1. Module details

Module name

Energy Efficient Building Design

Module duration

It is expected that students with the appropriate entry knowledge and skills will successfully complete this module in 60 hours.

Module code

NUER11

Discipline code

1105

2. Module purpose

This module provides an understanding of the principles used to design energy efficient buildings in Australia. It covers both the theory and application of design variables including insulation, ventilation, thermal mass, window positioning, shading. These are explored in the context of thermal comfort, climate type and site considerations.

It also provides training in the energy rating of domestic and small commercial buildings using appropriate score rating schemes and/or computer simulation software.

3. Prerequisites

NUER01 – Introduction to Renewable Energy Technologies

4. Relationship to competency standards

This module provides part of the underpinning knowledge and skills identified in the 'Evidence Guide' of specific units in the National Electrotechnology Competency Standards, namely NES411, NES709.

5. Content

Climate and thermal comfort

Australian climatic types
climate data
climate and comfort
calculations: heating degree days,
thermal neutrality

Solar geometry and radiation

terminology
conversions: solar-local time
incidence, irradiation

Heat transfer

conduction, convection, radiation
U-values
infiltration heat transfer

Glazing systems

special glasses
glazing systems and their characteristics
shading devices
solar heat gain
daily irradiation,
heat gain

Insulation

Types
installation
R-values

Thermal mass

advantages, disadvantages
location within buildings
terminology

Comfort control strategies

design strategies and selection

Energy efficiency in buildings

positions: north, sunset, sunrise
solar access
use of vegetation
cross ventilation

Header Topic Thermal performance in buildings

heating degree
day method
dynamic performance

Integration of active solar systems

types
components,
storage
collectors
roof locations

Energy rating schemes

approaches
energy performance

	Sustainable and safe building materials embodied energy sustainable raw materials: mining, logging manufacturing processes and pollutants release / outgassing of dangerous substances from building materials recycling and ultimate disposal

6. Assessment strategy

Assessment methods	Assessment should encompass both progressive and holistic elements in recognition of the interdependence between learning outcomes and to ensure the module purpose is met. To assist in ensuring validity, reliability and fairness, assessment instruments should include both practical exercises and written exercises consisting of a number of item types, such as multiple choice, short answer and problem solving. A home design / energy rating assessment project may serve as the major assessment item.
Conditions of assessment	Normally learning and assessment will take place in a classroom/ laboratory environment.

7. Learning outcome details

Learning outcome 1

Determine which aspects of a particular climate type need to be modified within a building for the maintenance of thermal comfort based on an analysis of climatic data.

Assessment criteria

1.1 List the characteristics of the different Australian climatic types.

1.2 Use climatic data in published and electronic forms to extract the quantities relevant to energy efficient design.

1.3 Show the relationship between climate and comfort using bioclimatic or psychrometric charts.

1.4 Calculate heating or cooling degree days or degree hours for various locations.

1.5 Calculate thermal neutrality for a given location.

Learning outcome 2

Determine the position and lengths of shadows and the solar energy incident on various parts of a building.

Assessment criteria

2.1 Explain these terms:

- declination
- hour angle
- zenith angle
- azimuth and altitude angles
- the equation of time

2.2 Convert solar time to local time and vice versa.

2.3 Calculate the position of the sun and the length of shadows with the aid of algorithms, tables, sun charts or computer software.

2.4 Determine the daily irradiation incident on a wall, window or roof of a given tilt and orientation.

2.5 Calculate the relative summer and winter irradiation of windows facing the cardinal orientations.

Learning outcome 3

Calculate the heat transfer through various building elements.

Assessment Criteria

3.1 Explain how the thermal processes of conduction, convection and radiation apply to the transfer of heat in buildings.

	3.2	Calculate the summer and winter U-values of building elements using tables and software.
	3.3	Calculate the infiltration heat transfer in a building.
Learning outcome 4	**Calculate the heat gain through both unshaded and shaded glazing elements**	
Assessment Criteria	4.1	List the different types of glazing systems and their characteristics.
	4.2	List the different types of shading devices and the window orientations for which they are most appropriate.
	4.3	Determine the solar heat gain for different glazing types and angles of incidence.
	4.4	Calculate the average daily irradiation of a window partly shaded by eaves, using computer software.
	4.5	Calculate the average daily heat gain through a window partly shaded by eaves.
Learning outcome 5	**Determine the role of insulation in reducing the demand for energy in a building.**	
Assessment criteria	5.1	List the different types of insulation and where they are used.
	5.2	Explain how different types of insulation are installed in roofs, walls and floors.
	5.3	Determine the minimum R-values of roof insulation for different locations using Australian Standard AS2627 or similar standards.
Learning outcome 6	**Assess the need for thermal mass in reducing energy consumption in buildings.**	
Assessment criteria	6.1	List the advantages and disadvantages of using substantial thermal mass in different climate types and for different heating and cooling regimes.
	6.2	Describe where thermal mass can be located in a building.
	6.3	Explain what is meant by the following terms: time lag decrement factor admittance response factor

Learning outcome 7	**Determine comfort control strategies for specific climatic regions.**
Assessment criteria	7.1 Interpret the usefulness of a design strategy with the aid of a psychrometric chart showing control potential zones for a particular location. 7.2 Select the most useful comfort control strategies for Australian climatic regions.
Learning outcome 8	**Assess a particular site in terms of its assets and problems as an appropriate location for an energy efficient building.**
Assessment criteria	8.1 Determine the direction of the following: both true and magnetic north winter and summer sunrise winter and summer sunset 8.2 Assess the solar access in summer and winter to various possible house locations on a site and room locations within the house. 8.3 Explain how vegetation can be used to both funnel and deflect wind. 8.4 Assess the possibility of using cross ventilation as a cooling strategy.
Learning outcome 9	**Determine the thermal performance of a building**
Assessment criteria	9.1 Determine the heating requirements of a building using the heating degree day or hour method. 9.2 Determine the dynamic performance predicted by a computer simulation program such as NatHERS or BERS.
Learning outcome 10	**Integrate an active solar system into the design of an energy efficient house.**
Assessment criteria	10.1 List the active solar system types available which can provide hot water, space heating and cooling. 10.2 Determine the best location on the roof, and the optimum tilt and orientation of the collector panels. 10.3 Describe the function of the main components of an air or water-based solar space heating system. 10.4 Draw a schematic of the fluid circuit of an air or water-based space heating system. 10.5 List the main solar cooling system types.

Learning outcome 11	**Determine the energy star rating of a building and cost effectiveness of energy efficiency measures with the aid of a house energy rating scheme or similar software.**
Assessment criteria	11.1 Describe the differences in approach used by house energy rating schemes in Australia.
	11.2 Assess the energy performance of a number of houses using a computer simulation program such as NatHERS or BERS.
	11.3 Evaluate other methods to reduce energy consumption within and outside a building including appliance efficiency, human behaviour changes, building management strategies and transportation minimisation.
	11.3 Evaluate the additional cost of energy efficiency measures and cost savings using life cycle cost or simple pay back methods according to Aust. Standard AS3595 and AS4536.
Learning outcome 12	**Determine the most appropriate building materials that have the least environmental impact based on available research.**
Assessment criteria	12.1 List common building materials and their embodied energy content.
	12.2 Describe the environmental impact of the production of various building materials.
	12.3 Outline some of the problems associated with the use or disposal of building materials.

8. Delivery of the module

Delivery strategy

Delivery strategies must be suitable for learning both theoretical and practical aspects described in the module purpose. It is considered that the most effective way to achieve this is by the integration of theory and practice where students learn by experimentation and through practical experience in working with real systems.

It is recommended that learning and assessment be facilitated in a holistic manner. A home design project may serve as the major assessment item on which a large part of the teaching and learning will focus. This may also facilitate learning about the integration of individual building envelope elements and/or system components. The learning outcome sequence may be other than that indicated in the module.

Resource requirements

Resources should be sufficient for students to carry out projects or experiments in pairs or individually. This will require access to a range of commercial building envelope elements as examples, or experimental devices and/or measuring instruments to confirm theory. Access to real homes that demonstrate energy efficiency building design principles is also required. Copies of all relevant standards are required. Appropriate software is required to analyse the dynamic performance of the energy flows through the building envelope.

Occupational health and safety requirements

A safe and healthy environment will be provided for students and teachers as well as adherence to safety procedures with regard to learning / teaching activity.

Minimum physical resources	Computer laboratory Computer software for evaluation of irradiation, U-values, and solar position Computer software that dynamically models the thermal performance of domestic or small commercial buildings such as NatHERS or BERS Computer software that evaluates the simple pay back or life cycle cost of energy efficiency improvements. Access to: Domestic or commercial buildings that demonstrate the application of energy efficiency principles including the building envelope, landscaping, active solar heating systems, internal appliances and user behavioural changes. A solar simulator to examine solar geometry in relation to building design (not essential but desirable). 1 Solarimeter or pyranometer + or – 3% accuracy 4 Digital indoor / outdoor min. / max. thermometers
Recommended References	AIRAH, (1989). *Handbook, Australian Institute of Refrigeration, Air-conditioning and Heating*, Parkville, Victoria. ASHRAE, (1989). *Handbook of Fundamentals - Metric Version*, American Society of Heating, Refrigeration and Air-conditioning Engineers, Atlanta, USA. Australian Bureau of Meteorology, *Climatic Averages - Australia*, (1975). Australian Government Publishing Service. Australian Bureau of Statistics, (1987). *National Energy Survey: Household Appliances Facilities and Insulation, Australia, 1985-86*. Catalogue No. 8212.0 Australian Construction Services, (1983). *Energy Efficient Australian Housing*, Canberra: AGPS. Australian Government and the Australian Consumers Association, (1991). *The Energy Guide*, Canberra: Australian

Government Publishing Service.

Bainbridge, David et. al. (1979). *Village Homes Solar House Designs*, Rodale Press.

Baker, E., Floro, C.L., Gostelow, J.P. and McCaffrey, J., (1984). *Solar Heating & Cooling Systems, Design for Australian Conditions*, Sydney: Pergamon Press.

Ballinger, J.A. and Szokolay, S.V., (1983). *The Final Report of the NERDDC/Solarch Passive Design Workshop for Residential Buildings in Australia*, Canberra: Department of Resources and Energy.

Ballinger, J.A., ed, (1982). *Thermal Design of Buildings Handbook*, Sydney: Solarch, School of Architecture, University of New South Wales.

Ballinger, J.A., Prasad, D.K. and Cassell, D.J., (1992). *Energy Efficient Housing in New South Wales*, Sydney: N.S.W. Office of Energy.

Baverstock, Gary and Paolino, Sam, (1986). *Low Energy Buildings in Australia. A Design Manual for Architects and Builders, Vol. 1*, Residential Buildings, Graphic Systems, East Fremantle.

Beckman, W.A., Klein, S.A. and Duffie, J.A., (1977). *Solar Heating Design by the f-Chart Method*, New York: John Wiley & Sons.

Biggs, K.L. and Michell, D., (1986). `Air permeability of some Australian Houses', *Building and Environment*, Vol. 21.

Bradford Insulation, *Insulation Reference Guide*.

Breuer, D.R. (Ed), (1985). *Design for the Sun, Volume 1, Working Manual*, Ministry of Energy, Wellington.

Breuer, D.R. (Ed), (1985). *Design for the Sun, Volume 2, Reference Manual*, Ministry of Energy, Wellington.

Building Regulation Review Task Force, (1991). *Model Codes for Energy Efficient Buildings*. Department of Primary Industries and Energy.

Butti, K. and Perlin, J., (1980). *A Golden Thread, 2500 Years of Solar Architecture and Technology*, Palo Alto, USA: Cheshire Books.

Chartered Institution of Building Services, (1979). *CIBS Guide A5, Thermal Response of Buildings*, London: Curwen Press Ltd.

Chartered Institution of Building Services, (1980). *CIBS Guide A3, Thermal Properties of Building Structures*, London: Curwen Press Ltd.

Charters, W.W.S. and Pryor, Trevor L., (1981). *Solar Energy: An Introduction to the Principles and Applications*, Melbourne: Beatrice Publishing.

Charters, W.W.S. and Pryor, Trevor L., (1982). *Solar Energy Theory and Design of Solar Thermal Systems*, Melbourne: Beatrice Publishing.

Clegg, Peter and Watkins, Derry, (1978). *The Complete Greenhouse Book*, Garden Way.

Close, D. J., (1980). *An Introduction to Solar Energy Systems and System Design*, Technical Report No. TR 26, Victoria: CSIRO, Division of Mechanical Engineering.

Coldicutt S. and Williamson, T.J., (1988). *Design Guide for Energy Efficient Housing in Adelaide*, Department of Architecture, The University of Adelaide.

Coldicutt, A.B., Williamson, T.J. and Coldicutt, S., (1989). *Thermal Properties of Construction Elements*, Adelaide: Department of Architecture, University of Adelaide.

Cole, G. and Bingham-Hall, P., (1984). *Australian Solar Buyers Book*, Castle Books.

Copper Development Association, (undated). *Copper Brass Bronze Design Handbook - Solar Energy Systems*, New York.

Den Ouden, Henk, (1980). *Low Energy Housing in South Australia*, Adelaide: Department of Mines and Energy.

Department of Housing and Construction, EBS, (1975). *Designing Houses for Australian Climates*, AGPS.

Department of Primary Industries and Energy, (1985). *Saving Energy in Commercial Buildings*, Advisory Booklet 16, Canberra: Australian Government Publishing Service.

Department of Productivity (1978). *Industrial Data Sheets A2, Control of Sunlight Penetration*, Canberra: Australian Government Publishing Service.

Drysdale, J.W., (1950). *The Thermal Behaviour of Dwellings*, EBS Technical Study 34, Sydney.

Drysdale, J.W., (1975). *Designing Houses for Australian Climates*, Canberra: AGPS.

Duffie, J.A. and Beckman, W.A., (1991). *Solar Engineering of Thermal Processes*, New York: John Wiley & Sons.

Energy Victoria, (undated) *A Guide to Energy Efficient Renovation*, Melbourne.

Gavin, G., (1989). *Economic Evaluation Techniques for Renewable Energy Systems: A Primer*, Energy Victoria.

Giffard S., Burton, R., Monsour P., (1999). *Energy Efficient Building Design - Student Learning Guide:* Renewable Energy Centre, Brisbane Institute of TAFE, Brisbane Australia.

Greenland, J. and Szokolay, S.V., (1985). *Passive Solar Design in Australia*, Red Hill, ACT: Royal Australian Institute of Architects.

Gregory, J. and Darby, F., (Eds.) (1990). *Solar Efficient Design for Housing: A Manual for Architects and Designers*, Melbourne: Victorian Solar Energy Council.

Hassell, D.N., (1977). *Reflective Insulation and the Control of Thermal Environments*, Sydney: St. Regis, ACI.

Jenkin, Tom and James John, (1979). *The Wise House - Adapting Your Home to the Australian Climate*, Adelaide: Rigby.

Kay, M., Ballinger, J.A., Hora, U. and Harris, S., (1982). *Energy Efficient Site Planning Handbook*, Sydney: Housing Commission of N.S.W.

Koenigsberger O.H., et al, (1974). *Manual of tropical Housing and Building, Part 1- Climatic Design*, London: Longman.

Lee, T, Oppenheim, D, Williamson T.J. *Australian Solar Radiation Data Handbook.* Available from the Aust. and NZ Solar Energy Society email: anzses@unsw.edu.au.

Lochhead, Helen, (1987). *Gardens for Living*, Greenhouse Publications.

Lunde, P.J., (1980). *Solar Thermal Engineering - Space Heating and Hot Water Systems*, New York, John Wiley & Sons.

Markus, T.A. and Morris, E.N. (1980). *Buildings, Climate and Energy*, London: Pittman.

Martin, P.L. and Oughton, D.R., (1989). *Faber and Kell's Heating and Air-conditioning of Buildings*, London: Butterworth.

Mazria, E., (1979). *The Passive Solar Energy Book*, Rodale Press.

McCullagh, James, (1981). *Movable Insulation*, Rodale Press.

McCullagh, James, ed., (1979). *The Solar Greenhouse Book*, Rodale Press.

Meinel, A.B. and Meinel, M.P., (1976). *Applied Solar Energy*, Addison-Wesley Publishing Co., Philipines.

Monsour P.M., Berrill T.D., et al (1997). *Introduction to Renewable Energy Technologies – Resource Book.* Renewable Energy Centre, Brisbane Institute of TAFE Brisbane, Australia.

Monsour P., Berrill T., et al (1997). *Introduction to Renewable Energy Technologies – Student Learning Guide.* Renewable Energy Centre, Brisbane Institute of TAFE, Brisbane, Australia.

Nunez, M, (1990). *Satellite Estimation of Reginal Solar Energy Statistics for Australian Capital Cities*, Bureau of Meteorology Study No. 39, Canberra: Australian Government Publishing Service.

Olgyay, V. and Olgyay, A., (1957). *Solar Control and Shading Devices*, Princeton: Princeton University Press.

Olgyay, Victor, (1963). *Design With Climate*, Princeton: Princeton University.

Paix, D., (1977). *The Design of Buildings for Daylighting*, EBS Bulletin 7, Canberra: Australian Government Publishing Service.

Parnell, M. and Cole, G. (1987). *Australian Solar Houses*, Sydney: Second Back Row Press.

Phillips, R.O., (1983). *Sunshine and Shade in Australasia*, NBTC Bulletin No. 8, Australian Government Publishing Service.

Saleh, M., (1988). *Design of Sunshading Devices*, Sydney: CSIRO, Division of Building, Construction and Engineering.

Spencer, J.W., (1979). *Brisbane Solar Tables - Tables for Solar Position and Radiation for Brisbane*, CSIRO, Technical Paper (Second Series) No. 29. (Separate titles are available for each capital city).

Standards Australia, (1983). *AS 2627.1, Thermal Insulation of Dwellings, Design Code Part 1, Thermal Insulation of Roof/Ceiling in Dwellings Which Require Heating.*

Standards Australia, (1990). *AS 3595 Energy Management Programs - Guidelines for Financial Evaluation of a Project*.

Standards Australia, (1990). *Tempest, The Energy Management Project Evaluation Software*.

Szokolay, S.V. and Sale, R., (1979). *The Australia and New Zealand Solar Home Book. A Practical Guide*, Sydney: Australia and New Zealand Book Co.

Szokolay, S.V., (1980). *Environmental Science Handbook*, London: The Construction Press.

Szokolay, S.V., (1980). *World Solar Architecture*, Architectural Press.

Szokolay, S.V., (1987). *Thermal Design of Buildings*, Melbourne:

Szokolay, S.V., (1988). *Climatic Data and Its Use in Design*, Melbourne: RAIA Education Division.

Szokolay, S.V., (1990). *Climatic Design of Houses in Queensland*, Brisbane: Architectural Science Unit, University of Queensland.

Szokolay, S.V., (1991). *Climate, Comfort and Energy: Design of Houses for Queensland Climates*, Brisbane: University of Queensland Architectural Science Unit.

Twidell, J. and Weir, T., (1986). *Renewable Energy Resources*, London: E. and F.N. Spon Ltd.

Walsh, P.J. and Spencer, J.W., (1980). *Heating Degree-Days for Australian Localities*, CSIRO, Division of Building Research, Technical Paper 35.

Walsh, P.J., Gurr, T.A. and Ballantyne, E.R., (1982). *A Comparison of the Thermal Performance of Heavyweight and Lightweight Construction in Australian Dwellings*, CSIRO Division of Building Research Technical Paper (Second series), No. 44.

Willrath H., Berrill, T.D. et al (1992). *Energy Efficient Building Design - Resource Book:* Renewable Energy Centre, Brisbane Institute of TAFE, Brisbane Institute of TAFE.