

## THERMAL PERFORMANCE STUDY OF CONVENTIONAL AND NEW HOUSE WALL SYSTEMS

Fayez Aldawi<sup>1,2</sup>, Hazim Moria<sup>1,2</sup>, Firoz Alam<sup>1</sup>, Abhijit Date<sup>1</sup> and Aliakbar Akbarzadeh<sup>1</sup>

<sup>1</sup>School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia

<sup>2</sup>Department of Mechanical Engineering, Yanbu Industrial College, Kingdom of Saudi Arabia

### ABSTRACT

The residential housing sector is one of the largest energy consumers in the developed world and subsequently the largest greenhouse gas emitter. The overall potential impact of the residential housing energy and materials consumption on global warming, ozone depletion, nitrification and acidification is significant. The ultra energy efficient residential house envelopes that utilises optimal thermal mass and insulation, ensuring occupant comfort, energy savings and good indoor air quality, will not only reduce ongoing energy bills but also reduce consumption of fossil fuel and greenhouse gas emissions. This paper describes the thermal performances of a conventional and new house wall system for two climatic zones (moderate and subtropical). The energy performance has been evaluated using an Australia wide accredited energy performance simulation software AccuRate. The simulated results indicate a significant improvement in terms of energy savings of the new house wall system compared to the conventional house wall system. A notable reduction of greenhouse gas emissions can also be achieved based on the simulated results.

**Keywords:** House Envelope, Energy Rating, Thermal Performance, Greenhouse Gas Emission.

### 1. INTRODUCTION

Energy consumption in the housing sector especially residential buildings is rapidly increasing globally. Therefore, greenhouse gas emissions are also increasing. As urbanization in developing countries has been accelerating exponentially, thanks to rapid economic growth, house construction activities will also be associated with this. Therefore, global warming due to the increase in the number of new houses being constructed will accelerate further unless new energy efficient house wall systems are introduced. Figure 1 shows the residential household energy uses in Australia for heating and cooling. The household energy consumption was estimated to be approximately 40% of the total energy used. [1-3]

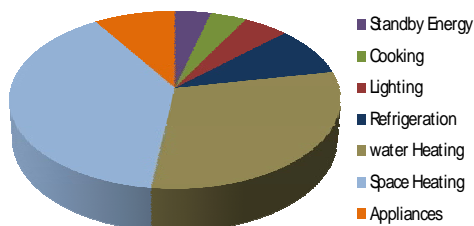


Fig 1. Residential household energy usage in Australia, 2007, adapted from [3,4]

Nevertheless, the floor space area is progressively expanding in modern residential houses as shown in Figure 2. As a result, the consumption of energy will increase despite the use of energy of advanced building materials and energy efficient appliance.

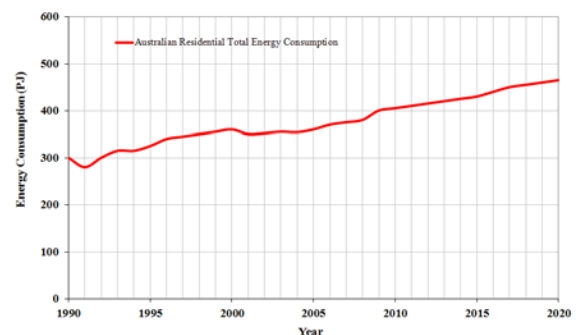


Fig 2. Average increment of house space, adapted from [4, 5]

In Australia, the energy consumption and CO<sub>2</sub> emission from heating and cooling in the residential housing sector have significantly increased over the past

decade and will continue in the predictable future. Various governments should monitor the energy usage in residential buildings to minimize the household energy needs by utilising suitable and effective house construction materials. One way to reduce energy consumption in the residential sector is to develop a new house envelope system that needs less energy for dwelling. A smart wall system will provide sustainable features using construction techniques, methods and materials. This can provides huge energy savings. The materials used in residential building construction should have innovations and standard specifications to minimize the energy consumption and improve thermal performance. Thermal performance is generally measured by proper use of various thermal dynamics and heat transfer principles which are embedded in computer based simulation software. The simulation software gives an initial estimation for the ongoing heating and cooling needs for specific geographical locations based on local climatic data and energy consumption patterns. It also, allows for evaluating smart construction materials that have higher heat transfer resistance and thermal mass by maintaining a suitable indoor environment with less energy consumption. Moreover, several governments including Australia have initiated various policies, regulations and guidelines in order to reduce energy consumption and improve sustainable living.

Although several studies [3, 6, 7] have investigated sustainable house construction systems using various smart materials, it has not been well studied and reported in the public domain that construction materials would have a high energy performance. The purpose of this study is to simulate a house with different types of construction materials and specifications in two climatic zones: moderate and sub-tropical climate. The objective is to optimize the physical parameters of the construction materials to achieve high performance of the house envelope system and low energy rates. The analytical method in optimizing house wall system performance has a significant impact on time saving, cost design and minimizing the greenhouse gas emissions. The optimization helps to evaluate the total annual energy consumption.

## 2. METHODOLOGY

### 2.1 Description of Simulated House

In order to estimate the total annual energy required for heating and cooling, the AccuRate simulation software has been used. The house dimensions and material details are important for running the simulation and obtaining a reliable result. The house selected in this study was a standard three bedroom house while the total floor area and the total physical volume is approximately 161.33 m<sup>2</sup> and 460 m<sup>3</sup> respectively. The house consists of a living area, dining area, kitchen, three bedrooms, two bathrooms, an alfresco area and a laundry. The plan view of the house is illustrated in Figure 3.

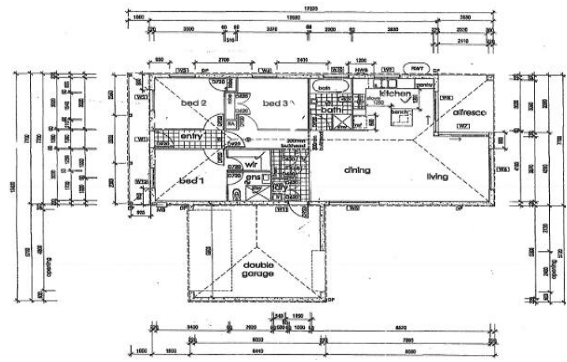


Fig 3. House design (plan view) [4]

Moreover, the foundation used is classified into (H class) concrete slabs which mean a highly reactive clay site with high ground movement and a trench full of reinforced concrete with 100 mm thickness. However, there are two types of concrete foundations widely used in Australia. The conventional variety is generally made of reinforced concrete whereas recently a waffle concrete foundation is becoming more popular due to its better insulation properties and lower construction costs. Figure 4 illustrates some different types of foundation used in this study. However, the windows are standard size with single glass and aluminum frame.

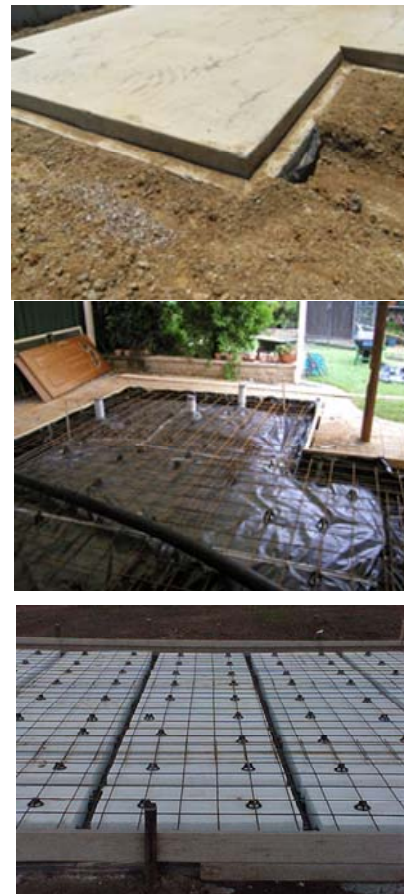


Fig 4. Different types of foundation [8]

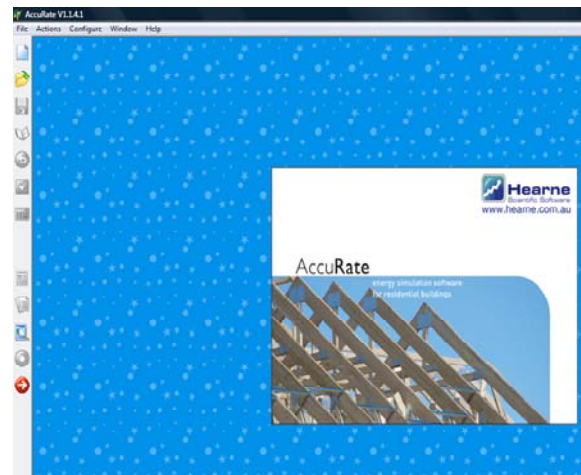
The conventional and the alternative wall systems used in this study were simulated in two climatic zones. These zones are the cities of Melbourne and Brisbane. Melbourne weather is considered to be moderate while the weather in Brisbane is considered a subtropical climate. A similar house design built in Australia is shown in Figure 5.



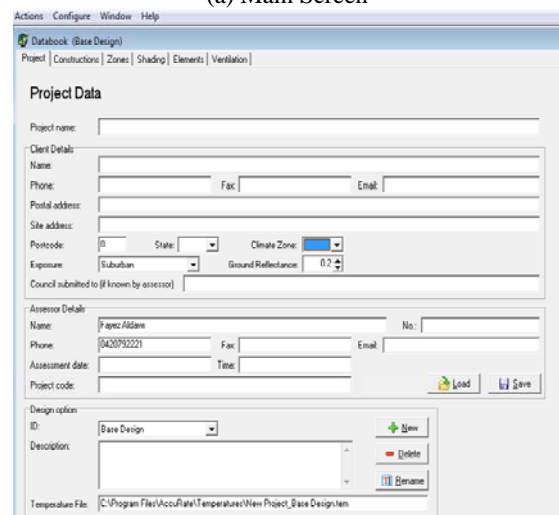
Fig 5. Conventional residential house design in Australia

## 2.2 Energy Simulation Software

The AccuRate simulation software was used for modeling the house. It was developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO). The first generation software was significantly improved by the Nationwide House Energy Rating Scheme (Nathers). Their second generation improved version is called AccuRate software. It is nationally accredited by most Australian states and territories. It is widely used for residential house energy performance. Furthermore, the simulation also identifies the house energy needed for ongoing heating and cooling at a scale rating from 1 to 10. The higher the star rating, the better it is for energy saving. The software has a large library of physical and thermal data for a wide range of construction materials, dimensions and characteristics for different climatic zones across Australia. Moreover, the AccuRate software contains major functions and features of heat transfer equations that are required in all the three modes (conduction, convection and radiation). It also, includes the effects of natural ventilation in the house energy rating compared to other commercial software available. An example for the AccuRate software simulation, such as main screen and data input screen, can be seen in Figure 6 a & b.



(a) Main Screen



(b) Data Input Screen

Fig 6. AccuRate Software

## 3. HOUSE WALL SYSTEM DESIGN

### 3.1 Design of Conventional Wall House System

The standard external conventional wall system in Australia generally consists of 110 mm brick veneer and 50 mm air gap. The 90 mm timber frame structure is filled with insulation bats. A 10 mm plaster board forms the internal. The roof structure is made of timber with terracotta/concrete tiles and/or corrugated iron sheet with an angle around 20°. The foundation floor area is made of 100 mm thick reinforced concrete. Figure 7 illustrates a model of an exterior brick veneer house under construction in an outer Melbourne suburb. [2, 7]



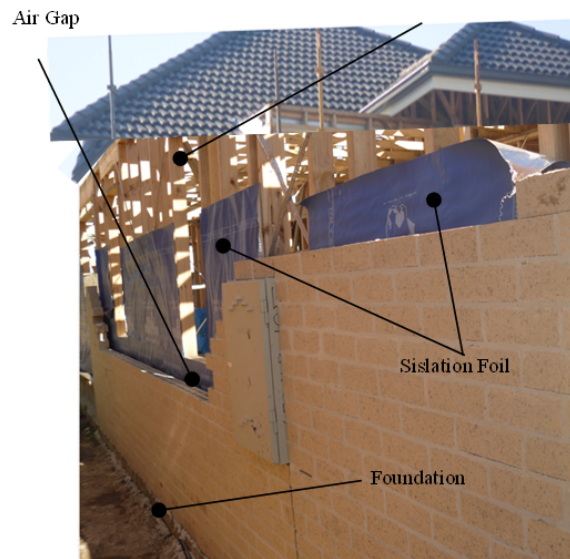
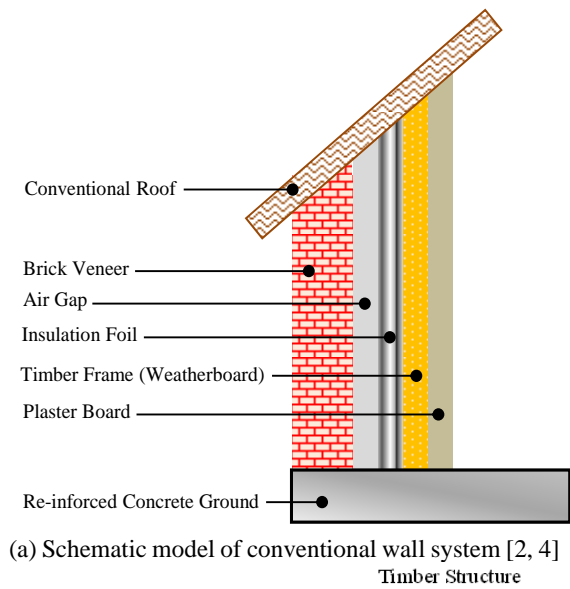
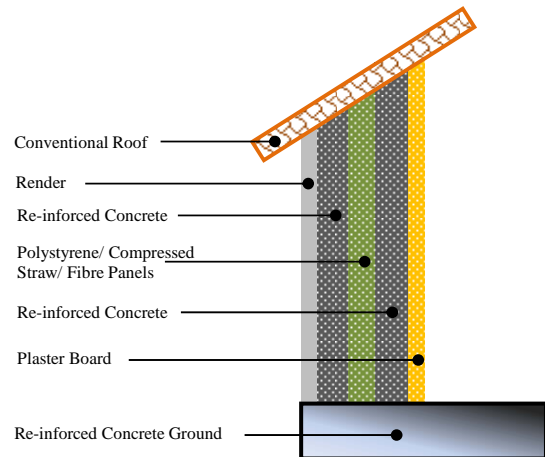


Fig 7. Schematic and common wall system in Australia (side view) [2,4]

### 3.2 New Wall System Design (Dual Concrete Panel with Insulation)

A new wall system consist of duals concrete panel with insulation in the middle has been selected. Using the AccuRate software, this new wall system will be studied for energy performance in comparison with the conventional wall system. The exterior part of the proposed wall system is a made of double sided reinforced concrete, installed with a total thickness of 150 mm (75 mm and 75 mm) and 10 mm render (outside). The insulation panel is made of 59 mm polystyrene, and/or compressed straw, and the interior insulation is 10 mm plaster board. However, the main focus of this study is only on new envelope wall systems without change to the typical reinforced concrete ground floor area and the same conventional roof system with tiles.

The thermal performance of the structure of the proposed construction material is expected to be better than the conventional wall system. Nevertheless, the conventional wall system has major disadvantages as it needs more energy for ongoing heating and cooling to maintain comfortable living inside the house during different weather conditions. The schematic of a new wall system is shown in Figure 8.



## 4. THERMAL PERFORMANCE CONDITIONS

### 4.1 Climatic Zones in Australia

The climate in Australia varies significantly starting from arid, middle and tropical zones. Australia is divided into seven main climatic zones based on climatic conditions, metrological data and solar radiation. Those zones are tropical wet, tropical dry, semiarid, desert, subtropical dry summer, humid subtropical and humid oceanic as shown in Figure 9. Also, the states have been subdivided into 69 micro climatic zones with a certain amount of energy required for heating and cooling. The weather patterns within the major seven climatic zones are also varied.



Fig 9. Different climatic zones in Australia [9]

## 4.2 Standard Energy Load across Australia

According to state and territory government regulations since mid-2008, all the new houses must comply with certain minimum energy consumption, which are measured against a star rating for ongoing requirements heating and cooling for different states. All 69 climatic zones across Australia have been rated with the star rating for their ongoing needs for heating and cooling. These scale ratings are called Star Energy Ratings which is a rating from 0 to 10. For example, Melbourne houses should not require more than 114 MJ/m<sup>2</sup> per year under energy 6 star rating. Figure 10 illustrates the star energy rating for the required heating and cooling energy for Australian states.

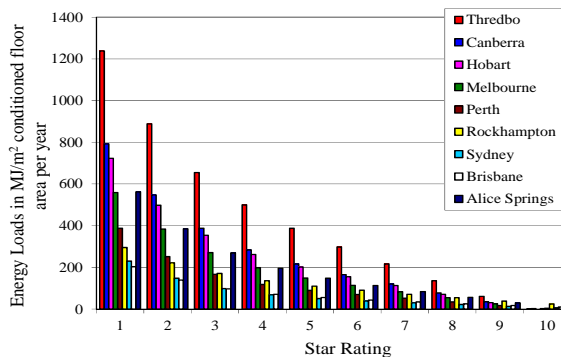


Fig 10. Standard energy loads against star rating for various cities across Australia [1-3]

## 5. RESULTS

As mention earlier, the two residential house wall systems (conventional and new wall system) were simulated using AccuRate software. The obtained results show the thermal performances of the two house wall systems located in two climatic zones in Australia (e.g. Melbourne and Brisbane cities). Melbourne is considered to be a moderate climate whereas Brisbane is considered as subtropical climate. The input data was fed to AccuRate software for both houses with the same wall characteristics and parameters (e.g., materials, specifications and dimensions). The roof structure, window configurations, foundations doors and internal walls were all kept constant without any changes. Also, the data entered considered the specifications of all types of windows, doors, floors, ceilings, roof, local latitudes and shading schemes. Window and door opening direction was kept with respect to the air flow direction.

### 5.1 Thermal Performance of Conventional Wall Systems in Melbourne and Brisbane

Using the AccuRate software, the simulated result indicated that the conventional house wall configuration requires 124 MJ/m<sup>2</sup> per year for ongoing heating and cooling. This means that the energy performance is to be rated only at 5.7 stars in Melbourne. On the other hand, the conventional wall configuration in Brisbane requires 42.3 MJ/m<sup>2</sup> per year and the energy performance is to be rated only at 6.1 stars. The results obtained from the simulation for both cities are shown in Figure 11 a & b.

AREA-ADJUSTED ENERGY REQUIREMENTS				
Heating	Cooling (sensible)	Cooling (latent)	Total Energy	Units
100.1	22.4	2.2	124.7	MJ/m <sup>2</sup> .annum
Star Rating				
★★★★★☆☆ 5.7 STARS				

(a) Melbourne city

AREA-ADJUSTED ENERGY REQUIREMENTS				
Heating	Cooling (sensible)	Cooling (latent)	Total Energy	Units
1.6	28.8	12.0	42.3	MJ/m <sup>2</sup> .annum
Star Rating				
★★★★★☆☆ 6.1 STARS				

(b) Brisbane city

Fig 11. Thermal performance of conventional wall systems in Melbourne and Brisbane cities

### 5.2 Thermal Performance of New Wall Systems in Melbourne and Brisbane

The total energy required for heating and cooling for the house with the new wall system is around 105.1 MJ/m<sup>2</sup> per year which equals a 6.3 star energy rating in Melbourne. This is a reduction of 15% compared to the conventional house wall systems. However, in Brisbane, the total energy required for heating and cooling is 34.8 MJ/m<sup>2</sup> per year which is rated at 6.9 stars. The total energy need for a new house wall system is reduced by 17.7 % compared to the conventional house wall system. Figure 12 a & b illustrates the results obtained from the simulation.

AREA-ADJUSTED ENERGY REQUIREMENTS				
Heating	Cooling (sensible)	Cooling (latent)	Total Energy	Units
97.1	4.2	4.6	105.9	MJ/m <sup>2</sup> .annum
Star Rating				
★★★★★☆☆ 6.3 STARS				

(a) Melbourne city

AREA-ADJUSTED ENERGY REQUIREMENTS				
Heating	Cooling (sensible)	Cooling (latent)	Total Energy	Units
3.6	16.3	14.9	34.8	MJ/m <sup>2</sup> .annum
Star Rating				
★★★★★☆☆ 6.9 STARS				

(b) Brisbane city

Fig 12. Thermal performance of new wall systems in Melbourne and Brisbane cities

## 6. CONCLUSIONS

The new wall system provides not only energy saving in Melbourne and Brisbane houses but also, provides almost 3 % more energy saving due to the climatic difference. Most conventional residential houses lack sufficient thermal mass, insulation and sustainability of design. For comfortable living and energy saving, both thermal mass and insulation are required. The higher thermal mass helps to keep the inside of the house cooler during the day in summer due to its large heat carrying capacity. Similarly, in winter, the material with higher thermal mass will help keep the inside of the house warm during the night and the insulation provides the energy saving. The proposed wall system has better thermal performance and insulation characteristics compared to current house wall systems. The new house wall system will allow the exterior wall to have a higher thermal mass. Current houses wall systems in Australia are not as energy efficient and emit more CO<sub>2</sub> compared to the new wall houses (i.e. contribute to global warming). The new

wall system is energy efficient. Hence, it will be environmental friendly.

## ACKNOWLEDGEMENT

We express our sincere gratitude to the government of the Kingdom of Saudi Arabia for providing the PhD Scholarships to 1st and 2nd authors.

## 7. REFERENCES

1. Alam, F., Rasul, M.G., Saman, W., Theos, T. Khan, M.M.K. and Akbarzadeh, A., Residential House Energy Rating in Australia, Central Region Engineering Conference (CREC), CQ University, Rockhampton, ISBN 1-921047-62-3, p 1-6, 14-15 August, Australia, 2009.
2. Alam, F., Khan, M.M.K. and Rasul, M. G., A Comparative Study of Residential Household Energy Consumption in Australia and USA, The International Journal of Mechanical Engineering and Materials Science, Vol. 3 (2), p 127-132, 2008.
3. Alam, F. and Theos, T., A New Generation Energy Efficient Residential House in Australia, Proceedings of the 4th BSME-ASME International Thermal Engineering Conference (ICTE2008), ISBN 984-300-002844-0, Vol. 2, p 710-718, Dhaka , 27-29 December, 2008.
4. Aldawi, F. G., Alam, F., Moria, H., Date, A., and Akbarzadeh, A. A Smart House Wall Energy Performance Study for Arid Climatic Region, accepted after peer review for the Proceeding of the Jordan International Energy Conference (JIEC2011), 20-22 September, Amman, Jordan, 2011.
5. Report on Energy Use in the Australian Residential Sector 1986-2020, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia, 2008, Canberra.
6. Chen, Y., Athienitis, A.K. and Galal, K., Modeling, design and thermal performance of a BIPV/T system thermally coupled with a ventilated concrete slab in a low energy solar house: Part 1, BIPV/T system and house energy concept, Solar Energy, 84: 1892–1907, 2010.
7. Zhu, L., Hurt, R., Correia, D. and Boehm, R. Detailed energy saving performance analyses on thermal mass walls demonstrated in a zero energy house, Energy and Buildings, 41: 303–310, 2010.
8. Renovation robot, Australian house foundation <http://www.renovationrobot.com.au/foundations/housefoundations.html>, accessed on 30 September, 2011.
9. Motor home road trip, Australian Weather <http://www.motorhomeroadtrip.com/australia/information/weather/>, accessed on 08 August 8, 2011.
10. Chowdhury, A. A., Rasul, M. G., Khan, M. M. K. and Alam, F., Performance Analysis of a Novel Building Material to Achieve Superior Thermal Comfort and Energy Efficiency in Arid Climate, Proceedings of the International Engineering Conference on Hot Arid Regions (IECHAR 2010), Al-Ahsa, KSA, 1-2 March, 2010.
11. Alam, F., Akbarzadeh, A., Dixon, C. and Theos, T., Thermal Performance of Residential House Envelopes, Proceedings of the International Conference on Mechanical, Industrial and Energy Engineering (ICMIEE2010), Paper MIE10-158, ISBN: 978-984-33-2300-2, Khulna, Bangladesh 23-24 December, 2010.

## 8. MAILING ADDRESS

### Mr Fayez Aldawi

School of Aerospace,  
Mechanical and Manufacturing Engineering,  
RMIT University  
Plenty Road, Bundoora, Melbourne, VIC 3083,  
AUSTRALIA

Telephone: +61 3 99256103

Fax: +61 3 99256108

E-mail: [s3299445@student.rmit.edu.au](mailto:s3299445@student.rmit.edu.au) or  
[faiz0505@hotmail.com](mailto:faiz0505@hotmail.com)