Abstract
The Australian Cooperative Research Centre for Renewable Energy (ACRE), in conjunction with Murdoch University, has developed a range of undergraduate and postgraduate university courses in renewable energy technology and systems, energy policy and economics and energy efficiency which are available via the World Wide Web. Over the last two years these courses have been offered nationally and internationally in conjunction with Murdoch University and Engineering Education Australia. The students studying these courses entirely via the web have been widely spread geographically including local, on campus students, and distance education students from remote areas in Western Australia, other Australian states and overseas. This paper will discuss the strategies used to present these courses, including examples of the web based courses, and report on students’ experiences of studying renewable energy via the web. An evaluation of the outcomes provides a basis for a discussion of the potential, the practice and the possible problems of tertiary renewable energy education on the web.

Introduction
The Australian Cooperative Research Centre for Renewable Energy (ACRE) seeks to meet the increasing need for more tertiary trained scientists, engineers and policy makers with the knowledge and skills needed to develop and implement renewable and efficient energy systems and policies [Jennings, 1996]. It is doing this by developing, in conjunction with Murdoch University, a range of internationally focussed, online (internet-based) university courses in renewable energy technology, energy policy, energy efficiency and greenhouse issues. This includes a number of units (courses) in several disciplines at the university undergraduate and postgraduate level that will be available for both internal (on campus) and external (distance education) study. The target market is undergraduate Higher Education Contribution Scheme (HECS) based students and full-fee paying postgraduate students, both within Australia and internationally.

The structure of the courses and qualifications has been discussed in detail elsewhere [Lund and Jennings, 1997]. There are currently five coursework units and one project unit that form the basis of the undergraduate program and the first year of the postgraduate program in Energy Studies. These are Energy in Society, Energy Policy, Energy Economics and Energy Studies Project. There are four coursework units and one research unit that form the basis of the second year of the postgraduate program in Energy Studies. These are Renewable Energy Devices, Renewable Energy Resources, Renewable Energy Systems Design, Case Studies of Renewable Energy Systems and Renewable Energy Dissertation.

Beginning in 1997, ACRE, in conjunction with Murdoch University began to develop these units into online (internet based) units. Three of the units, Energy in Society, Energy Policy and Energy Systems were developed and trialed in 1997 and run again as online units in 1998. The remaining three units required for the first year of the postgraduate program in Energy Studies, these are Energy in Society, Energy Policy, Energy Economics and Energy Studies Project were developed and run as online units in 1998. Online versions of the units required for the second year of the postgraduate program are planned for development and offering in 1999 to 2000.

This paper discusses the strategies used to present these units and reports on student’s experiences of studying renewable energy via the web. Based on evaluations of the outcomes from the Energy Studies online units offered so far, and other research related to online units in other disciplines, the potential, the practice and the possible problems of tertiary renewable energy education via the web are also discussed.

The potential - Why online?
The Energy Studies units offered by ACRE and Murdoch have a diverse target student market. Students can come from a wide range of backgrounds and requirements. They are widely spread geographically, with some studying on campus, while others are interstate and overseas and can only study via distance education. The Energy Studies offering was
therefore developed in such a way that it can be used by all of the different types of students in a similar way. In order to make the units relevant to the widest possible audience, flexible programs were developed based on a range of internationally focussed units available online.

The advantages of offering the units online have been discussed elsewhere [Lund and Jennings, 1997, Lund et al. 1997] and include:

- **Greater access** - the potential to reach a greater number of students because the units can be completed via internet, from CDROM, or a mixture of both, without the students having to come onto campus.
- **Greater flexibility** - the convenience for students of studying in the comfort of their own surroundings, at a time and pace that suits them, means that online presentation is very suited to professional development and part-time studies.
- **Greater relevance** - the ability to use World Wide Web sites that are continually updated means that it is easier to keep information in the units up to date and relevant, as well as introduce materials from a wider range of sources especially in an international framework.
- **Greater choice of instructional methods** - the ability to introduce interactive multimedia and simulations into units via CDROM or the internet means a greater range of teaching options are available. The learning experiences of the students can be enriched beyond that normally available from print based material, especially for distance education students.
- **Better communication** - Email and online discussion groups enable significantly faster and more convenient student-student and student-teacher interaction, electronic submission and marking of assignments, and help with student problems, especially for geographically isolated external students. As electronic communication has no geographical constraints there is the potential for increased interaction between students from a wide range of countries and backgrounds who can share different perspectives on the material.
- **Easier course maintenance and administration** - the units are generally easier for the academic and the education institution to maintain and administer as changes can be made to the material on the website and this will instantly be available to all the students.

It is clear that the advantages of offering renewable energy studies via the internet are significant. It has the potential to significantly increase the number of people who can receive training in renewable energy and to enhance the learning experience of the students, especially those studying via distance education. This has been clearly seen in our experience of offering Energy Studies units online.

**The practice - What was it like?**

The online units were designed to enable the unit material to be offered in the same way to as wide a range of students as possible, taking into account students having different amounts of internet access, from fast, unlimited access (via the University or the workplace), to slow, or limited access via a modem and Internet Service Provider (ISP), to email only, or no access. This was best achieved through the units having a common interface and format that could be effectively by both internal (on campus) and external (distance education students). In light of this the approach taken was to design the unit material so that it was accessed via a World Wide Web browser interface. This meant it could be served from an internet server or from CDROM in the same way.

Following advertising of the Energy Studies program and the opportunity to complete it externally via the internet in 1997 there was a significant increase in the number of students studying Energy Studies courses. The profile of the applicants and their reasons for choosing the Energy Studies courses is described elsewhere [Jennings and Lund, 1998]. In 1998 the Energy Studies postgraduate program had twenty-five students completing one of the postgraduate Energy Studies qualifications either full-time or part-time. Of these the majority were studying externally (23/25) and part-time (21/25). All the students were Australian nationals and had a wide geographic distribution. Ten of the 25 students were from the Perth metropolitan area, 4 were from regional Western Australia, 10 were from other states in Australia and 10 were overseas (France). Figure 1 shows the geographic distribution of the students completing Energy Studies program in 1998 in Australia. Twenty-one of the 25 students had at least access to email, with only four students who could not complete the courses via conventional print based distance education due to no internet or email access. Two of these students were completing the units using email only distance education. This meant that the majority of students accessed the unit materials via the internet, using a modem and ISP, or a work or university based system connected directly to the internet.
In part-time education it is easier to gain access to sources of information and students can access the unit materials through a range of educational institutions. The diversity in the student’s modes of study meant that the units were delivered using a number of teaching methods. External students were encouraged, but not required, to access the unit material using predominantly the online mode. Four external students could not get any access to email or the internet and completed the units as conventional distance education students. These students received all the unit materials in print based form and submitted and received all assessable work in hardcopy written form. Correspondence with the university staff and tutors was conducted either in written form or via telephone. Two students, who had email access but no internet access, completed the units as email only students. These students received all of their unit materials in print based form but submitted and received all their assessable work, with the exception of the final exam, via email. All correspondence with the tutors was conducted via email. This ability to communicate via email was seen by these geographically isolated students as a significant advantage compared to print or telephone based communication. The email communication enabled fast responses to any questions the students had, and enabled much shorter times for feedback on assignments. The remainder of the external students used the fully online mode of study.

All internal (on campus) students in the Energy Studies units had priority access to a computer laboratory set up for using the internet, email and wordprocessing and they were required to access the unit material using the online mode. On campus students also had, as needed, supplementary face-to-face teaching, including lectures, tutorials, practical sessions and site visits. All students, whether studying in conventional mode, email only or online had to sit a supervised written examination. All internal and external students who used the internet mode of study accessed the unit material in the same way. For these students the unit material usually consists of a range of media, including published...
textbooks or technical brochures, printed course readers containing compiled supplementary material, online multimedia material provided via the host material, either from a server or CD-ROM, and links to other non host sites on the internet. The design of the online interface and unit structure, was based on contemporary teaching and learning theory and practice [Brown, 1997]. These design principles and features of the online units have been described elsewhere [Lund and Jennings, 1997, Lund et. al. 1997]. Figure 2 shows the first page of a typical Energy Studies unit, showing the online interface. Demonstration versions of the units developed so far can be viewed at the ACRE website http://acre.murdoch.edu.au/ under Education.

The operation and effectiveness of the online Energy Studies units was monitored during the initial trial period, and later during full implementation, by gathering extensive feedback from the students themselves. One of the authors also been involved in a broader study looking at students studying online for the first time across a large number of online units from several disciplines within the university [Lund and Volet, 1998], including the Energy Studies units. This has led to a number of observations about offering online units generally, and some specific to renewable energy units.

Most of the students who were able to use the online versions of the Energy Studies units showed high levels of satisfaction with the online mode of delivery of the units, with many encouraging and positive responses received. Energy Studies students perceived the main benefits of the online mode of delivery to be, easy access to unit material, more flexibility in how and when to study, and an increase in the amount of information available. In response to the question “What, if any, were the major benefits or drawbacks of having the unit available online?, typical responses were:

“Major benefits: (1) easy access (2) suits my timetable.”

“In this unit no drawbacks. Flexibility was a major benefit. Also increased amount of information.”

“Easily accessible. Allowed to run at own pace.”

These perceived benefits are in line with those seen in our studies of students taking online units for the first time [Lund and Volet, 1998, Lund et. al., 1997]. Students from a wide range of disciplines perceive the major advantages of studying online to be:

- Flexibility in learning place and time;
- Guided access to useful resources beyond those available in the conventional mode; and
- The convenience of electronic contact with university staff and other students, especially for those studying at a distance education.

The problems - What were the difficulties?
The drawbacks of studying the Energy Studies units online that were reported by the students mainly related to operational difficulties. Most of these problems will be addressed in subsequent offerings of the units. Although the students, when surveyed, did not report any significant drawbacks, our experience has shown a number of problems are encountered by students when studying online. Some of these are general to all online units, and some are more specific to renewable energy units.

Our studies of online students generally [Lund and Volet, 1998] has shown that internal students who are required to study an online unit for the first time report three main problems with studying online. These are:

- A perceived loss of face-to-face contact with university staff and other students;
- Uncertainty about how to study using this “new” mode of learning; and
- A lack of adequate access to computers and the Internet, on and off campus.

External students generally only rated the third one of these as a problem with studying effectively online. One problem specific to the Science based renewable energy units that has been observed is that of a lack of practical, hands-on experience. There are a number of ways in which these problems can be addressed and these will now be discussed.

Uncertainty about how to use this new mode of learning
Our studies [Lund and Volet, 1998] of students studying online for the first time, including Energy Studies students, have shown that they often lack the confidence and skills needed to study using this “new” mode of learning. These problems can be reduced by careful consideration of the instructional design of the unit, and the provision of appropriate support to assist students.
A perceived loss of face-to-face contact with university staff and other students.

The loss of face-to-face contact with university staff and other students is the primary concern of internal students who are taking online units for the first time. Results of our studies [Lund and Volet, 1998] have shown that even if it is possible to complete the unit entirely online on campus students also want to have face-to-face contact with each other and teaching staff. Effective teacher-student and peer support networks have been shown to reduce the problems encountered by first time online users [Lund and Volet, 1998]. Online delivery also enables greater teacher-student and student-peer support for distance education students. The use of email and electronic discussion groups/bulletin boards, can greatly reduce the isolation normally felt by distance education students, and they value this kind of interaction.

“A little more interaction with a lecturer would be nice, I don’t like being spoon fed, but people I’m contacting are faceless, which can be a little offputting.”

Teacher-mediated interaction between external and internal students on the electronic discussion group, CafeChat, has been shown in the Energy Studies units to be very effective.

“I think the idea of having a summary of the tutorials on the cafe chat is fantastic. As an external student without the interaction with other students this is most helpful and I hope other subjects take up this initiative.”

To quote Freeman [1997] “Considerate student communications are still critical to ensuring positive student learning conceptions. Moral support from friends, supervisors and colleagues can go a long way to maintaining enthusiasm...”

Slow or no Internet access

One of the important issues with offering renewable energy units online is the diversity of computing facilities and internet access available to external students. Although a large percentage of the students taking the postgraduate Energy Studies units appear to have access to the internet (21/25) there are still ~25% who have no access or “email only” access. These students can be catered for by conventional print based delivery, supplemented by email communication where available. This lack of adequate access to the internet is likely to be a problem for a decreasing number of students in developed countries such as Australia [Ivanoff and Clarke, 1996]. Adequate access to computing and internet facilities will however remain a problem for students in developing countries for some time, and it is expensive to live and pay tuition fees to study on campus in a developed country. This is a particular issue for renewable energy studies as developing countries are often those that have an emphasis on renewable energy for power generation, but have few trained professionals to install and maintain them. A different approach will be needed in these countries if an adequate number of students are to receive training in the renewable energy field in this way.

For a significant number of external students access is through a modem and Internet Service Provider (ISP). Because modem speeds are still very slow, down-loading large amounts of online unit material can be time consuming and expensive. For this reason it is still not possible to make extensive use of interactive multimedia or graphics via the internet. It is important that the design of an online unit that is to be offered via distance education takes into account the amount of material that needs to be down-loaded via modem. This problem is approached in two ways in the Energy Studies units. One approach is to develop a “modem friendly” version of the website, where file sizes are kept small and the amount of graphics is reduced, compared to the on campus local area network (LAN) version. An alternative option,
also being developed, is to create a version of the online materials designed for access from a CDROM. With this approach no significant extra development of the unit is needed as the material on the server can be burnt directly to CDROM. The materials are then accessed in the same way using the web browser interface, but the bulk of the material now comes directly from the local CDROM rather than via modem from the host university server. The student only needs to access the internet for other non-host university web sites and electronic communication and this approach can lead to a significant reduction in the time and cost required to access the unit materials. This method is being tried in two of the Energy Studies units this semester and will be implemented on all units in 1999.

A lack of practical hands on experience.

One problem mentioned by a number of students, particularly those with a Science or Engineering background, was that the online units do not provide enough practical hands on experience. This is a difficulty with offering distance education in any Science or Engineering based unit that has a practical component, and is not unique to online units. Although this is a problem that cannot be overcome entirely, there are a number of ways that it can be reduced. Online delivery offers a number of advantages over conventional print-based distance education in this regard. One of these advantages, whether from a server or from CDROM, is the ability to incorporate multimedia, simulations and an interface to real data collection and equipment control. Some examples of the features that can be incorporated into online renewable energy courses include:

- **Multimedia.** The Center for Renewable Energy and Sustainable Technology (CREST) have developed a very interactive CD entitled “The Sun’s Joules” which contains a large amount of information on various renewable energy, energy conservation and climate change topics. One of its features is the incorporation of multimedia video clips showing various aspects of the content being discussed. A typical screen from “The Sun’s Joules” CDROM incorporating a multimedia video clip is shown in Figure 3. An internet version of this CDROM can be found at [http://solstice.crest.org/renewables/SJ/](http://solstice.crest.org/renewables/SJ/), but due to bandwidth considerations this site does not have multimedia movie clips.

  ![Figure 3: A typical screen from "The Sun’s Joules" showing the incorporation of video clips in renewable energy interactive multimedia teaching materials.](image)

- **Simulations.** A number of simulations of renewable energy systems are now becoming available. These range from simple interactive demonstrations such as the SolarSim program developed by the Australian National University [Hume and Cuevas, 1997] to complex system simulation and analysis tools like RAPSIM, which has been developed by the Murdoch University Energy Research Institute. A web based version of the SolarSim simulation is available at [http://hilbert.anu.edu.au/~stefano/Sun/](http://hilbert.anu.edu.au/~stefano/Sun/). These simulations, which are available as online simulations (SolarSim) or can be downloaded as stand-alone programs (RAPSIM) from the internet or CDROM, can be incorporated into the online units to give more practical experience. RAPSIM and other complementary programs are used extensively in the second year postgraduate unit Renewable Energy System Design.

- **Interface to real renewable energy equipment and systems.** A number of Internet sites are now being developed which incorporate a computer interface to enable the collection and display of data from a real world system. These systems, which can display data in close to real time, enable the user to see the system in operation without actual having http://we for demo. Another, Institute (close to r operates http://wv will be u Case Stu

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having to be at the physical site. One such site is the National Instruments site at http://weather.natinst.com/javaweather/, which displays real-time weather information, and is therefore useful for demonstrating the use of instruments for resource assessment. A page from this site is shown in Figure 4. Another, more sophisticated site is the WebRAPS site developed by the Murdoch University Energy Research Institute (MUERI) and ACRE. This website is designed to display both weather and system performance data in close to real-time for the physical RAPS demonstration system at MUERI. Again the user can see how the system operates without actually having to visit the physical site itself. This site, at http://wwwphys.murdoch.edu.au/WebRAPS/ which is described in more detail elsewhere [Lund et al., 1998], will be used in 1999 in the online Energy Studies units Energy Systems, Renewable Energy System Design, and Case Studies of Renewable Energy Systems.

Figure 4. Picture of a page from the real-time weather monitoring system website at National Instruments. The weather conditions are displayed in close to real-time. This demonstrates one use in renewable energy teaching of a computer interface to display real-time data from a physical system.

One important way in which the difficulty of obtaining hands on practical experience when studying online is tackled in the Energy Studies program is through the incorporation of research projects. These projects which constitute one quarter of the total MSc program enable the students to concentrate in more detail on an area of renewable energy that they wish to pursue in more detail. Students are encouraged to work with industry, utility or University groups to look at real practical issues or applications. This gives the student the chance to get practical experience in the area that they are interested in. Therefore, although the problem of students receiving less practical hands on experience when studying online, compared to conventional on campus study, cannot be entirely overcome, there are a number of ways in which it can be reduced.

Conclusions
The Australian Cooperative Research Centre for Renewable Energy (ACRE) in conjunction with Murdoch University have successfully developed and run a range of internationally focussed university courses in renewable energy technology, energy policy, energy efficiency and greenhouse issues, which are available entirely via the world wide web (online). Our experiences so far have shown that there are many potential benefits of offering renewable energy units online and these have been presented. The features of the online units and the methods used to present them, or the practise, have also been discussed. Evaluations of students’ responses to their experiences of studying units online have shown high levels of satisfaction. The students perceive the major advantages of studying online to be; flexibility in learning pace and time; access to useful resources beyond those available in conventional modes of delivery; and the convenience of electronic interaction with university staff and other students, especially for distance education students.

The student responses have also highlighted some operational difficulties that will be addressed when the units are run again in the future. As well as these operational difficulties, which are easily rectified, our experience has highlighted some potential problems of running renewable energy courses online. These include: Uncertainty about how to study using this “new” mode of learning; a perceived loss of adequate face-to-face contact with university staff and other students difficulties with adequate access to the internet; and a lack of practical hands on experience for those studying the online units via distance education.

A number of strategies to overcome these problems have been presented.
Acknowledgments

The work described in this paper has been supported by the Australian CRC for Renewable Energy (ACRE). ACRE activities are funded by the Commonwealth's Cooperative Research Centres Program. ACRE also receives investment funding from the former Energy Research & Development Corporation (ERDC) which managed the federal government's direct investment in energy innovation. The authors would like to thank Simone Volet from the School of Education for her assistance with the collection and analysis of student response data. They would also like to thank Trevor Pryor, Kenneth Cheok, Laura Stocker and Frank Harman for their input to the development of the Energy Studies program. Support for assistance with various aspects of online implementation and instructional design by Geoff Rehn, Roger Atkinson, Allison Brown and Romana Pospisal of the Teaching and Learning Centre at Murdoch University is gratefully acknowledged.

References


