

# Motivating student interest in sustainable engineering and alternative energy research through problem based learning

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## Abstract

There is increasing evidence that the cost of our 'disposable society' is beginning to take a toll and that the continued use of unsustainable resources will have a severe detrimental affect upon the living standards of our successive generations. The possibility of our fossil-fuel resources running dry becomes more likely as the global demand for power increases. This particular resource is also directly responsible for releasing copious quantities of previously entombed carbon directly into our atmosphere, possibly causing global warming. Quite obviously there is therefore a need to consider other means of energy generation that reduce our rate of consuming this finite resource, while also reducing the potential for damage to our planet. This is by no means a new concept, but while scientists and engineers have the ability to initiate change through design, there does not seem to be the level of urgency required to implement effective action. Perhaps there is public confusion regarding alternative energy sources, or perhaps there is simply not sufficient widespread concern for something dramatic to happen right now. As this paper will show, engineering education can be the starting point for change. Graduate engineers can lead the way by researching, designing and developing new practical alternative fuel applications if they are sufficiently enthusiastic. These same engineers can also improve the public's understanding of alternative energy applications. A number of problem based learning projects have therefore been introduced at The University of Adelaide to develop the necessary graduate attributes while also developing a passion for the development of alternative energy solutions. The merits and outcomes of two projects are discussed here: The Biodiesel Motorbike Project and The Hybrid Electric-Solar Car Project.

*Keywords:* *problem based learning, alternative energy.*



## 1 Introduction

While we all seek to improve our level of comfort, research suggests that the convenience of the 'disposable society' in which we now live, threatens the standard of living to which we have all become so accustomed, and perhaps take for granted. In all likelihood, unless a significant change occurs soon, generations of our successors will have a harder way of life, with less energy to go around that needs to be fairly shared by all. As less privileged countries now rapidly develop the consumption of finite supplies of fossil fuels is increasing at an alarming rate. The combustion of this unsustainable carbon based resource may also be adversely affecting our environment by the release of copious quantities of previously entombed carbon dioxide directly into our atmosphere, perhaps contributing to global warming. The interpretation of well-publicised meteorological data (Hansen and Lebedeff [16]) indicates that the earth is warming with a distinct correlation between the underlying pattern of global temperature change, the carbon dioxide concentration in our atmosphere and the carbon dioxide emissions from burnt fossil fuels (Kuo et al [19], Etheridge et al 2002, Keeling and Whorf [18] and NASA [20]). Therefore the need for mainstream alternative, sustainable, eco-friendly energy sources in order to protect our environment is further compounded by the fact that one day our existing fuel sources will run out (Deffeyes [8]).

An Engineers Australia 2004 survey (Engineers Australia [13]) demonstrated that 79% of those polled believed that the reduction of greenhouse gases from the energy generation and transport sectors is extremely important and most believed that renewable energy was the best option for reducing greenhouse gas emissions. Scientific data supports these beliefs. The transport sector is a huge consumer of energy and Australians recognise that sustainable transport issues are now of particular significance to the community and therefore to engineers (Engineers Australia [11, 12]). However, despite these beliefs and while we are able to all directly influence CO<sub>2</sub> pollution by our choice of personal vehicles or use of public transport, the CO<sub>2</sub> emissions from Australian cars and power generation still increase at an alarming rate (Australian Government [1]). Only very recently, amidst the hardship of never-before-seen high petrol prices (The Age [24]) are Australian consumers are considering the switch to smaller cars (NRMA, 2006) and alternative fuels are once again becoming a mainstream media interest. It appears that collectively we do not possess a social conscience towards environmental issues but share a common need to protect our standard of living, which ironically is currently self destructive. Unger (1992) stated that scientific evidence of environment damage is insufficient to encourage change and that it is only taken seriously when the evidence is complimented by a significant and disturbing real-world event such as extraordinary weather conditions. Change can happen though and is beginning to happen in some countries.

One stand out example is Sweden that intends to be fossil fuel independent by generating most of its electricity by hydroelectric power stations and nuclear reactors (the latter of which is still only a short term solution with a finite



uranium supply). In such an economy that does not burn significant amounts of fossil fuels to generate grid power, hydrogen fuel cell vehicles (that use an efficient alternative for storing and transferring energy) have a distinct advantage. General Motors have made significant progress in hydrogen fuel cell vehicles so that their usage is not only entirely feasible but extremely probable (Boroni-Bird [6]). These vehicles would clearly lend themselves well to any infrastructure that harnesses clean energy from, Wave, Hydro, Solar, Wind, Geothermal or Nuclear energy (which is a confrontational unsustainable option, but still an alternative regardless of opinion).

However, some countries are still heavily reliant upon a fossil-fuel fired power industry and the inefficiencies of transferring this energy to transportable storage systems in vehicles may ultimately lead to more carbon emissions. Biomass fuel is another sustainable fuel option that while not clean is far cleaner. Biodiesel is one such fuel and is efficiently produced by a simple chemical transesterification process in which waste or harvested vegetable, seed or tallow (animal fat) is transformed into biodiesel and glycerol (MacLean et al 2000). Biodiesel only requires 0.31MJ of fossil-fuel energy across its entire lifecycle in order to generate 1 MJ of energy during combustion. This total energy output to fossil-fuel energy input ratio of >3:1 implies that biodiesel can significantly reduce our dependence on fossil fuels. When the feedstock is produced from plant or seed matter it also possesses a huge environmental benefit because when the feedstock is grown, it absorbs CO<sub>2</sub> through the process of photosynthesis, resulting in a substantially reduced net CO<sub>2</sub> emission (78% less than those from fossil-fuels) across the entire lifecycle of the fuel (Beer et al 2004, Sheehan et al 1998 and Bowman et al 2006). Biodiesel is also more oxygenated than regular diesel and produces far less particulates; it contains no sulphur or aromatics; it is biodegradable and non-toxic; it has superior lubrication characteristics and can run in unmodified diesel engines (which are more efficient than petroleum spark-ignition engines).

It becomes evident that when considering the previously mentioned alternatives that when multiple alternative energy sources are matched to ideally suited applications and environments, that there can be a significant combined impact on the problem. In the transport sector alternative energy and hybrid vehicles can now offer similar cost and performance to existing modes of transport and the introduction of these vehicles will start to ease the burden on fossil-fuel consumption and CO<sub>2</sub> emissions. But research and development needs to be accelerated so that all become part of a mainstream solution soon. It is therefore important to ensure that engineering students develop a positive interest with respect to sustainability so that they continue to enthusiastically practice it once they have graduated. While good lectures can be inspirational (Edwards et al [9]), engineering curricula are bursting at the seams and 'sustainability' can easily become insignificant amongst the plethora of engineering subjects that need to be covered.



## 2 Using problem based learning techniques

At the University of Adelaide, lectures in sustainable engineering are now complemented by problem-based-learning (PBL) projects that stimulate student-centred learning (such as a bio-diesel motorbike and a hybrid electric-solar car). In these the students encounter the issue of sustainable alternative energy and apply their existing body of knowledge to deduce what further research and development is required towards a comprehended solution (Schwartz et al [23]). Problem based learning forces the students to learn the principles of the subject in the context of requiring the knowledge in order to solve the problem (Woods 1998). These projects will also develop the attributes that students need for their future profession while encouraging them to discover how viable alternative energy concepts can be. Wee [25] defines these types of problem based learning exercises as ‘authentic problem based learning (APBL)’ because of the student engagement of the same activities that they are likely to practice in their profession. The encouragement of self-motivated research and the opportunity for students to practice sustainable engineering principles first hand ultimately provides a sense of pride and ownership of the solution. To ensure this self-directed learning, it is therefore important that the project problem is defined in such a way that students perceive the project to be charismatic, stimulating and appealing. Additionally, if students successfully complete these projects with pride, they are more likely to take on the lessons learnt with a desire to put them into practice once employed.

As discussed in the following paragraphs, two teams of students were set two different challenges. The first (which has shown the most progress to date), was to design and build a motorbike that runs well on biodiesel. The second was to design and build a commercially viable electric car in which the range would be extended by the use of solar cells.

## 3 The Hybrid Solar Electric Vehicle (HSEV)

In 2006 the Hybrid Electric Solar Car Project was established to encourage a team of four mechanical engineering students and five electrical engineering students to consider a commercially viable electric vehicle that would also incorporate electric solar cells to prolong its range. Design and building such a car within an academic year would be impossible and to expect such a magnitude of achievement would be unfair and ultimately demoralising for the students. The project was therefore broken down into two initial phases so that the goals, while still challenging, were achievable. Phase one (for 2006) required that the students design an attractive concept vehicle and produce a physical mock up, using the tools that would normally be used in the design and development of a prototype or concept vehicle. The students wanted the vehicle to have market appeal and so went for a sporty design that would also enable the car to be small and hence lightweight. The 3D digital prototype (Figure 1) was used to develop the aesthetics, ergonomics and the packaging of subassemblies such as the power train and the control systems.



A systems engineering approach was adopted and each student tackled a specific sub-system of the design in which they further developed engineering attributes that were directly pertinent to their area. Once the digital prototype was completed the students began the manufacture of a full scale proof of concept mock-up that had some limited functionality. This was to clearly demonstrate the projects potential to ultimately develop a commercially viable vehicle. While only a rudimentary chassis was constructed from spare parts and whatever material was at hand (because of a very limited budget) the students' intent however was only to build a feasibility study mock-up and so what was beneath the shell was unimportant at this stage. The 3D digital prototype was then used to develop a CAM model from which a full size foam model was CNC milled (Figure 1). Once the wheels were fitted with in-hub electric motors (to provide some limited motion) and the early prototype control and energy management system fitted to the car, the outside of the car was fibre glassed, painted and fitted with accessories (Figure 1). While the finished vehicle has some dissimilarities to the model (due to the availability of affordable components), the students achieved their aim in producing a hybrid electric solar vehicle that could be commercially viable.



Figure 1: The Hybrid Electric Solar Vehicle (HESV) from digital prototype to mock-up manufacture.

Phase two of the project has commenced at the start of this year in which participating students, who were satisfied with the previous proof of concept study, have embarked upon building a far more functional car. This year's team are therefore currently engineering a lightweight fully functioning chassis, suspension, steering system and ancillary components that will comply with the Australian Design Rules. This is stage of the project is scheduled to be completed by the end of 2007.

#### **4 The Biodiesel Motorbike Project (Biobike)**

The second of these two projects is the Biodiesel Motorbike Project" (or the "Bio-Bike" as the students have named it) which demonstrates the feasibility of biodiesel in a small lightweight novel application. The choice of a lightweight vehicle (such as a motorbike), not usually associated with diesel was also intended to test their innovation, theoretical understanding, research and general automotive engineering skills. A further dimension was added to the challenge when the inaugural students decided to add the additional goal of aiming to participate in the alternative fuel (Greenfleet) class of the 2007 World Solar Car Challenge.

At the beginning of 2006 the project proved to be extremely popular and as such was oversubscribed with students wishing to participate as part of their final year honours project. Nine enthusiastic students commenced their research well before the start of their semester (during their Christmas vacation) and set about planning their strategy. They identified their needs, they set their goals and they attracted sponsorship. Once again as in the case of the HSEV, the students adopted a method of systems engineering in their approach to the project and divided it into a number of smaller projects so that each student had a specific area of responsibility. They initially developed a digital prototype (Figure 2) to assist with their engineering analysis and to ensure that both the designed and off-the-shelf components would assemble as intended. Once the modelling was completed the team built a 'proof of concept' physical prototype to demonstrate that the bike could be used for an agricultural application. An agricultural application was chosen to reinforce the notion of sustainability and to show that farmers could use biodiesel bikes to help manage the land on which they grow feedstock for biodiesel.

The 2006 prototype of the bike is shown at various stages of assembly in Figure 2 and consists of a heavily modified recycled Husaberg motocross bike frame, a modified 410cc Yanmar diesel engine and a CVT transmission. All of these components were selected and integrated towards the objective maximising ease of manufacture and the fuel efficiency.

The completed bike (Figure 3) was unveiled at the Royal Adelaide Show, which is a very popular local annual agricultural carnival. At the show it received considerable praise.



Figure 2: The biodiesel from digital prototype to completion.



Figure 3: The completed biodiesel bike at the Royal Adelaide Show.



## 5 Outcomes

In terms of the design and manufacturing requirement, the biodiesel motorbike is a far simpler challenge than the HSEV and so was able to advance to a more mature stage of its evolution. Consequently the students attracted significant media attention thus raising the profile of sustainable engineering and alternative fuels (Figure 4). News of the bike was published on the front page of the University of Adelaide's quarterly publication, *The Adelaidean* and the Alumni magazine *Lumen* (Ellis [10]), which in turn led to a glowing review in Adelaide's popular daily news paper, the *Advertiser* (Cooper [7]). The Bio-Bike was also featured on three of the major television networks; Channel 7, Channel 10 and the ABC (Fat Bike [15], Bio-Bike [4] and Green Machine [17]) and all of the coverage praised the students' practical application of an alternative sustainable fuel.



Figure 4: The media response.



Both projects have proven to be truly charismatic with both attracting significant interest in both the inaugural and second year of being offered. Although the students were attracted to the projects for different reasons they now all have well balanced opinions regarding alternative fuels and sustainable engineering. Both projects have proven to be extremely popular and continue to be excellent catalysts for promoting sustainable engineering ideologies, or more specifically, sustainable alternative fuels and their application. The participating students have developed self-motivated research skills and have learnt how to work in teams towards achieving a common goal. They have also learnt how to market themselves in order to raise finances and how to work within the budget constraints of those finances. Their engineering skills have developed through their comprehensive use of CAD, engineering analysis software and prototype testing and their confidence and communication skills have also improved through their continued liaison with industry. The main achievement however has been that most of the students who took part in the projects last year and have since graduated are now pursuing rewarding professional careers in which they can practice many of the lessons that they have learnt.

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