22.3</td>
<td>26.3</td>
</tr>
<tr>
<td>April</td>
<td>17.2</td>
<td>23.1</td>
<td>21.1</td>
<td>25.1</td>
</tr>
<tr>
<td>May</td>
<td>12.9</td>
<td>21.8</td>
<td>19.8</td>
<td>23.8</td>
</tr>
<tr>
<td>June</td>
<td>11.1</td>
<td>21.2</td>
<td>19.2</td>
<td>23.2</td>
</tr>
<tr>
<td>July</td>
<td>10.5</td>
<td>21.1</td>
<td>19.1</td>
<td>23.1</td>
</tr>
<tr>
<td>August</td>
<td>11.6</td>
<td>21.4</td>
<td>19.4</td>
<td>23.4</td>
</tr>
<tr>
<td>September</td>
<td>14.7</td>
<td>22.4</td>
<td>20.4</td>
<td>24.4</td>
</tr>
<tr>
<td>October</td>
<td>17.7</td>
<td>23.3</td>
<td>21.3</td>
<td>25.3</td>
</tr>
<tr>
<td>November</td>
<td>18.7</td>
<td>23.6</td>
<td>21.6</td>
<td>25.6</td>
</tr>
<tr>
<td>December</td>
<td>21.8</td>
<td>24.6</td>
<td>22.6</td>
<td>26.6</td>
</tr>
</tbody>
</table>

Figure 49. Adaptive thermal comfort range for Richmond, NSW. Source: Author (2014)
According to CLEAR (2014), the building’s fabric is a key element as it will regulate the indoor environment. Additionally it states that, ‘an optimal design of the building fabric may provide significant reductions in heating and cooling loads’, which will translate to a greater independence from HVAC and less energy consumption. Nevertheless, and taking into account that Murcutt’s projects are designed as free-running buildings, the building’s light and operable envelope should respond to climate, providing the inhabitant control of their environment, yet they are not intended to maximize or minimize heat and cooling loads. Kallenbach (2002), echoes Murcutt’s own words, ‘[just as] we layer our clothing, putting more on when it’s cold, taking more off when it’s hot…I think our buildings should equally respond to their climates.’

In order to grasp the relationship between the envelope’s design and its building materials, Table 6, shows the thermal properties considered for the thermal simulation of the house.

**3.6.1. Thermal simulation and results**

Table 6. Typical thermal properties of common building and insulating materials. Table by Author based on Appendix 1 by Kyle (1999).

<table>
<thead>
<tr>
<th>Description/Composition</th>
<th>Thickness (mm)</th>
<th>Density (kg/m3)</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Specific heat (kg/m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boards</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsum (plaster board)</td>
<td>10</td>
<td>800</td>
<td>0.19</td>
<td>1.09</td>
</tr>
<tr>
<td>Plywood board</td>
<td>6mm</td>
<td>545</td>
<td>0.12</td>
<td>1.21</td>
</tr>
<tr>
<td><strong>Woods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardwoods (oak, maple, tallowwood)</td>
<td>-</td>
<td>720</td>
<td>0.16</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugated iron</td>
<td>5mm</td>
<td>-</td>
<td>8.5</td>
<td>1.22</td>
</tr>
<tr>
<td>Steel (mild)</td>
<td>-</td>
<td>7883</td>
<td>45.3</td>
<td>0.50</td>
</tr>
<tr>
<td>Glass</td>
<td>-</td>
<td>2530</td>
<td>1.0</td>
<td>0.84</td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral wool**</td>
<td>-</td>
<td>190</td>
<td>0.04</td>
<td>-</td>
</tr>
</tbody>
</table>

* Technical data for Insulwool (natural wool) was unavailable. Mineral wool used as reference.

The thermal simulation performed for the Ball-Eastaway (Appendix 7) house aimed to have an overall idea on the annual performance of the main living spaces. Separate simulations for each space were performed to have more accurate results. Additionally, the chimney’s effect is fundamental for heating during the cold season, hence its heat transfer into space had to be considered.

Three simulation cases (Table 7) were designed with the intention to provide evidence of the relationship and effect that solar radiation, natural ventilation and internal heat gains have on the

Table 7. Ball-Eastaway description of thermal simulation cases. Source: Author (2014)

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1</strong></td>
<td>Shell with 0.5 infiltration rate, no ventilation or internal heat gains considered.</td>
</tr>
<tr>
<td><strong>Case 2</strong></td>
<td>Shell with 0.5 infiltration rate + natural ventilation* (1.5 ach) with 30% aperture when resultant temperature reaches 19°C + internal heat gains.</td>
</tr>
<tr>
<td><strong>Case 3</strong></td>
<td>Shell with 0.5 infiltration rate + natural ventilation* (1.5 ach) with 90% aperture when resultant temperature reaches 19°C + internal heat gains + chimney heat gains **</td>
</tr>
</tbody>
</table>

* Natural ventilation is assumed not to be needed during wintertime (May - August)
** Chimney heat gains only considered during occupancy hours.
envelope’s thermal performance and the resultant temperatures in these key spaces during a year. For these cases, the following assumptions were considered (Table 8).

Table 8. Summary of internal conditions and assumptions considered during thermal simulation. Source: Author (2014)

<table>
<thead>
<tr>
<th>Internal conditions</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed occupancy hours</td>
<td>24 hours / 7 days a week</td>
</tr>
<tr>
<td>Assumed occupancy</td>
<td>2 adults</td>
</tr>
<tr>
<td>Opening schedule</td>
<td>Based on occupancy - not considered during winter</td>
</tr>
<tr>
<td>Heat gains from occupants*</td>
<td>180W (sensible) and 100W (latent)</td>
</tr>
<tr>
<td>Equipment sensible gains</td>
<td>25 W/m²</td>
</tr>
<tr>
<td>Chimney sensible gains**</td>
<td>40 W/m²</td>
</tr>
<tr>
<td>Lighting gain</td>
<td>2.5 W/m²</td>
</tr>
<tr>
<td>Natural infiltration rate</td>
<td>0.5 ach / 24 hours</td>
</tr>
</tbody>
</table>

* Occupants heat gains were assumed to be 90W (sensible) and 50W (latent) per adult, and a child is 75% of the figures for an adult.

** Chimney sensible gains were only considered during the winter period under occupancy schedule. Thermal gains are based on the Walltherm Zebri, wood burning stove (Appendix 5)

Firstly, a monthly simulation for the living space (Figure 50) was performed, followed by a seasonal average (Figure 51) which was calculated to have a whole understanding on the house’s performance. Nevertheless, winter’s performance was a priority.

Figure 50. Living space monthly percentage of hours in comfort zone vs. average monthly temperatures. Source: Author (2014)
Even when considering that Murcutt intentionally gave the living space priority to solar access and its heat gains, in both a monthly and annual basis the thermal simulation findings are not positive, however anticipated based on Murcutt’s design principles.

As expected, Case 1 yielded the poorest performance results; when seen in a monthly basis (Figure 50), the space’s performance decreases twice the percentage of time in the comfort during the coldest months when compared with the warmer ones, with the poorest performance in July. On a yearly basis the space as designed, will only perform an average of twenty percent of the time throughout the year, except during winter when performance falls to fifteen percent, inferring that heat gains are essential to improve the thermal performance and comfort in the space.

When Case 2 is analysed, the performance results show signs of improvement in the space’s thermal performance and comfort. When compared to Case 1 in a monthly basis, the percentage of time within the comfort zone increases from an average of twenty percent to twenty five percent, having a dramatic increase during the colder months (May – August). On an annual basis, compared to the operative comfortable temperatures (Table 5), it shows that despite the percentage of time within the comfort zone more than doubles compared to Case 1, the average resultant temperature falls below 19°C, and therefore below the comfort zone.

Case 3 reveals that the combination between internal heat gains and natural ventilation (during summertime), additionally to the heat loads transferred from the chimney (during wintertime), improve
the overall performance of the space. On a monthly basis and despite that on an average the percentage of time within the comfort zone lies in forty percent, there seems to be a better performance during the colder months, suggesting that heat loads greatly improve the thermal performance of the space. Considering this point, on a yearly basis, while there is a continuous improvement in the thermal performance when compared to Case 2, the most significant improvement can be seen during winter, showing that the chimney’s heat transfers are essential to increase internal temperatures; nevertheless, the average resultant temperatures still fall below the comfort zone.

Generally, the results show that the overall performance of the living space falls below fifty percent of the time in the comfort zone, suggesting the envelope is not very efficient and will require extra heating or cooling to achieve more comfortable levels. Despite this, it has to be emphasized how essential the chimney’s heat gain is to cope during winter; it is during this period that the house has the highest percentage of time in the comfort zone, significantly increasing from fifteen percent to over forty percent.

When analysing the performance of the bedrooms (Figures 52 and 53), important findings during winter were revealed, following the performance pattern of the living space.

Figure 52. Bedroom monthly percentage of hours in comfort zone vs. average monthly temperatures. Source: Author (2014)
Just as the living space’s performance for Case 1, the bedrooms’ results under the same condition were the poorest when compared to the other cases. When the monthly and annual outputs are studied and compared with the living space’s results, the bedrooms too - with no ventilation or heat gains - only perform for an average of twenty percent of the time; decreasing significantly during winter, implying the building alone is not efficient.

As opposed to the results for the living space’s performance for Case 2, this scenario represented the best condition for the bedroom’s performance during winter. Surprisingly, these results indicate that when the openings’ apertures are controlled during winter (retaining heat gains), the bedrooms double their performance; still, the resultant temperatures remain below the comfortable range. It is important to mention that for this case, the results show that as exterior temperatures decrease towards winter as shown in Figures 52, the bedrooms perform better than during summer, indicating that more ventilation might be needed to improve the comfort conditions.

Case 3 represents a very significant outcome, as it shows that the heating loads released by the chimney during winter are released by the envelope and do not impact the thermal performance of the bedrooms. In a monthly basis the bedrooms perform on an average of twenty-five percent of the time, which is low. Nevertheless, and more importantly, as the exterior temperatures fall (autumn), the percentage of time within the comfort zone falls dramatically from thirty percent in May, to fifteen percent...
in July, showing that evidently the envelope’s efficiency is dependant of the climate and that during winter, the bedrooms will require extra heating to offer comfortable temperatures to the inhabitants as the resultant temperature falls below 9°C when compared to the acceptable lower temperature for July.

3.7. The Ball-Eastaway house: Summary

According to the results yielded from the basic rules of thumb for daylighting, additionally to the performance and comfort analyses, these results have proven that the luminous environment as designed conveys a well-lit and comfortable space accordingly to the minimum daylighting recommendations by CIBSE. Nevertheless and as the results suggest, simple elements (such as blinds) designed by Murcutt to control the access of sunlight, will improve the performance and visual comfort in the house.

Despite the current orientation of the house responds to the views, still Murcutt accomplishes to design a space that through subtle light variation guides the inhabitant through a journey of different states of mind. This subtle light variation and therefore, atmosphere, is achieved by the house’s symmetrical form and carefully selected building materials, which in combination with the natural scenery, continually invites the inhabitant to contemplate nature and relax.

While it seems that despite the house’s orientation the daylighting performs as required, when the thermal environment is considered the results are not as encouraging. As designed, the main space’s performance falls below fifty percent of time in the comfort zone, showing that while the envelope does respond as designed, during climate peaks (especially winter), additional heating is needed to provide comfort. Furthermore, the results suggest that better insulation levels (in openings and flooring), might improve the overall performance of the house; nevertheless, it seems the inhabitant’s behaviour, activities and clothing levels will influence the perception of comfort in this house.

When considering the balance between the rational and the emotional, it seems that, (despite Murcutt’s expertise in analysing and manipulating the site’s context to benefit the performance and spatial quality of the house) he intentionally oriented the house towards the views, suggesting his awareness of the potential consequences this could signify for the house’s visual and environmental performance. If the optimal orientation for the house was considered on further studies, it might represent an opportunity to show the potential improvements in both the visual and thermal environments, nonetheless the house’s main design intention, (i.e. providing a relaxing atmosphere while enjoying the scenery) might be lost.

Finally, it seems that Murcutt’s distinctive pragmatism when designing was surpassed by his poetic side; however, through this sensible design, when the manmade space meets the natural background, a new symbiotic relationship is formed, the interior and exterior spaces are now fused and their only aim is to delight and enhance the inhabitants well-being through the contemplation of nature.
4. THE MARIKA-ALDERTON HOUSE

4.1. Background

Murcutt’s architectural imagery seems to remain open-ended instead of closing down around a singular type. The fact that his buildings always arise from exact, specific local and individual conditions provides a wide set of design variables which tend to create a sense of unique fit, regardless of the repeated use of general principles. — Pallasmaa (as cited in El Croquis — 2012)

The Marika-Alderton house (Figures 54), was finalized in 1994, positioned by the seaside of the tropical landscape of Eastern Arnhem, NT. According to Beck and Copper (2002), the house was designed for a couple composed by an aboriginal artist and her English partner with the intention of creating a dwelling which followed native traditions.

![Figure 54. Exterior view – Southern facade of the Marika-Alderton house. Photography by Reiner Blunck. Source: El Croquis (2012)](image)

When discussing the design’s concept, it was essential for Murcutt to understand the spatial intention required by the clients. According to Murcutt’s, as cited by Godsell (El Croquis, 2012), the main intention behind this design was to allow the inhabitants to observe and interact with the exterior world (i.e. the landscape, climate, visitors) while remaining hidden.

For Murcutt, this project embodies both the pinnacle in his career, as well as a seeming controversy. It is in this design that Murcutt converges and materializes his life learnings on modern architecture, by combining them with Thoreau’s philosophies, lessons learnt from vernacular architecture and the site-specific climate with his long-term appreciation for the aboriginal way of life.
At the same time as it represents a climax, and according to Drew (1985), there seems to be a strong correlation between the New Guinea’s longhouse (Figure 55), with its slim plan, high-pitched roof and raised floor – with Murcutt’s design. However, Murcutt (as cited by El Croquis, 2012) rejects this idea by clarifying that his buildings are born under ‘logical, dynamic and aerodynamic’ concepts and are not related to a romantic reminiscence of the past.

Figure 55. Illustration of the New Guinea traditional longhouse. Unknown author. Source: Jane (2011)

Regardless of this controversy, the similarities between them are palpable; nevertheless, when this nostalgia meets Murcutt’s pragmatics, the influence that vernacular architecture had on the final design is evident.

Figure 56. Conceptual sketches showing the spatial and environmental relationship between the plan and section. Sketches by Glenn Murcutt. Source: El Croquis (2012).

Formally, the house’s plan and section were conceived to fully respond to the site’s climate, (specially the sun’s path and winds) and the cultural necessities of his clients as Figure 56 shows;
interestingly enough, during the design process the roof evolved from curvy-linear outline into a traditional double-pitched roof, increasing the resemblance with the aboriginal hut. Nevertheless, the profile of this house is found in the confrontation between aboriginal and vernacular as this house embodies the evolution of the verandah.

Designing to respond to the site’s tropical climate (i.e. harsh sunlight, high temperatures and humidity levels, as well as cyclones), while providing visual contact with the exterior, yielded in a symmetrical building (Figure 57) raised off the ground. It’s thin plan and long eaves, offer protection from sun and rain, while an operable envelope constantly provides fresh air. The envelope is mainly composed by slatted shutters and doors (no glazing) and tilting plywood panels, which allow the inhabitant to control and adapt its environment according to their needs.

![Figure 57. Section of the Marika-Alderton house, showing the relationship between shape, materiality and a responsive envelope. Drawing by Glenn Murcutt. Source: El Croquis (2012)](image)

According to Fromonot (2003), and as shown in Figure 57, the denominated ‘sun-breakers’ demonstrate the in-depth understanding of the sun’s path. This ‘fin-like’ divisions provide not only to the bedrooms shading from low-angled sunlight, but they become part of Murcutt’s discourse of refining the edges between the manmade world and nature.

The spatial arrangement of the house according to Murcutt (El Croquis, 2012), evolved from the design principle of separating serving and served spaces, while responding to the aboriginal traditions were the adult’s room is positioned to the West, where the sun sets and dies, while the children’s bedrooms are located to the East, where the sun rises symbolizing new life.
When the envelope’s and structure materiality is observed, the minimalistic and pragmatic mind of Murcutt surfaces, demonstrating that through the use of unpretentious building materials such as steel (to support the cyclonic winds), timber, plywood and corrugated iron, it is possible to orchestrate a space that transforms as time passes, one which continuously connects the inhabitant with the sacred landscape. Through pragmatism and simplicity, Murcutt achieves a space that transcends time and yields in poetry.

4.2. Architectural promenade

From a distance (Figure 58), the ochre coloured walls of the house contrast with the clear blue skies and the green background. Sun is bright, the air warm. Not far away, the sound and aroma of the sea caressing the sand and wind blowing through the trees, instantly sets you in tropical bliss.

As you approach the building, a continuously changing melody of slatted shutters and tilting plywood panels caught the eye (Figure 59). A long and slim house, composed of basic building materials...
stands on thin steel pillars rising from the ground; yet, through this apparent disconnection, the house and place fuse, becoming one. The background and foreground are lost in a thin line.

Once the viewer reaches the wooden stairs, tall and sensibly separated timber slats allows the gaze to slowly discover the interior of the house. Like a hide-and-seek game, the house’s operable elements invite the visitor to play and discover, while always framing nature. Suddenly, a long slatted door opens.

Once inside, the guest steps into the houses’ open and unrestricted living space (Figure 60), one where light, shadows and fresh air are continually combined. To the left, a floating wooden volume (i.e. the kitchen’s furniture) is framed by a mesh at floor level and four large openings carefully separated by thin and curvy pointed plywood dividers (i.e. the sun-breakers), which extend beyond the edge of the room. Once the gaze revolves around the space, the metal-wooden realm is fully discovered.
Moving along the corridor, following the direction of the timer floor, the continuous game of shadows guides the visitor; turning left several wooden-louvered doors reveal the children’s bedrooms. Just as in the living space, the bedroom’s beds (Figure 6) are once more disconnected from the floor, allowing ventilation to run freely in the space.

When the backside of the bed is reached, a wide wooden frame allows the gaze to be enraptured by nature; the views and close relationship between man and landscape are always present in this house.

Figure 60. Interior views from the living space. A realm of steel and wood - the materialization of a balanced world between manmade and nature. Photography by Reiner Blunck. Source: El Croquis (2012)
Once back in the corridor, the last louvered door announces the end of the journey, the master bedroom is revealed. Once the visitor steps in, a double-bed touches the wooden flooring and welcomes you. In this room, the space where the bed would’ve stretch out into the exterior, a soft fabric invites you to sit (Figure 62) and contemplate nature. Openings on the three sides of the room are permanently reminding the inhabitant that the significance of this space lies in how through the thoughtful liaison, between manmade space and nature, a lost and profound relationship is revitalised. Light, space and materiality are always outlining the holiness of the natural environment. Finally, man is free.

Figure 61. Interior view of the children's bedrooms. A floating bed, and operable slatted shutters continually frame nature. Photography by Reiner Blunck. Source: El Croquis (2012)

Figure 62. Interior view from the master bedroom. Detail on the sitting area and operable openings which always link interior with exterior. Photography by Reiner Blunck. Source: El Croquis (2012)
4.3. Microclimate analysis: Eastern Arnhem Land, NT

Eastern Arnhem Land, is located in the northern coastline of Australia (Figure 63). According to NatHERS’ climate zoning, it is located within the 1st climate region based on weather data from Darwin, NT. Due to its location (within the Tropic of Capricorn), and conforming to BOM (2014), the tropical climate in the north of NT, experiences high temperatures, humidity levels and rainfall annually. Essentially, the site experiences two distinct seasons (Figure 64): wet (October - April) and dry (May - September) during which, strong monsoon winds might impact the site.

Figure 63. Marika-Alderton house: Location and coordinates. Source: Author (2014)

Figure 64. Monthly Diurnal Averages. Weather data for Darwin, NT. Source: NatHERS (2014)
As Figure 64 shows, this site experiences constant high temperatures, having an annual average temperature of 27°C and a maximum and minimum temperatures of 35.1°C (September) and 16.2°C (July), additionally to this, high levels of solar radiation (averaging in 500 W/m²) suggest that the design must cope with these conditions, allowing heat loses, while blocking sunlight. Correct shading and opening design is essential to encourage passive cooling.

Additionally to the sunlight's effect, and according to BOM (2014), the annual average rainfall for Darwin is above 900 mm, which shows that high levels of rainfall has to be considered. Figure 66, shows the total annual rainfall in the zone.
Annually, the sky conditions for this zone (Figure 67), shows that the median cloud cover ranges from mostly clear (wet season) to mostly cloudy (dry season), greatly varying during the year. This fluctuation is substantial, suggesting that both types of sky should be considered for the house’s daylight performance and comfort analyses.

Due to the site’s location, and that during the dry season the building might be impacted by strong gusts of winds, considering the frequency and direction of the prevailing winds is fundamental, as the combination between temperatures, radiation, rainfall and winds will influence on the overall performance of the building.

According to NatHERS (2014), the annual wind frequency (Figure 67), indicates a higher frequency direction of prevailing winds from the W and SE. Nevertheless, during summer, (wet conditions) the prevailing winds come mainly from the W, while during winter (dry conditions) they come from the SE.

Figure 67. Wind frequency and direction for Darwin, NT. Left: Annual frequency. Middle: Wet season prevailing wind frequencies. Right: Dry season prevailing wind. Diagrams by Weather Tool (ECOTECT).

Source: NatHERS (2014)

Figure 68. Marika-Alderton house orientation vs. Optimum orientation for Darwin, NT. Source: NatHERS and Ecotect’s weather tool (2014)
The building’s positioning and orientation is fundamental to have an overall balanced performance. Figure 68 shows that the sunpath will be very similar throughout the year; implying that the site will be exposed to sunlight similarly during both seasons, therefore providing equal shading in the N and S facades is essential.

According to NatHERS (2014), the optimum orientation for any building in the zone implies a 357.5° compromise from the North. From the sunpath and orientation analysis, it is suggested that in order for the house to perform, sunlight has to be continually minimized through proper shading and ventilation strategies.

Taking into account all these climatic characteristics is fundamental to understand Murcutt’s design intentions and to test both the visual and environmental performance of the house. A correct orientation, plus carefully designed openings, skin thickness and shading, will yield in a comfortable space throughout the year, as shown by the psychrometric chart (APENDIX XX).

4.4. Orientation, sun, wind and form: Rules of thumb design analysis

As previously discussed, orientation due North is fundamental to Murcutt’s work and, as Figure 69 shows, the Marika-Alderton follows this principle, denoting a careful understanding of the sunpath. This strategy assures that shorter facades will receive higher intensity of solar radiation, while the longer facades less; when the Eastern and Western facades are observed, despite having openings, these are opaque, making it possible for them to completely block the sunlight as required. Additionally, given the proximity to the Equator, the roof will constantly receive the highest solar radiation – and heat gains.

Figure 69. Floor plan and orientation. Source: Author (2014)
The relationship between the spatial arrangement and the sun’s trajectory can be fully appreciated in Figure 70. Echoing Murcutt’s design intention – of designing the house based on the traditions of the aboriginal people, when the sun path is overlapped with the plan, his words are materialized. As it can be appreciated, Murcutt positioned the living space to the East, were the sun rises, bathing the space with daylight and wind throughout the year; to the West, the master bedroom faces towards the symbolic death of everyday - the sunset -; while to the East, - were each day is born -, the children’s bedrooms were carefully positioned. Finally, to the South, the fin-like sunbreakers protect all spaces from the low angles sunlight of morning and afternoon. Undoubtedly it seems the house was intentionally designed to respond to the sun.

Figure 70. Solar access and spatial arrangement. Floor plan is over layered by the sun path diagram during summer solstice and winter solstice. Source: Author (2014)
In order to fully appreciate the relationship between the sun’s path and the spatial design, it is necessary to analyse the shadow patterns projected into the interior both at 08:00 (Figure 71) and noon (Figure 72), as the critical cases. It is important to consider that during noon, the building must provide correct shading to ensure that undesired heat gains are obstructed, while at 08:00, direct sunlight is desirable in the living spaces but not the bedrooms; therefore, it is essential to assess the actual performance of the sun-breakers.

As Figure 71 evidences, during early morning (08:00h), the shading provided both by the roofing and the sun-breakers perform as designed; as expected, early sunlight is allowed into the living space once tilting plywood panels are left open, while the sun-breakers block the low-angled sunlight falling into the Southern façade and therefore bedrooms.

During noontime, as Figure 72 shows, the roof as designed by Murcutt offers complete shading to the interior space, blocking not only the harsh direct sunlight, but most importantly the heat gains linked to it.
The sun-breakers block the low angled sunlight of the morning, providing protection to the Southern facade and interior spaces.

Direct sunlight penetrates the interior of the living space only; the sun-breakers provide complete shading to the bedrooms, blocking direct light and heat gains.

Figure 71. Sun and space: solar access and shadow cut-away sections at 8 a.m. Source: Author (2014)
The roof’s eaves provide complete shading to the interior spaces throughout the year during noon, the most critical time.

Figure 72. Sun and space: solar access and shadow cut-away sections at noon. Source: Author (2014)
Despite that it seems that most of the design was carried out through the development of the plan, the house’s section emphasizes its significance to conveying a climate responsive project; furthermore, in the section Murcutt is able to study the interaction and spatial outcome between climate and geometry, materializing and translating into his own architectural language the lessons learnt from vernacular architecture.

When the house’s section is overlapped with the different solar angles during summer and winter solstice and equinox (at noon), as Figures 73 and 74 show, the relationship between the section and sun becomes stronger, and corroborates the significance of the section as a basic design tool for correctly dimension elements (e.g. roof) in accordance to the climate’s conditions, yielding in an equally shaded space regardless of the season.

The combination between the roof and the sun-breakers yield a completed shaded interior space. The only moment when direct sunlight touches the envelope - at noon - is during summer, nonetheless the effect is almost imperceptible.

Figure 73. Marika-Alderton section and solar access at noon. Left: Summer solstice - Right: Winter solstice. Source: Author (2014)
Sun and wind are inherently fused in this design. Exterior and interior are merged into one, allowing the house to receive constant fresh air, aiming to cool down the interior space naturally once combined with the shading strategies. Nevertheless, it is important to consider as CLEAR (2014) explains, open spaces (such as this house), will gain heat during the day, as they are permanently in contact with the exterior and therefore are dependant of the exterior temperatures. This condition suggests that possibly, shading strategies alone will not sufficiently cool down the space, requiring an increase in wind speeds in order to decrease temperatures inside.

Both in plan and section the house was designed by Murcutt to encourage continuous cross-ventilation, as shown by Figure 75. The basic rule of thumb calculation (Appendix 6) for naturally ventilated spaces indicates that cross-ventilation will work independently of the season, as a passive strategy aiming to cool down the interior temperatures.

Figure 74. Marika-Alderton section and solar access at noon during Winter solstice. Source: Author (2014)
Increasing the wind’s speed coming into the house is essential to attempt decreasing the interior temperature. Considering this, additionally to the fact that the site is exposed to monsoon winds, Murcutt cleverly included in the roof several Windworkers, in order to continually encourage the exhaustion of warm air and odours from the inside (Venturi effect), while the devices reduce any pressure built on the inside of the building during cyclones (Windworker, 2014). As Figure 76 shows, these devices will help to increase air flow within the house, leading to the extraction of heat trapped in the roof.

Figure 75. Rule of thumb calculation for cross-ventilation in the living space. Natural ventilation is continually encouraged through the operable slatted openings, tilted plywood panels or flooring. Source: Author (2014)

Figure 76. Cross-ventilation and Venturi effect produced by Windworkers. Air movement is continually encouraged in order to decrease the interior temperatures. Source: Author (2014)
According to these basic analyses, they point towards a building which was carefully designed to wholly respond to climate. The findings indicate that a thoughtful consideration of climate yielded in the design of the house’s envelope, allowing it to be light-weighted and virtually fully operable and giving the inhabitant control of their environment. Lastly, these results indicate that the house was designed to convey a comfortable, secure and spiritual space. The uninterrupted and balanced connection between man and nature has once again be materialized into an expressive, yet practical architecture.
4.5. Visual environment and daylighting performance analysis

As described in Figure 5, and given the activities held within a household, no exceptional daylighting requirements are needed, nevertheless and to ensure that the spaces are correctly day-lit a minimum daylight factor of two percent was considered as a guide to analyse the visual performance.

As Figure 77 shows, the average daylight factor in the main living spaces ranges between three to five percent, indicating that even during an overcast sky condition, all spaces are naturally well-lit and no extra lighting from artificial sources is needed. Additionally, the uniformity of illuminance achieved shows there’s a more evenly distributed daylighting in the bedrooms (0.6) when compared to the living space (0.4); the dimensioning of these bedrooms, as well as the sunbreakers were designed to achieve a more soothing and calming atmosphere; whereas in the living space, Murcutt thoughtfully orchestrated the openings intentionally to create a more vibrant atmosphere, in accordance with the activities held there.

Figure 77. Daylight factor plot, uniformity ratios and light journey in the Marika-Alderton house. Source: Author (2014)
Figure 78. Light journey’s views showing the spatial daylighting variation. Source: Author (2014)
The daylight variation within the house can be better appreciated through a light journey (Figure 78), which provides further evidence on Murcutt’s design intentions. Through the design of slatted openings, not only is ventilation controlled, but daylight too; through these wooden slats, acting as screens, daylight is filtered, giving the inhabitant’s sight a rest from the harsh exterior light.

Once the journey is analysed in section (Figure 79), the dynamism in light variation throughout the spaces is noticeable, aiming to make a difference between the lively spaces (i.e. living space and corridors), from the calmer atmosphere needed in the bedrooms.

Figure 79. Daylighting sections, showing the effect the building’s geometry has on the daylight distribution.

Top: Living space. Bottom: Bedrooms Source: Author (2014)
4.5.1. Visual performance study under sunny sky conditions: Illuminance

In order to understand how daylight varies - and the effect it has on space -, it is essential to assess the illuminance distribution. The study aims to have a full understanding on the daylighting performance of the house; illuminance was assessed both under overcast and sunny sky conditions, at noon time (worst case scenario), during summer and winter solstice, as well as during equinox. All results were compared to Table 7.

According to Figure 80, there is a significant variation in the illuminance levels under both sky conditions. Firstly under sunny skies the overall illuminance levels are considerably higher than CIBSE’s (2007) recommendations, nevertheless it is very important to remark how daylight is fragmented once it touches the sunbreakers, providing further evidence on their importance to the overall performance of the house. Once light is broken, it is reflected by the countertops and wall’s edges into the roof, and later to the space. Despite this light filtering, the lux levels under sunny sky conditions remain very high (above 700 lux), suggesting that once the slatted openings, or tilting plywood panels are closed, the condition will be greatly improved throughout the year.

Under overcast skies, light has already been filtered before it reaches the sunbreakers. This circumstance greatly enhances the illuminance levels in the interior, achieving comparable illuminance levels (ranging between 250 – 300 lux) as recommended.

Despite the high levels of illuminance achieved by the house (with all openings horizontally), the interior space is well-lit and will not need further artificial lighting to provide visual acuity. Nevertheless, the results under both sky conditions point towards a better daylighting performance – and ambiance -, once the slatted shutters are brought down.
## II. VISUAL PERFORMANCE ASSESSMENT: MARIKA-ALDERTON HOUSE, East Arnhem (NT)

### SUNNY SKY CONDITION

<table>
<thead>
<tr>
<th>Season</th>
<th>Date</th>
<th>Time</th>
<th>Solar angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer solstice</td>
<td>21st December</td>
<td>Noon</td>
<td>75°</td>
</tr>
<tr>
<td>Equinox</td>
<td>22nd March</td>
<td>Noon</td>
<td>72°</td>
</tr>
<tr>
<td>Winter solstice</td>
<td>21st June</td>
<td>Noon</td>
<td>52°</td>
</tr>
</tbody>
</table>

### OVERCAST SKY CONDITION

<table>
<thead>
<tr>
<th>Season</th>
<th>Date</th>
<th>Time</th>
<th>Solar angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer solstice</td>
<td>21st December</td>
<td>Noon</td>
<td>75°</td>
</tr>
<tr>
<td>Equinox</td>
<td>22nd March</td>
<td>Noon</td>
<td>72°</td>
</tr>
<tr>
<td>Winter solstice</td>
<td>21st June</td>
<td>Noon</td>
<td>52°</td>
</tr>
</tbody>
</table>

**Illustration:**

- **Figure 80.** Illuminance mapping (using Radiance) of living space and bedrooms under overcast and sunny sky conditions.  Source: Author (2014)
4.5.2. Visual comfort study: Luminance ratio study

Due to human's sensibility to brightness, the space has to be designed to assure that high brightness of the light emitted or reflected (CIBSE, 1994) is controlled to a minimum in order to offer visual comfort too. Moreover, it is very important to study the luminance environment in the house, to understand whether the chosen building materials and geometry may lead the inhabitant to look away from a bright light source (e.g. artificial lighting, sunlight or an overcast sky), or to simply struggle seeing a task (CIBSE, 1994). For this assessment the same methodology as described in Section 3.5.2 was followed.

According to the results (Figure 81), in all the spaces, the relationship between the visual targets and their surroundings proves that experiencing glare is unlikely to occur. The clever selection of building materials with low reflectance (i.e. mostly wood in the interior), decreases the chance of experiencing glare. Nevertheless, this study was performed considering that all openings remained opened, in order to have the worst case scenario. Accordingly, if the openings were lowered, this most probably will enhance the comfortable levels in the interior, by lowering the luminance levels and preventing furthermore any possibility of experiencing visual discomfort.
II. VISUAL COMFORT ASSESSMENT:

<table>
<thead>
<tr>
<th>LUMINANCE (cd/m²) ASSESSMENT – RADIANCE OUTPUT + MEASURING POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer solstice (21st December)</td>
</tr>
<tr>
<td>Time: Noon Solar angle: 75°</td>
</tr>
<tr>
<td>Equinox (22nd March)</td>
</tr>
<tr>
<td>Time: Noon Solar angle: 72°</td>
</tr>
<tr>
<td>Winter solstice (21st June)</td>
</tr>
<tr>
<td>Time: Noon Solar angle: 52°</td>
</tr>
</tbody>
</table>

Figure 81. Luminance mapping (using Radiance) of living space and bedrooms under overcast and sunny sky conditions. Source: Author (2014)
4.6. Thermal Environment

Analysing the thermal environment of the Marika-Alderton house is essential to have a full understanding of the building’s performance, and its impact on the comfort and spatial ambiance.

For this analysis, initial considerations like the fact that the house is mainly a large verandah, (semi-open space with no glazing) and therefore is dependent on the exterior air temperatures and wind speeds to cool down, was considered. Additionally, the shallow envelope (built on elements with low thermal properties), and warm air been constantly pushed into the house, pointed towards a not very encouraging thermal performance study.

In order to determine whether the house offers comfortable conditions as designed, separate simulations were carried out and the resultant temperatures in key spaces were compared to the monthly acceptable comfort zone for Darwin, NT. (Table 9)

Table 9. Monthly average temperature vs optimal temperature for comfort in Darwin, NT.  Source: Author (2014)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average temperature (°C)</th>
<th>Comfortable operative temperature - Tcomfop (°C)</th>
<th>Acceptable lower temp band (°C)</th>
<th>Acceptable top temp band (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>27.9</td>
<td>26.4</td>
<td>24.4</td>
<td>28.4</td>
</tr>
<tr>
<td>February</td>
<td>27.8</td>
<td>26.4</td>
<td>24.4</td>
<td>28.4</td>
</tr>
<tr>
<td>March</td>
<td>27.8</td>
<td>26.4</td>
<td>24.4</td>
<td>28.4</td>
</tr>
<tr>
<td>April</td>
<td>27.7</td>
<td>26.4</td>
<td>24.4</td>
<td>28.4</td>
</tr>
<tr>
<td>May</td>
<td>26.8</td>
<td>26.1</td>
<td>24.1</td>
<td>28.1</td>
</tr>
<tr>
<td>Jun</td>
<td>24.8</td>
<td>25.5</td>
<td>23.5</td>
<td>27.5</td>
</tr>
<tr>
<td>Jul</td>
<td>24.3</td>
<td>25.3</td>
<td>23.3</td>
<td>27.3</td>
</tr>
<tr>
<td>Ago</td>
<td>25.4</td>
<td>25.7</td>
<td>23.7</td>
<td>27.7</td>
</tr>
<tr>
<td>Sep</td>
<td>27.7</td>
<td>26.4</td>
<td>24.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Oct</td>
<td>29</td>
<td>26.8</td>
<td>24.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Nov</td>
<td>28.9</td>
<td>26.8</td>
<td>24.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Dec</td>
<td>28.6</td>
<td>26.7</td>
<td>24.7</td>
<td>28.7</td>
</tr>
</tbody>
</table>

Figure 82. Monthly adaptive thermal comfortable range for Darwin, NT.  Source: Author (2014)
In order to comprehend the relationship between the envelope’s design and its building materials, Table 10, shows the thermal properties considered for the thermal simulation of the house. Additionally, in order to simulate the Windworkers ‘Venturi’ effect on the house, opaque openings were added to the roof.

Table 10. Typical thermal properties of common building materials found in the Marika-Alderton house. Table by Author based on Appendix 1 by Kyle (1999).

<table>
<thead>
<tr>
<th>Description/Composition</th>
<th>Thickness (mm)</th>
<th>Density (kg/m³)</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Specific heat (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood board</td>
<td>6mm</td>
<td>545</td>
<td>0.12</td>
<td>1.21</td>
</tr>
<tr>
<td>Hardwoods (oak, maple, tallowwood)</td>
<td>-</td>
<td>720</td>
<td>0.16</td>
<td>1.25</td>
</tr>
<tr>
<td>Corrugated iron</td>
<td>5mm</td>
<td>-</td>
<td>8.5</td>
<td>1.22</td>
</tr>
<tr>
<td>Steel (mild)</td>
<td>-</td>
<td>7833</td>
<td>45.3</td>
<td>0.50</td>
</tr>
</tbody>
</table>

4.6.1. Thermal simulation and results

The thermal simulation performed for the Marika-Alderton house (Appendix 8) aimed to have an overall idea on the annual performance of the main living spaces. Separate simulations for each space were performed to have more accurate results. Three simulation cases (Table 11) were designed with the intention of providing evidence of the relationship and effect that solar radiation, natural ventilation and internal heat gains have on the resultant temperatures in these key spaces during a year. For this study, the assumptions described in Table 12 were considered.

Table 11. Marika-Alderton description of thermal simulation cases. Source: Author (2014)

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Shell with 0.5 infiltration rate + 1 ach (30% natural ventilation*) NO internal heat gains considered.</td>
</tr>
<tr>
<td>Case 2</td>
<td>Shell with 0.5 infiltration rate + 1.5 ach (30% natural ventilation*) + internal heat gains considered.</td>
</tr>
<tr>
<td>Case 3</td>
<td>Shell with 0.5 infiltration rate + 2.5 ach (90% natural ventilation*) + internal heat gains considered.</td>
</tr>
</tbody>
</table>

* Natural ventilation is assumed 24 hours, 365 days

Table 12. Summary of internal conditions and assumptions considered during thermal simulation.
Source: Author (2014)

<table>
<thead>
<tr>
<th>Internal conditions</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed occupancy hours</td>
<td>24 hours / 7 days a week</td>
</tr>
<tr>
<td>Assumed occupancy</td>
<td>2 adults / 4 children</td>
</tr>
<tr>
<td>Opening schedule</td>
<td>Based on occupancy - yet partial natural ventilation is allowed 24 hours a day / 7 days a week</td>
</tr>
<tr>
<td>Heat gains from occupants*</td>
<td>450W (sensible) and 250W (latent)</td>
</tr>
<tr>
<td>Equipment sensible gains</td>
<td>25 W/m²</td>
</tr>
<tr>
<td>Lighting gain</td>
<td>1.5 W/m²</td>
</tr>
<tr>
<td>Natural infiltration rate</td>
<td>0.5 ach / 24 hours</td>
</tr>
</tbody>
</table>
The living space’s performance was analysed from a monthly and seasonal (Figures 83 and 84) perspective, in order to have a holistic approach to the envelope’s thermal performance; as mentioned before, Murcutt’s intention of designing the house as a semi-permeable verandah, has to be continually recalled in order to have an impartial analysis.

Figure 83. Living space monthly percentage of hours in comfort zone vs. average monthly temperatures.
Source: Author (2014)

Figure 84. Living space seasonal thermal performance vs. average exterior and resultant temperatures.
Source: Author (2014)
On a monthly basis (Figure 83), Case 1 generated mixed performance results, having a better performance (compared to the other cases) during midseason, while declining at peak seasons months; overall, the room’s performance is fairly unchanging (with an average of twenty percent of the time within the comfort range), nevertheless remains low. During peak winter months, the performance falls five percent between May and June, and then increases to over twenty percent in August, clearly coinciding with the exterior temperature pattern, and therefore reinforcing CLEAR’s (2014) argument on the dependency of semi-open spaces on the exterior temperature.

On a yearly basis and in correlation with the monthly performance, the results follow the same pattern, demonstrating that when the operable openings are maintained closed, resultant temperatures (ranging between 30°C and 35°C) are affected, leading to higher interior temperatures when compared to the average exterior ones. Overall Case 1 yields a low percentage of time within the comfortable range.

When Case 2 is analysed, the performance results show slight improvement in the space’s thermal performance (even when internal heat gains are considered) when compared to Case 1. As Figure 83 shows, the percentage of time within the comfort zone increases from an average of twenty percent to twenty five percent; denoting that a slight increase in air supply (i.e. 1.5 ach with an aperture of 30%) represents a slim improvement for the internal conditions and comfort levels.

Annually, and when compared to the Operative comfortable temperature (Table 9), it shows that despite the percentage of time within the comfort zone is higher and temperatures are decreased (when compared to Case 1), the resultant temperatures are still higher than the exterior, ranging between 28°C and 32°C, and indicating an overheating potential.

Unexpectedly, even when Case 3 in a monthly basis yields a slight improvement when compared to Case 2, it reveals that even when a much higher ventilation rate is available (2.5 ach with 90% of aperture in all openings) still, the space is not able to significantly decrease the interior resultant temperatures. However, it is important to notice the difference in the performance during peak season’s months; while from July to August, Case 3 represents the best performance scenario, (increasing the percentage of time within the comfortable range) during November and December, it falls below Case 1, denoting that still with a higher supply of air, the space is not capable of exhausting the heat retained under the roof.

Overall, the performance of the living space falls on an average of twenty percent of the time in the comfort zone, suggesting that the envelope’s design is not efficient and might require extra cooling to achieve higher levels of comfort.
Following the living space analysis, the bedrooms’ thermal performance was assessed; the monthly and seasonal results are shown in Figures 85 and 86. It is important to consider that compared to the living space, the bedrooms have a more enclosed spatial configuration and mainly receive single-sided ventilation.

![Figure 86. Bedrooms monthly percentage of hours in comfort zone vs. average monthly temperatures.](source)

![Figure 85. Bedrooms seasonal thermal performance vs. average exterior and resultant temperatures.](source)
When the overall results for the bedrooms’ performance is analysed, as shown in the previous figures, their performance follow a very similar pattern as the living space’s, only reinforcing the fact that the building by itself, is only capable of providing thermal comfortable spaces for an average of twenty percent of the time.

It is very important to mention that based on Murcutt’s design principle, were his buildings are designed to thermally react as a person would do to temperature changes, (i.e. by adding or removing clothing layers) the Marika-Alderton house is no exception. Thermal comfort in this location is very hard to achieve, mostly by its climate conditions (high temperatures and humidity levels), nevertheless, Murcutt designs an envelope fully capable of responding to its context, allowing the inhabitant to control their environment and most importantly, the needed air movement and speed in the house; however, behaviour and low clothing insulation levels might play an important factor in order to achieve an adaptive thermal comfort.

Finally, while Murcutt intentionally designed an air gap between the interior walls and the roof, no ceiling or insulation is provided. As mentioned before, the roof is the most exposed surface to solar radiation throughout the year, therefore these results suggest that the air gap, additionally to the Windworkers are not sufficient to yield a more comfortable space; adding a ceiling with roofing insulation might improve this condition as the study by Wang, Chen and Zhengen (2010) shows.

4.7. The Marika-Alderton house: Summary

According to the results from the basic rules of thumb for daylighting and the performance and comfort analyses, the results have proven that the luminous environment performs as designed, conveying a well-lit and comfortable space accordingly to the minimum daylighting recommendations for housing design by CIBSE.

Murcutt correctly oriented the house, providing it with the correct solar access when needed, while blocking the heat gains and harsh low-angled sunlight during crucial hours. From a holistic point of view, the combination between the house’s symmetrical form, its long eaves, the selected building materials and the operable slatted openings, an interior that not only protects the inhabitant from the harsh sun, but also provides shading and continuous fresh air is shaped.

In terms of daylighting, and despite that all values fall within the established benchmarks -, simple elements (such as the operable slatted shutters, or tilted plywood panels) designed by Murcutt to control the access of sunlight, will further improve the performance and visual atmosphere of the house if tested while closed.

Thermally speaking, despite the results are not as encouraging, the house performs as expected. It was designed to be continually in contact with the exterior, thus it will always be dependent on the exterior temperatures and humidity levels. Despite that Murcutt properly sized the roofs’ eaves to protect
the interior from sunlight, the house, as a free-running building seems to need additional cooling strategies, in order to yield a more comfortable space. Additionally, it is evident that the quantity of air flow and speed needed in the interior to exhaust warm air trapped in the roof is considerable; air flow when combined with the shade provided by the roof is fundamental to decrease the internal temperatures; without proper ventilation and air speed, the house alone seems unable to provide a comfortable atmosphere. Nevertheless, as Nicol, Humphreys & Roaf (2012) explain, the perception of thermal comfort varies between people, their behaviour, metabolic rate and clothing. Being the house positioned in the shoreline, the sea breeze, additionally to lower clothing levels and reducing the level of activity will potentially enhance this condition.

Finally, despite the house’s romantic reminiscence of the aboriginal house, it is very important to emphasize that the combination between Murcutt’s pragmatic ideas, with a thorough understanding of the site-specific climate, yielded in what could be considered an almost perfect ‘machine’ to live. The brutal honesty of this design, and its building materials, clearly show the convergence between Murcutt’s beliefs and the client’s needs, but most importantly, through this design, Murcutt’s materializes his teachings and well known motto of ‘touching this Earth lightly’ (as cited by Drew, 1986).
5. COMPARATIVE ANALYSIS

From a quick glance, both the Ball-Eastaway and Marika-Alderton houses deceives the viewer; their apparent simple and modest proportions, materials and aesthetics might seem diametrically different, but once observed from a closer distance, their similarities are revealed.

As Figure 87 shows, both houses have an elongated, narrow plan; undisputedly, one of Murcutt’s most rooted design principles. It is through this narrow plan that Murcutt assures the interior spaces will be well-lit and ventilated. Nevertheless of this similarity, the most significant difference between the houses lies on their orientation.

According to Murcutt’s design doctrines, orientation due north is the most common, as it implies the optimum alignment in terms of gaining access to sunlight and winds. However, when designing the BEH, and accordingly to Murcutt, the house was intentionally oriented to 45°, in order to exploit the site’s views. Differing, the MAH was oriented facing north, responding directly to the climate elements. As it has been previously shown, while in the design of the BEH the poetic side of Murcutt prevailed, for the MAH, his practicality reigned.

As mentioned before, modern architecture had an important influence on Murcutt’s work; influence which is clearly stamped in these plans in the spatial arrangement, as serving spaces are positioned in one extreme, separated from the served spaces through a transitional space.

Although in plan both houses show great similarity, it is in their sections that essential and specific differences between each house are exposed. The BEH’s section was designed following three main factors, the views, the potential bushfires and the copious rainfall. The views were Murcutt’s main inspiration to fulfill the house’s intention of offering a soothing and relaxing atmosphere. Considering this reason, the building’s orientation is justified despite the performative consequences shown earlier. Additionally, the threat of occasional bushfires pointed the need to raise the building off the ground, while protecting the envelope’s exterior by using steel and iron elements. Finally, rainfall suggested the need to design a concave roof with wide gutters and downpipes to harvest rainfall in case of a fire.

When the MAH section is studied, it shows a simpler and pragmatic outline, one that entirely responds to the climate. Just as the BAH is raised off the ground, the MAH is raised too, nevertheless it is raised to encourage natural ventilation in the house. Contrasting with the BEH’s envelope, in the MAH, the envelope is lighter and mostly operable, as the high temperatures of the site suggested to Murcutt the need of providing continuous airflow and airspeed, as essential strategies to exhaust warm air from the interior space. Additionally, once Murcutt considered the sunpath, a double-pitched roof with long eaves was designed to cope with harsh daylight, protecting the interior from sun, wind and rain. For the MAH it is clear that Murcutt’s pragmatic side reigned during the design.
In terms of daylighting, and in relationship with each houses’ design intentions, two different daylighting conditions were designed. As Figure 88 shows, and despite the orientation of the BEH, Murcutt managed to provide proper daylighting to the space; furthermore, through the careful placing and sizing of openings, a smoother light variation throughout the house is conveyed, generating a calmer atmosphere. Opposing to this effect, in the MAH, Murcutt seeks to offer the space with a dynamic lighting, one that varies from a vivid ambiance in the living space, to a more peaceful atmosphere in the bedrooms. This effect is achieved through the composition of the different operable openings, which are able to filter or block daylight. In terms of visual acuity and comfort, both houses as designed yield well-lit spaces and provide a sense of well-being to the inhabitant.

The thermal comfort in these houses, and throughout Murcutt’s works, is intimately related to the effect that daylighting and natural ventilation have on the building’s envelope. As mentioned before, if there is one indisputable design principle in Murcutt’s work, designing free-running buildings has to be it, and to attain this most of Murcutt’s projects have light-weighted and operable envelopes, allowing the inhabitant to control their space, and therefore the effect sun, wind and heat might have on it.

Despite the thermal analyses for both houses yielded similar results, evidencing their low energy efficiency, these results only emphasize Murcutt’s beliefs of designing spaces that just as a person, are able to increase or eliminate layers as needed. The significance of this lies in the freedom Murcutt conveys through his designs. Whether in a hot or cold climate, Murcutt’s buildings share a common architectural language, by been open, light, operable and more importantly, to respond to the changing climate. Just as his houses perform, the inhabitant is expected to have an active role, adjusting the spaces, activity or clothing levels according to the needs.

Just as Farrelly (2002) noted, Murcutt’s architecture is considered both universal and specific. Undoubtedly, this is the case for these houses; even though they share an essence (in spite of their very different contextual conditions), once Murcutt thoroughly examines the site-specific climate conditions, distinctive architectural elements emerge, transforming the general into particular. In the case of the BEH, skylights were included to enhance both the daylighting and natural ventilation, while the chimney designed becomes essential to cope with the cold climate; on the other hand, in the MAH, Murcutt sensibly designed sun-breakers to manage the low-angled summer sun, while Windworkers in the roof enhance the airflow and airspeed pursuing to exhaust warm air from inside the house.

Finally, it is important to stress the fact that regardless of the location and climate of Murcutt’s projects, and despite their apparent withdrawal from their natural environment, all of his buildings while modest-looking, they follow a constant and disciplined design methodology, one that through observance of climate and the Australian landscape, yields in a whole range of responsive spaces and elements which are created once his poetic and pragmatic sides fuse. Evidently, to Murcutt spatial and environmental delight are a consequence of masterly orchestrating light, wind and landscape with humble shapes and materials. Through his operable and adapting spaces, Murcutt not only gives control of the manmade space to the inhabitant, but he quietly signalizes a way of living - in freedom.
Figure 87. Architectural and spatial comparative analysis. Source: Author (2014)
Figure 88. Daylighting performance and comfort comparative analysis. Source: Author (2014)
PASSIVE COOLING

(NATURAL VENTILATION STRATEGIES)

THERMAL PERFORMANCE AND DELIGHT

RESULTS IN LIVING SPACE'S AND BEDROOMS'

Figure 89. Ventilation and thermal performative comparative analysis. Source: Author (2014)
6. CONCLUSIONS

Through an in-depth analysis of two of Glenn Murcutt’s most distinguished projects, this research has attained a widespread understanding on the significance of his oeuvre. Moreover, through a critical and evidence based approach in the performative aspect of the buildings, it has contributed towards the study’s main objective by filling the gap in the existing knowledge of Murcutt's work.

Additionally, the study aimed to focus in two particular questions described below:

- How light and space design influences the spatial and environmental delight in Glenn Murcutt's houses?
- Are the key living spaces (i.e. bedrooms and living rooms) as designed, capable of performing and yielding a comfortable atmosphere and thermal delight?

From a qualitative point of view, this study managed to reveal not only Murcutt’s design intentions behind both houses, but moreover, the intricate relationship between the manmade space and nature. As Farrelly (2002) commented on the apparent contradictions in Murcutt's designs, the qualitative results have proven Murcutt’s (as cited by Godsell in El Croquis, 2012) own words, through simple forms and humble materials, Murcutt is continuously separating man from nature, not implying the superiority of one over the other, but on the contrary, through this ‘disparateness’ he continually frames nature’s sacredness. This process is evidenced through the refinement of his edges, or ‘feathering’ as described by Beck and Copper (2002).

Through a thorough site-specific climate analysis, the sunpath, prevailing winds and orientations were superimposed to fully grasp the environmental design intentions behind both houses; from this essential analysis, the first signs on the conceptual differences between both houses (and its possible performative consequences) were drawn. For instance, in the Ball-Eastaway house a poetic approach of the design reigned, intentionally giving priority to the site’s views over the optimum orientation and its daylighting and thermal implications; whereas in the Marika-Alderton house a pragmatic methodology ruled, leading to a building which is completely carved by and responsive to the climate.

This qualitative study included basic solar access and shadow analysis, as well as basic rule of thumb calculations for daylighting and natural ventilation which gradually pointed towards the quantitative results yielded, while enhancing the understanding of Murcutt’s spatial design and its relationship with nature.

From a quantitative perspective, the houses’ main rooms (i.e. living space and bedrooms) were analysed in terms of their luminous and thermal environments, in order to reveal the spatial delight produced by the relationship between Murcutt’s science (pragmatics) and art (poetics).
The luminous environments of both houses, although differing in conception (while in the Ball-Eastaway house, an overall soothing and calming ambiance is achieved; in the MAH, a wavering atmosphere, ranging from a vibrant living space to restful bedrooms is attained), the analyses results indicate that both buildings, as designed, are well-lit and won’t need artificial lighting to improve visual acuity, according to CIBSE (1994) recommendations. The daylighting design, in addition to the humble building materials, convey to the spaces a general sense of well-being and comfort.

When the thermal environments were studied, (and despite their not encouraging results), instead of weakening Murcutt’s design decisions, they were strengthened, as these houses regardless of the results, actually perform as designed.

As the results show, and considering the houses’ envelopes as designed, in the Ball-Eastaway house, the performance of the main spaces fall below an annual average of thirty-five percent of the time within the adaptive comfort range, being winter the most critical period of the year and suggesting extra heating might be needed (even when considering the positive impact the chimney’s heat gains yield), to enhance the overall comfort in the house However in the MAH, the percentage of time within the adaptive comfortable zone falls to an annual average of twenty-five percent, showing that the house is dependent on the exterior conditions, suggesting that additional strategies, (even when the effect of the Windworkers is considered) to increase the airspeed are necessary to decrease the interior temperatures throughout the year.

Nevertheless, when analysing these results it is necessary to consider that Murcutt designed these buildings to adapt accordingly needed. Their envelopes are light-weighted and operable, meaning that while the inhabitant controls the entry of fresh air and sunlight into the space, heat transfers will continuously leak through the envelope, having an impact on the thermal comfort.

The spatial and environmental delight in Murcutt’s buildings is found exactly in the delicate relationship between his romanticism and practicality. Through his pragmatism, Murcutt designs details and elements meant to respond to particular conditions and climates, when these details are seen as a whole, an architectural orchestra whose solely purpose is to enrapture the inhabitant in an emotive composition of light, wind, colours and textures borrowed from nature is revealed. Through this balance between poetics and pragmatics, amongst man and nature, Murcutt designs spaces which are vivid, healthy and delightful, but moreover, he creates spaces which continually invite the inhabitant to contemplate the landscape and live a simpler life.

The significance of this research not only lies in filling a missing gap on the existing knowledge on Murcutt’s work by depicting through evidence the energetic performance of these houses. Moreover, this study has revealed that his design methodology and principles are translated into performing spaces; therefore, this investigation might also embody a significant guideline of Murcutt’s design process, which can be applied and further developed by anyone interested in environmental design and free-running buildings.
7. LIMITATIONS AND FURTHER RESEARCH

The main limitation to complete this investigation was time. Hence, in order to have a broader panorama of how these houses would perform (visually and thermally) in other conditions, the following further studies could improve the researches scope:

- Study the visual and thermal performance that lowering the blinds (in the Ball-Eastaway house) and operable shutters (in the Marika-Alderton house) could have on the main spaces. Compare results.
- Study the effects that changing the Ball-Eastaway’s house orientation (towards north) might have on the visual and thermal environments and compare results.
- Analyse the effect that including a ceiling with insulation might bring to the Marika-Alderton house overall performance.
- Use physical modelling to study to complete shadow study.
8. BIBLIOGRAPHY AND REFERENCES

Books


Architectural magazines


Journals


109
Technical references


Photography, images and websites.


Mei (2010). Detailed section of the Marika-Alderton house. Available at: [http://megangroth.blogspot.co.uk/2010_03_01_archive.html](http://megangroth.blogspot.co.uk/2010_03_01_archive.html) [Accessed 3rd September 2014].


9. APPENDIX

MAIN FOCUS: ENERGY EFFICIENCY THROUGH BUILDING FABRIC DESIGN

Appendix 1 – Source: Author (2014)
Assumption assessed: Right window size – for right amount of daylight

Rule of thumbs states that: The window need to comprise at least 20% of the wall area

Assessment:

Areas:
- Wall area: 23.3m²
- NW opening (louvers): 8.8m²
- Opening area vs. Floor area: 37.7%

Results:

Window sizing in the NW façade seems correct, suggesting there is good access to daylight in the living space of the house. Additionally, the opening area to the verandah has to be considered, as well as the rooflight in the kitchen area.

Appendix 2
Source: Author (2014)
Assumption assessed: Right window size – for right amount of daylight

Rule of thumbs states that: The window need to comprise at least 20% of the wall area

Assessment:

Areas:
- Wall area: 14.5 m²
- SW opening (louvers): 14 m²
- Opening area vs. Floor area: 95%

Results:

Window sizing in the SW façade seems correct, suggesting there is good access to daylight in the bedrooms of the house; nevertheless, due to the houses' orientation, these rooms have no direct access to sunlight throughout the year, especially during winter, which may affect not only the visual comfort and performance, but specifically the thermal.

Source: Author (2014)
Assumption assessed: Single sided ventilation (roof light and verandah’s opening closed)

Rule of thumbs states that:
1- Maximum room depth for single sided ventilation is 6m
2- Opening area of at least 5% of the floor area

Assessment:
1 - Room depth: 6.6m (not complied)
2 - Areas: 
   - Floor area: 60.7 m²
   - NW opening (louvers): 8.6m²
   - Opening area vs. Floor area: 14.5%

Results: Single-sided ventilation MAY work, although plan is deeper.

Assumption assessed: Cross ventilation (roof light and verandah’s doors opened)

Rule of thumb states that:
1- Maximum room depth: 5 times height
2- Opening area at least 5% of the floor area

Assessment:
1 - Room depth: 6.6m - maximum depth: 11m
2 - Areas: 
   - Floor area: 60.7 m²
   - NW opening (louvers): 8.6m²
   - NE opening (door): 26.4 m²
   - TOTAL: 35.2m²
   - Opening area vs. Floor area: 58%

Results: Cross-ventilation will work.

Source: Author (2014)
Assumption assessed: Bedroom single sided ventilation

Rule of thumbs states that:
1. Maximum room depth for single sided ventilation is 6m
2. Opening area of at least 5% of the floor area

Assessment:
1. Room depth: 4.2m (complies)
2. Areas:
   - Floor area: 13.4 m²
   - NW opening (louvers): 6.7 m²
   - Opening area vs. Floor area: 50%

Results: Single-sided ventilation WILL work in the bedrooms.

Appendix 4
Source: Author (2014)
Here we have the award winning Walltherm Zebru, the most efficient wood burning stove in the world. It is shown above with the optional log box and tool store, priced separately. It is available in black or grey and has a nominal output of 10.5 kW to water and 4.5 kW to the room. The combustion rate is thermostatically controlled and the air can be brought directly from outside making it suitable for highly insulated houses. The direct air fitting can be taken from the back or the base of the appliance. The stove would normally be connected directly to a thermal store, allowing you to harness the heat when and where you want it and providing the domestic hot water as well as heating the house.

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Source: Stoveonline.co.uk (2014)

http://www.stovesonline.co.uk/wood_burning_stoves/Walltherm-Zebru.html
Assumption assessed: Cross ventilation (slatted main door and openings opened)

Rule of thumb states that:
1. Maximum room depth: 5 times height
2. Opening area of at least 5% of the floor area

Assessment:
1. Room depth: 4.5 m - maximum depth: 22.5 m
2. Areas:
   - Floor area: 35.4 m²
   - N openings (slatted doors and windows): 15.8 m²
   - S openings (slatted windows): 9 m²
   - E openings (plywood windows): 9.6 m²
   - TOTAL: 34.4 m²
   - Opening area vs. Floor area: 97%

Results: Cross-ventilation will work.
Appendix 6 cont.
Source: Author (2014)
Top: Ball-Eastaway 3D model and zoning in TAS. Bottom: description of thermal cases simulated in key spaces (i.e. bedrooms and living space).
Source: Author (2014)
**Top:** Marika-Alderton 3D model and zoning in TAS. **Bottom:** description of thermal cases simulated in key spaces (i.e. bedrooms and living space).

Source: Author (2014)