Flexible Delivery Flat-Pack Module

An Overview of Energy Efficiency Opportunities in Information, Telecommunications, and Electronics Engineering

Produced by

The University of Adelaide and Queensland University of Technology (The Natural Edge Project)

The EEERE Project:

Energy **E**fficiency **E**ducation **R**esources for **E**ngineering

Consortium Partners:

Queensland University of Technology

The University of Adelaide

Victoria University Melbourne Australia

RMIT University

University of Wollongong

La Trobe University Australia

Project Partners:

Engineers Australia

aced

Australasian Association for Engineering Education

energy efficiency council

asbec Australian Sustainable Built Environment Council

Australian Government

Department of Industry

Citation Details

All resources developed for the EEERE project are made available to the public through the Creative Commons Attributes licence. Accordingly, this document should be cited in the following manner:

Hargroves, K., Wilson, K., Lawry, N., McKeague, F. and Desha, C. (2014) *An Overview of Energy Efficiency Opportunities in Information, Telecommunications, and Electronics Engineering*, The University of Adelaide and Queensland University of Technology (The Natural Edge Project), commissioned by the Australian Government Department of Industry, Canberra.

Acknowledgements

The team from Adelaide University and QUT that developed this document acknowledge the work of our colleagues at QUT David Sparks, Fiona McKeague, and Cheryl Desha who we supported to develop the accompanying video resources, along with the partners involved. The consortium thanks the 40 workshop participants (Brisbane, Sydney and Melbourne) including stakeholder partners, Engineers Australia College Members, industry and academic colleagues, who provided their time and ideas so generously during the stakeholder engagement parts of the project, and to those who have assisted in reviewing the drafted resources, in particular Alan Pears, energy efficiency expert, and Dr Nickolas Falkner, Associate Dean (Information Technology), University of Adelaide. We would like to thank the students at the University of Adelaide who provided review comments on the lecture and the accompanying video resource. The consortium thanks our project partners for their continued commitment to building capacity in delivering sustainable solutions, and the federal government for funding the initiative, in particular Mr Stuart Richardson, Mr Luiz Ribeiro, Ms Denise Caddy and Mr Nick Jackson, for their contribution to engineering capacity building. Material contained in this document includes content drawn from The Natural Edge Project (TNEP) Sustainable Energy Solutions Program and is adapted herein as per licencing agreements with CSIRO and Griffith University.

Project Background

Energy efficiency is widely recognised as the simplest and most cost-effective way to manage rising energy costs and reduce Australia's greenhouse gas emissions. Promoting and implementing energy efficiency measures across multiple sectors requires significant development and advancement of the knowledge and skills base in Australia, and around the world. Engineering has been specifically identified as a profession with opportunities to make substantial contributions to a clean and energy-efficient future. To further enable skills development in this field, the Department of Industry commissioned a consortium of Australian universities to collaboratively develop four innovative and highly targeted resources on energy efficiency assessments, for use within engineering curricula. These include the following resources informed by national stakeholder engagement workshops coordinated by RMIT:

1. *Ten* ***'flat-pack'*** *supporting teaching and learning notes for each of the key disciplines of engineering (University of Adelaide and Queensland University of Technology);*
2. *Ten short* ***'multi-media bite'*** *videos to compliment the flat-packs (Queensland University of Technology and the University of Adelaide);*
3. *Two* ***'deep-dive case studies'*** *including worked calculations (University of Wollongong); and*
4. *A '****virtual reality experience'*** *in an energy efficiency assessment (Victoria and LaTrobe Universities).*

These resources have been developed with reference to a 2012 investigation into engineering education[1] funded by the Australian Government's former Department of Resources, Energy and Tourism (RET), and through further consultation workshops with project partners and industry stakeholders. At these workshops, participants confirmed the need for urgent capacity building in energy efficiency assessments, accompanied by clear guidance for any resources developed, to readily incorporate them into existing courses and programs. Industry also confirmed three key graduate attributes of priority focus for these education resources, comprising the ability to: think in systems; communicate between and beyond engineering disciplines; and develop and communication the business case for energy efficiency opportunities.

Content

1. 'Allen Key' Learning Points

Information, Telecommunications and Electronics Engineers will be a key part of the World's response to climate change, from the mega data centres and computing equipment that uses far less energy, to the use of control systems and monitoring to minimise energy demand of industrial operations across the economy. ITE Engineers have critical skills the economy needs to thrive in a carbon constrained future. The following learning points provide a summary of the ITE engineering video – our 'Allen keys' to building the flat-pack content!

Watch the '***ITE Engineering***' MMB

1. The information, telecommunications and electronics industry is rapidly growing and is developing a capacity to support every industry, and it is especially equipped to support the achievement of significant increases in energy efficiency. The tools now available in ITEE allow information to be collected, analysed, and communicated in ways can transform entire industrial systems, resulting in the compounding of energy efficiency improvements.
2. Within ITEE itself we are seeing enormous advances that stand to deliver significant energy efficiency improvements. For instance virtualisation technology, remote data centres, and the use of the online data cloud, are reducing the capital and space requirements across all sectors for computer systems by requiring less energy, less equipment, and less server room air-condition,
3. As a result of virtualisation and data storage improvements, Cook Medical was able to drastically reduce the size of its physical data server equipment. Engineers at Cook Medical developed a pilot study with Dell and monitored the results over 18 months. As a result of the trial cook reduced their physical servers to just 10 and are able to run 184 virtual servers. An essential component of Cook Medical's success in adopting virtualised data servers was the ability of engineers to communicate the potential savings to the financial and operational decision makers in the company.
4. ITEE also involves the design of monitoring devises that facilitate energy management and identify opportunities to save energy, time, resources and money. These systems are themselves being constantly refined and redesigned to run more efficiently and deliver more savings.
5. In the Springfield Orion Town Centre near Brisbane, clever software modelling was used to control both air-conditioning and daylighting to reduce energy demands. Sophisticated software was created which took account of louver positions, sunlight, sunlight intensity, and lighting energy to eliminate energy demand during the day while creating an environment with appropriate and safe lighting in the variable conditions. Once the system was modelled, engineers were able to develop software and hardware solutions that were within the 'cost envelope'.
6. Information, Telecommunications and Electronics Engineers stand to gain from working closely with other engineering disciplines and professions to identify and implement energy efficiency improvements. Hence engineers of all disciplines will need good communication skills in order to integrate the significant potential for energy saving opportunities that come from working with other disciplines, stakeholders, and project members.

2. Energy Efficiency and ITEE

1.1. Why is Energy Efficiency important for Engineers?

In the 21st Century much of the world will experience untold wealth and prosperity that could not even be conceived only a century ago.[2] However as with most, if not all, of the human civilisations, increases in prosperity and population have accumulated significant environmental impacts that threaten to result in what Lester Brown refers to as '*environmentally-induced economic decline*'.[3] There have been a number of significant advances in technology over the last 300 years that have delivered a step changes in the way industry and society has operated, as shown in Figure 1. Given the now advanced level of technological development we are in a very strong position to harness this technology to create a '6th Wave' that can deliver significant reductions in a range of environmental pressures, such as air pollution, solid waste, water extraction, biodiversity loss and greenhouse gas emissions.[4]

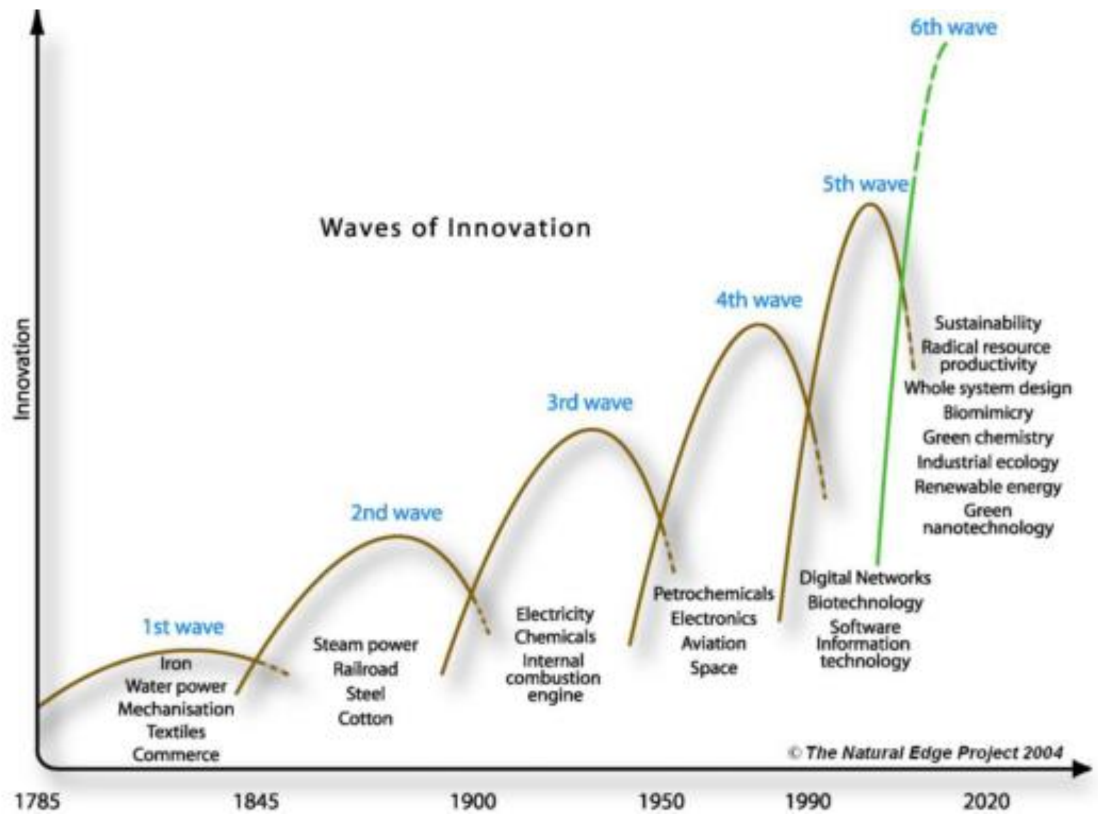

Figure 1: A stylistic representation of waves of innovation since the Industrial revolution[5]

What this means is that over the coming decades the impact we are having on the environment will have a direct negative effect on our economies and societies, this will, and is, lead to louder and lauder calls to reduce negative impacts on the environment which will need innovation and creativity. In particular there is a fundamental need to shift from fossil fuel based energy to low/no carbon energy sources, preferably renewable options, in order to significantly reduce greenhouse gas emissions. Building on the technologies and processes from the previous waves of innovation engineers are now in a strong position to deliver such a shift and create a range of innovative and creative solutions to the meet the needs of society, with a key part of this achieving greater efficiency of the use of resources and energy.

According to the World Business Council for Sustainable Development (WBCSD) in their 1992 publication 'Changing Course', the term 'efficiency' was used to seek to encapsulate the idea of using fewer resources and creating less waste and pollution while providing the same or better services, and entailed the following elements:

- A reduction in the material intensity of goods or services,
- A reduction in the energy intensity of goods or services,
- Reduced dispersion of toxic materials,
- Improved recyclability,
- Maximum use of renewable resources,
- Increased durability of products, and
- Greater service intensity of goods and services.

Each of these approaches provides valuable tools to reduce a range of environmental pressures, especially greenhouse gas emissions.

Identify an ITE Engineering example of the application of each element.

For each element identify the potential for collaboration with other engineers.

Since the late 1990's Engineers Australia has advocated for Engineers to play a key role in supporting the achievement of such ambitious targets, and cautions that, '*The need to make changes in the way energy is used and supplied throughout the world represents the greatest challenge to Engineers in moving toward sustainability.*'[6] By the end of 2014 this shift had built significant momentum with the European Union committing to reduce emissions by at least 40 per cent by 2030 (compared to 1990 levels), China setting the goal of 40 to 45 per cent by 2020 (compared to 2005 levels), India setting the goal of 20-25 per cent by 2020 (compared to 2005 levels), and the United States of America setting the goal of 26-28 per cent by 2025 (compared to 2005 levels). Further the Intergovernmental Panel on Climate Change (IPCC) reports that all nations will need to achieve significant reductions in greenhouse gas emissions in the order of 60-80 per cent by 2050.[7]

> ***These ambitious targets will create significant pressure to reduce emissions in the coming decades, in particular between 2015 and 2030; and all industries grapple with the challenge of reducing greenhouse gas emissions in a manner that delivers ongoing prosperity, jobs, and profits.***

A key part of this energy transition is to swiftly reduce the growing demand for energy across society as this will generate numerous cost savings that can be invested in the shift to low/no carbon energy, along with reducing demand levels that need to be met by the new energy solutions. Reducing the energy demand say of a building or a processing plant delivers the following benefits:

- *Generates cost savings* by reducing the energy charges, extending the life of equipment by reducing the loading, reducing operating times and levels of equipment and even allowing decommissioning of some equipment, and often reduces heat generated from equipment or lighting that adds load to the HVAC system.
- *Creates capital for investment* in the transition to the use of low/no carbon energy, often by investing in onsite renewable energy generation options that can harness waste heat from the existing system while providing security of supply for the operation of the building or plant.

- *Creates demand for new products and services* that will be needed around the world to assist industries and economies to reduce energy demand. This will translate into significant opportunities for Australian engineering firms that can innovate low/no carbon solutions ahead of international competition.[8]

Energy efficiency as a concept has gained significant attention over the last few decades, as governments and industries around the world have grappled with issues such as rapidly expanding needs for energy, the cost of supplying infrastructure to meet peak demand, the finite nature of fossil based energy reserves, and transition timeframes for expanding renewable energy supplies. Coupled with a growing number of cases of companies achieving significant fossil fuel consumption reductions in a timely and cost effective manner, energy efficiency is quickly becoming a core part of the practice of engineers, as shown in Table 1.

Where can ITE Engineers reduce greenhouse gas emissions?

How could energy efficiency provide benefits to an ITEE firm?

Table 1: *Example opportunities to significantly reduce greenhouse gas emissions*

Sector	Best Practice Case Studies
Steel Industry[9]	Leading US steel company, Nucor Steel, is around 70% more energy efficient than many steel companies around the world,[10] using state-of-the-art electric arc furnace systems, adopting leading practices such as net shape casting, and by implementing options such as energy monitoring, systems for energy recovery and distribution between processes.[11]
Cement Industry[12]	Ordinary Portland cement manufacture is responsible for between 6-8% of global greenhouse emissions and this is rising with demand. The good news is that an Australian company Zeobond Pty Ltd, based in Melbourne, is now making geo-polymer cement which reduces energy usage and greenhouse gas emissions by over 80%.[13] Geo-polymers can be used for most major purposes for which Portland cement is currently used.[14]
Paper and Pulp Industry[15]	Catalyst Paper International improved their energy efficiency by 20% across all operations since 1990, saving the company close to US$26 million between 1994 and 2004. At the same time, they've reduced their greenhouse gas emissions by 69% through greater use of biomass and sourcing electricity from hydro power.[16] The pulp and paper sector has the potential in both existing and new mills to become renewable electricity power generators through the use of Black Liquor Gasification-Combined Cycle technologies.[17]
Transport Vehicle Efficiency[18]	Integrating technical advances in light-weighting, hybrid electric engines, batteries, regenerative breaking and aerodynamics is enabling numerous automotive and transport vehicle companies to redesign cars, motorbikes, trucks, trains, ships and aeroplanes to be significantly (50-80%) more fuel efficient than standard internal combustion vehicles. Plug-in vehicle technologies are opening up the potential for all transportation vehicles to be run on batteries charged by renewable energy.[19]
Transport Efficiency from Modal shifts. (Passenger)[20]	Shifting transport modes can also lead to significant energy efficiency gains. One bus with 25 passengers reduces energy and greenhouse gas emissions per capita by approximately 86% per kilometre compared to 25 single occupant vehicles (SOV).[21] Trains are even more efficient. Typically, rail systems in European cities are 7 times more energy-efficient than car travel in US cities.[22]
Transport Efficiency from Modal Shifts (Freight)[23]	Shifting freight transport from trucks to rail can also lead to large efficiency gains of between 75 and 85%.[24] Several countries are moving to improve the efficiency of their transport sectors by making large investments in rail freight infrastructure, including improving the modal interfaces. For instance, China has invested US$292 billion to improve and extend its rail network from 78,000 km in 2007, to over 120,000km by 2020, much of which will be dedicated to freight.

Source: Based on von Weizsäcker, Hargroves, K. *et al* (2009)[25] as presented in Hargroves, K., and Desha, C. (2014)[26]

Considering Buildings, efficiency expert Joseph Romm explains that key to delivering improved energy efficiency of buildings is the understanding that the design phase is critical, pointing out that, '*Although up-front building and design costs may represent only a fraction of the building's life-cycle costs, when just 1 per cent of a project's up-front costs are spent, up to 70 per cent of its life-cycle costs may already be committed*'.[27] As pointed out in the book '*Whole System Design: An Integrated Approach to Sustainable Engineering*',[28] the cost of design changes increases significantly through the design and construction process, and as such it is important that early in the concept design phase opportunities for energy efficiency are identified and incorporated into the design rather than retrofitted at a later date, especially as buildings and civil infrastructure are designed with an operational life of some 50-100 years.[29]

A key part of the design is to consider the potential for compounding energy efficiency savings. Energy efficiency expert Alan Pears uses the example of an electric motor driving a pump that circulates a liquid around an industrial site.[30] If each element in the chain is improved in efficiency by 10 percent, the overall efficiency is not improved by 10 per cent but rather 47 per cent as the overall efficiency is the product of the component efficiencies: 0.9 x 0.9 x 0.9 x 0.9 x 0.9 x 0.9 = 0.53. Applying this systems approach can deliver significant energy demand savings, such as: [31]

– By focusing first on reducing both the mass of a passenger vehicle and the aerodynamic drag by 50% this can reduce rolling resistance by 65%; making a fuel cell propulsion system viable and cost effective, and delivering significantly better fuel consumption per kilometre.

– By using the right-sized energy efficient components to reduce generated heat, a computer server can be designed to have 60% less mass and use 84% less power than the equivalent server, which would reduce cooling load in a data centre by 63%.

A key outcome of a focus on energy efficiency is that it often also delivers multiple benefits across the system can be often overlooked. For example energy efficient cleaning systems may use less water and detergents, light-weighting vehicles to improve fuel efficiency may reduce material consumption, reducing cooling loads in a building through external shading may extend the operating life of air-conditioning equipment, reducing pumping loads in a system may lead to decommissioning of unneeded pumps, reducing residential energy demand during peak times can significantly reduce overall capacity requirements and defer infrastructure upgrades.

1.2. Why is Energy Efficiency important for Engineering Students?

In 2006 the Australian Government created the Energy Efficiency Opportunities (EEO) Act with the objective to '*improve the identification, evaluation, and public reporting of energy efficiency opportunities by large energy-using businesses, to increase the uptake of cost effective energy efficiency opportunities*'.

The EEO Act was applicable to corporations that used over 0.5 petajoules of energy per year; this represented some 300 companies and just over half of Australia's total energy use. Participating companies were required to undertake an energy efficiency assessment and report to the government on the findings.

Watch an Introduction to the EEO Program

Between 2006 and June 2011 participants in the program identified the potential for annual energy savings of 164.2 PJ through a focus on energy efficiency across each major sector, as shown in Figure 2. As part of the program 89 PJ of energy was saved, the equivalent of 24 billion kWh's per year.

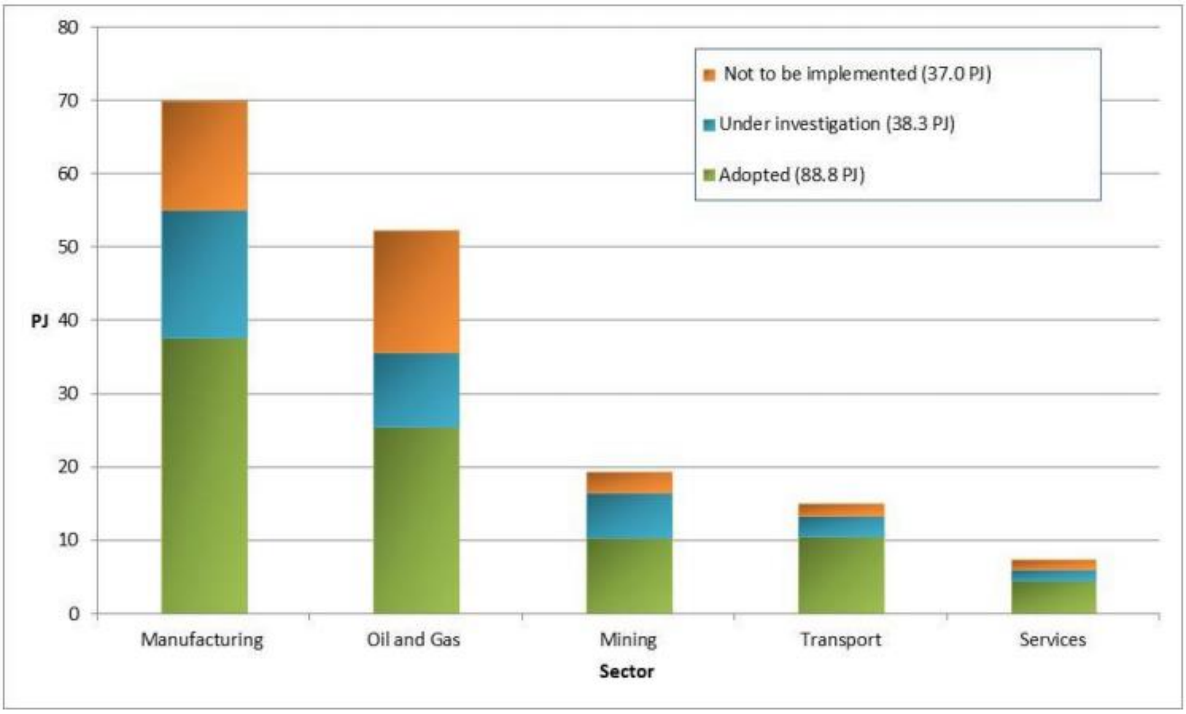

Figure 2: Summary of energy efficiency achievements in by participants in the Australian Government Energy Efficiency Opportunities (EEO) program (2006-11)[32]

This energy saving is estimated to have resulted in an annual economic benefit of just over $800 million, with the majority of investments to achieve the energy savings having either a 1 year or 2 year return on investment.[33] The significance of this program for engineering students is that the largest energy using companies in the country have developed processes to undertaken energy efficiency assessments and the ability to contribute to such assessments is likely to become a part of graduate recruitment preferences given the strong economic results from the EEO program.

> ***In 2011 an investigation found that 6 out of the 10 largest engineering companies operating in Australia provided in-house training on energy efficiency to supplement graduates formal training, and 4 out the 10 had included energy efficiency requirements in graduate recruitment criteria.[34]***

Of further interest to engineering students is that the participants in the program listed an aggregate of 38.3 PJ of energy saving opportunities (or some 10 billion KWh per year) as being 'under investigation', meaning that graduates can differentiate themselves by ensuring they are well versed in energy efficiency.

List a specific opportunity for ITE Engineers to achieve energy efficiency improvements in each of the sectors involved in the EEO Program (Figure 1).

3. Key Knowledge and Skills in ITEE

According to the European Commission in 2008, '…*the continued growth of the European economy … needs to be decoupled from energy consumption … ICTs have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy*'.[35] As such Information, Telecommunications and Electronics Engineering (ITEE) is in a position to make a substantial contribution to societies around the world in achieving improved energy efficiency by contributing in most industry sectors, through the development of *'hardware, software, control systems and sophisticated electronics that regulate energy demand and supply*'.[36] In short, ITEE can offer a great deal towards achieving sustainable development through increasing energy efficiency in the design of software to enhance energy management, reducing the energy wasted in ITE systems such as stand-buy power, smart communications networks to enhance electricity grid management, advanced video communications to reduce physical travel, and building management systems to minimise energy consumption in buildings.

According to Francis Barram, the Director of Innovation and Strategy at Ensight, significant savings can be made by optimising air conditioning and day lighting using sophisticated software systems. The software designed by Ensight for the Orion Springfield Central Shopping Centre in Queensland takes into account louver positions, sunlight intensity, and lighting energy to ensure the shopping areas were safe and shadows were avoided. The software engineers worked with time constraints to develop a code, test, and commission the system. A further example of opportunities for engineers to assist industry to increase energy efficiency is in the area of data management.[37] Data management is essential for all medium to large businesses and it consumes large amounts of energy to run servers and maintain specific temperature and humidity levels. Reductions in energy use by servers and server farms of up to 80 per cent have shown to be possible by targeting each major energy consuming step in the process.[38] Engineers play a key role in such achievements in areas including:

- infrastructure architecture,
- virtualisation and consolidation,
- efficient rack equipment,
- power supply and distribution,
- rack cooling,
- equipment layout and air flow,
- room external cooling load,
- computer room air-conditioning, and
- heat and power recovery.[39]

ITEE systems allow users to gain energy efficiency benefits which compound due to the interconnection of different systems which require energy. This occurs on many scales (a house, an organisation or a city), as there are multiple choices which can be made regarding practices which impact on the environment. The systems allow informed decisions to be made through creating the capacity to collect, analyse and communicate information, which can transform practices and change the use of resources, achieving both monetary savings and the opportunity to make an ecological difference.

When considering the discipline-specific considerations related to the graduate attribute "*Ability to Participate in/Contribute to Energy Efficiency Assessments*" this could include creating software tools to assist energy efficient design and management in other disciplines (buildings, manufacturing processes etc) and achieving energy efficiency in numerous energy using systems such as lighting, heating and air-conditioning, lifts, pumps and motors, and computers/ servers/ telecommunications.

4. Energy Efficiency Opportunities in ITEE

*Here we provide a summary of key materials outlining energy efficiency opportunities related to chemical engineering. This section informs **'Tutorial Exercise 6: Identify examples of energy efficiency opportunities in particular engineering disciplines'** from the Introductory Flat-Pack.*

2.1. Heating, Ventilation and Air-Conditioning (HVAC)[i]

The use of control systems can help to identify potential energy efficiency opportunities in HVAC systems. Complimenting options for reducing energy demand of HVAC systems through the design of such systems by Mechanical Engineers, ITEE provides the option to develop control systems that can optimise the operation of HVAC systems and further reduce energy demand. According to the UK Carbon Trust, '*Making even small adjustments to systems can significantly improve the working environment and at the same time, save money'.*[40] Control systems that are adequately commissioned and programmed can reduce HVAC energy consumption through a number of ways, including: ensuring that the right amount of air-conditioning is provided when it is required, harnessing a building's thermal mass to achieving small reductions in operation time,[41] shutting down compressors when not needed, and reducing use during peak energy demand periods. There are several types of control systems available for HVAC systems:

- *Time-switches* are a simple, low-cost technology for activating and deactivating HVAC systems at specific times, such as activating an hour before a shift starts and deactivating an hour before a shift ends. *Intelligent time-switches* also learn the operating period and adjust activation and deactivation times accordingly; this can reduce operating time by 5-10 per cent. Time-switches should also incorporate holiday programming and timed overrides to allow extended use when required.
- *Thermostats*[42] are a popular control technology for HVAC systems. Thermostat location is an important consideration because poorly located thermostats can increase energy consumption.[43] Thermostats provide accurate readings when located on an interior wall (which is nearer to the average space temperature than exterior walls), or near a return duct (where flow is constant and unrestricted). Thermostats will provide inaccurate readings when located in direct sunlight, near artificial heat sources such as office and refrigeration equipment, or when isolated behind doors or curtains. Locating multiple thermostats in the same space with conflicting air-conditioning set-points will make HVAC systems work against each other and thus increase energy consumption.[44]
- *Energy management systems*[45] are popular in retail, food service, and other regularly occupied buildings. They allow advanced control, monitoring, and alarm of several HVAC system components. Control options include unit operation for either heating or cooling, fan operation and scheduling, and economiser control. Monitoring options include supply and return air temperature information. Alarm options include fan failure, dirty filters, compressor high- or low-pressure lockout, and economy cooling status. Energy consumption can be further reduced by adjusting controls for seasonal variations in ambient climate.[46] Each 1°C forward increase in set-point will increase energy consumption by about 15 per cent in winter and 10 per cent in summer.

[i] The following is an edited extract from Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007) *Engineering Sustainable Solutions Program: Sustainable Energy Solutions Portfolio*, The Natural Edge Project, Lecture 2.3.

– *Demand-controlled ventilation* adjusts outdoor air intake to maintain an optimal range of indoor carbon dioxide concentration; a typical indicator of indoor air quality. Preventing over-ventilation minimises undesirable heat transfer and humidity. Demand-controlled ventilation is most effective in spaces with highly variable occupancies such as auditoriums and meeting rooms, to prevent over-ventilation.[47]

Metering and monitoring is essential in order to ensure that the benefits of good design intentions and retrofits are not whittled away. Systems are now available which automatically record and communicate energy consumption, e.g. through the building automation system, or systems such as www.eco-tracker.com. Monitoring of maintenance contractor observations and recording (see above) will also help to safeguard energy efficiency and equipment. Next generation systems are now being designed to allow 'Predictive Energy Optimisation' where the software compares ambient conditions and building usage with operating parameters to 'learn' how to optimise energy performance of buildings. The Australian company BuildingIQ, who's core technology was developed by CSIRO, suggests that the use of predictive energy optimisation can result in 'e*nergy reductions in the range of 10-25% are typical, with reductions climbing to as high as 40% during operational peaks*.[48]

Identify a case study from Australia where each of the above options has been used to deliver reduced energy demand in HVAC systems.

2.2. Electric Motor Systems[ii]

The energy efficiency of motor systems can be increased in a number of ways through the use of control systems that can provide real time information on the demands and performance of the system to allow optimisation. This information can be used to shut down and start up specific motors depending on demand rather than having them run all the time to cover periods when they are required.[49] Control technologies for motors can include:

- Calendar time switches, which prevent motors from starting up on public holidays and rostered days off,
- Level float switches, which control pumps that would otherwise be running continuously, and
- Thermostats, which allow chilled water pumps to operate only in warm weather.

Matching the speed of the motor to the demand of the system can deliver significant energy efficiency improvements. This is typically done by introducing dampers or valves in the system to slow down the flow rate, however in order to do so they create impediments to the flow that create turbulence and add to the pumping power needed for the system. Hence the use of control systems such as variable speed drives avoids this increase in pumping energy to alter the flow rate and can adjust the motor speed and torque to match the load in real time.

According to the American Council for an Energy Efficient Economy, *'Other technologies include microprocessor-based controllers that monitor system variables and adjust motor load accordingly, and power-factor controllers that can trim the energy use of small motors driving grinders, drills, and other devices that idle at nearly zero loading most of the time. There are also application-specific*

[ii] The following is an edited extract from Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007) *Engineering Sustainable Solutions Program: Sustainable Energy Solutions Portfolio*, The Natural Edge Project, Lecture 3.1.

controls such as those that sequence the operation of multiple compressors in a compressed air system'. [50]

Identify a case study from Australia where each of the above options has been used to deliver reduced energy demand in electric motor systems.

2.3. Data Centres[iii]

In Australia data centres typically contribute 15-40 per cent of an office building's energy consumption.[51] About half of the energy consumed in early designs for data centres is for IT equipment,[52] while the rest is primarily for air-conditioning and lighting. There is now a strong shift away from onsite data centres to offsite (or cloud based) mega data centres, with those still using onsite options shifting to a virtualisation of data centres to maximise the use of computing equipment (See Cook Medical Case Study). Mega data centres present a significant opportunity to aggregate computing equipment and systems and reduce energy consumption. A number of reports have been released over the last decade that show very large savings are achievable in data centres that are applicable to the growing number of mega data centres, namely:[53,54]

1. *Adopt infrastructure architectures that can adapt to changing requirements*: Most data centres are grossly oversized to accommodate a capacity that will never be required. Hence it is important to design the installation of equipment and supporting services to be responsive to actual loading to avoid redundant energy demand.
2. *Analyse equipment layout and air flow to optimise cooling efficiency*: This includes orienting equipment such that hot exhaust air from one item is not transferred directly to the intake of another item, and allowing sufficient space between equipment to avoid excessive localised hot spots.
3. *Incorporate high efficiency power supplies:* High efficiency power supplies can reduce energy consumption by 10-20 percent and reduce energy costs by US$2700-$5700 per rack per year, thus giving very short payback periods.
4. *Incorporate direct liquid cooling technology to remove heat from server racks*: Rather than carrying away large volumes of air from server racks to be mixed with ambient air and air-conditioned air, small volumes of air can be cooled locally by chilled water cooling coils and circulated around the rack. Water carries about 3,500 times as much heat as air per unit volume.
5. *Provide feedback and allocate accountability for energy consumption and costs*: Providing feedback on energy consumption and costs through sub-metering and itemising energy bills assists in establishing performance benchmarks and raising awareness of energy issues.

Identify a case study from Australia where each of the above options has been used to deliver reduced energy demand in Data Centres (onsite or offsite).

[iii] The following is an edited extract from Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007) *Engineering Sustainable Solutions Program: Sustainable Energy Solutions Portfolio*, The Natural Edge Project, Lecture 5.3.

4. Case Studies of ITE Engineering and Energy Efficiency

*Building on the multi-media bite on chemical engineering and energy efficiency the following example provides further details on the energy efficiency improvements related to ITEE. This section is also designed to inform **'Tutorial Exercise 7: Review industry case studies for areas of energy efficiency opportunities'** from the Introductory Flat-Pack.*

3.1. R.M. Williams

R.M. Williams was started in South Australia in 1932 and has since grown to an international brand with exports to 15 countries with more than 800 stockists worldwide. The organization's environment committee has led a sustained drive in reducing cost by increasing efficiency and optimization and has resulted in significant savings. Since 2004, some 17,800 tonnes of carbon dioxide emissions have been saved and waste to land fill reduced by 84 tonnes per annum.[55]

The Challenge

The company's primary manufacturing site in Salisbury, SA, employs 340 staff and has high energy use associated with lighting, HVAC, and dozens of 3-phase and single phase motors and large manufacturing equipment with different loads.

Identify 5 ways that ITE Engineers can deliver energy savings in lighting systems in Australian manufacturing operations, support this with case studies.

The Solution

Asking "*where could energy savings be found*?" the team from Pangolin Associates undertook an energy audit and identified multiple energy savings measures with a payback period of less than 3 years that would reduce energy consumption by 21 per cent with costs savings of more than $66,000 per year.[56] From the recommendations a reduction of 84,500 KWh was achieved in 2012 through energy management techniques.

Working with partners Energywise, a voltage power optimisation company, it was identified that the incoming voltage was above the recommended efficiency range for most plant equipment and the power factor was at sub-optimal levels. An Ark Energy Saving unit that optimizes incoming voltage for distribution throughout the site was installed to reduce the incoming voltage range of 235-245V to 220-230V and a power factor correction unit was used to reduce the amount of unused energy that remains in the electrical system;[57] achieving a combined demand reduction of 13 per cent with a payback period of just over 2 years.

3.2. Cook Medical

Cook Medical is the largest family owned producer of medical devices, specialising in the manufacturing of minimally invasive medical equipment. Since its beginnings in 1979, it has grown to a global company with more than 10,000 employees and annual sales revenue in excess of $2 billion.[58] The manufacturing facility in Brisbane exports to 126 countries worldwide and is the headquarters for its Asia Pacific operations, employing over 1,000 staff in the region. The Healthcare Business Solutions division develops more efficient ways of delivering healthcare and through the recent implementation of more efficient technology systems has helped improve efficiency and reduce costs of routine business.

The Challenges

Cook Medical has faced a number of challenges to reduce energy use, such as:

1. The efficient and effective movement of supplies in any manufacturing and supply company is crucial to the success of its operations. The manual activities involved in the ordering process, including the checking of purchase orders and rectifying ordering errors, is resulting in unnecessary costs.
2. The traditional approach to data storage and management is to use numerous servers sitting next to each other that consume a growing amount of electricity.

The Solutions

Asking "*where could energy savings be found*?" the Cook Medical team considered a range of options for each challenge and created the following solutions:

1. Implementation of e-commerce systems has allowed Cook Medical to introduce cost effective measures that have significantly improved the entire process. Cook Medical developed an electronic data interchange (EDI) system that provides a direct electronic link with hospitals. Product data is common and shared across the e-supply chain which includes the manufacturer, importer, distributor, wholesaler, hospitals, and health departments. The sharing of information through the EDI system enables real-time access to Cook's product catalogue, and results in fewer errors and more efficient processes. It also provides the major benefit of providing accurate and up to date information crucial to the industry by ensuring products are more efficiently tracked and recorded. When compared to the cost of traditional manual activities Cook's EDI system is more than ten times more energy efficient – resulting in significant cost savings both locally and in the bigger supply chain.[59]
2. Besides helping increase productivity, cloud-based services can reduce energy use, lower carbon emissions and save money in the process. A typical organisation has a lot more servers than it needs—for backup, failures and spikes in demand for computing. Cloud-based service providers aggregate demand, substantially increasing how much servers are utilised. The cloud can do the same work much more efficiently than locally hosted servers. The move from housing and running 184 servers to 10 virtual servers improved the information usage and requirements (with better quality capture and reporting capacity), reducing power consumption and emissions (running, dehumidifying and cooling the servers), reducing other resource use (plant, maintenance, replacement parts), freeing up space for other uses, and saving money.

5. Key Supporting Resources

The following resources are recommended by the research team to assist lecturers to expand the content contained in this introductory level lecture. For guidance as to embedding such materials into existing course see the 2014 book 'Higher Education and Sustainable Development: A Model for Curriculum Renewal'.[60]

3.3. Energy Efficiency Exchange (EEX)

Heating, Ventilation and Air Conditioning: Heat generated by IT equipment is a significant contributor to cooling demand. Poor design and management of HVAC systems for data centres is a growing area for improvement. HVAC dominates peak building electricity demand, so improving its efficiency can reduce peak demand electricity charges.[61] (See Resource)

Pumps and Fans: Pumps and fans are used widely throughout industry. Together, they account for around 40% of the end uses of motive power in Australian industry. Smart controls and optimisation of motor, fan, and control system design and management, and matching of pump and fan operation to loads are key opportunities. Potential energy savings in pump and fan systems can be as much as 50% and in some cases even higher.[62] (See Resource)

Motors and Motor Systems: Optimising motor systems has the potential to save more electricity than in any other electricity end-use. Investing in motor efficiency also makes sense given the total cost of supplying electricity to a motor can overtake the motor purchase price in just two weeks. Effective management of electric motors will also improve their reliability, minimise the risk of lost production time and minimise life-cycle costs.[63] (See Resource)

Waste Heat Minimisation and Recovery: Waste heat minimisation and recovery are two of the most effective ways to reduce energy costs and greenhouse gas emissions. Reducing heat loss not only reduces energy and maintenance costs, but can also lower unwanted emissions of air pollutants while improving the productivity of furnaces, ovens, boilers and other heating equipment.[64] (See Resource)

3.4. The Natural Edge Project (TNEP)

Opportunities for Energy Efficiency in the IT Industry and Services Sector: This lecture provides an overview of the energy efficiency opportunities in the ICT sector.[65] (See Resource)

Opportunities for Improving the Efficiency of HVAC Systems: This lecture reviews the energy efficiency opportunities in HVAC systems. This lecture addresses the question of how can more efficient HVAC systems be designed? This lecture also looks at seven ways to reduce the overall load required from HVAC systems.[66] (See Resource)

Opportunities for Improving the Efficiency of Motor Systems: This lecture reviews the energy efficiency opportunities in motors systems and covers key components of design, operation and maintenance.[67] (See Resource)

Transforming the Global Economy through 80% Improvements in Resource Productivity: Information and Communication Technologies: This case study overviews the potential for Factor 5 improvements in ICT resource productivity and outlines a whole system approach to Factor 5 in data centres based on the IPCC Mitigation Framework.[68] (See Resource)

References

[1] Desha, C. and Hargroves, K. (2012) *Report on Engineering Education Consultation 2012*, a report and accompanying Briefing Note, Australian Government Department of Resources, Energy and Tourism, Canberra.

[2] Hargroves, K., and Desha, C. (2014) 'Energy Productivity and Decarbonization of the Global Economy: Factor Five Resource Productivity', *Energy and Environment*, WENE-217, Wiley Interdisciplinary Reviews.

[3] Brown, L.R. (2008) Plan B 3.0: Mobilizing to Save Civilization, W.W. Norton & Company, New York.

[4] Smith, M., Hargroves, K. and Desha, C. (2010) *Cents and Sustainability: Securing Our Common Future through Decoupling Economic Growth from Environmental Pressure*, Earthscan, London.

[5] Hargroves, K. and Smith, M. (authors and eds) (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan/Routledge, The Natural Edge Project, London.

[6] Engineers Australia (1997) *Towards Sustainable Engineering Practice: Engineering Frameworks for Sustainability*, Engineers Australia, Canberra, Australia. (https://www.engineersaustralia.org.au/environmental-college/sustainability-resources)

[7] IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the International Panel on Climate Change, Cambridge University Press, Cambridge.

[8] Desha, C., Hargroves, K., and Smith, M. (2009) '*Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development*', International Journal of Sustainability in Higher Education, vol 10, no 2, pp184-199.

[9] See von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany, Chapter 3.

[10] Boyd, B.K. and Gove, S. (2000) 'Nucor Corporation and the U.S. Steel Industry', in Hitt, M.A., Ireland, R.D. and Hoskisson, R.E. (eds) Strategic Management: Competitiveness and Globalization, 4 Edition, Southwestern Publishing.

[11] Worrell, E., Price, L. and Galitsky, C. (2004) Emerging Energy-Efficient Technologies in Industry: Case Studies of Selected Technologies, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California, USA.

[12] See von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany, Chapter 3.

[13] The Natural Edge Project (2009) 'Factor 5 in Eco-Cements', CSIRO ECOS Magazine, Issue 149.

[14] CSIRO (undated) 'Geopolymers: Building Blocks of the Future', www.csiro.au/science/ps19e.html, accessed 30 October 2014.

[15] See Smith, M., Hargroves, K., Desha, C. and Stasinopoulos, P. (2009) *Factor 5: The Pulp and Paper Online Sector Study*, The Natural Edge Project, Australia.

[16] von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany.

[17] Worrel, E., Price, L. and Galitsky, C. (2004) Emerging Energy-Efficient Technologies in Industry: Case Studies of Selected Technologies, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California, USA.

[18] See von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany, Chapter 5.

[19] Light Rail Now (2008) 'CTrain Light Rail growth continues with North East extension', News Release, January 2008, Light Rail Now, Texas, USA.

[20] See von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany, Chapter 5.

[21] Northern Territory Government (2007) 'NT Greenhouse Gas Emissions - Transport' http://www.nt.gov.au/nreta/environment/greenhouse/emissions/transport.html, accessed 4 April 2010.

[22] Newman, P. and Kenworthy, J. (2007) 'Transportation energy in global cities: sustainability comes in from the cold', Natural resources forum, vol 25, no 2, pp91-107.

[23] See von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity, Earthscan, UK and Droemer, Germany, Chapter 5.

[24] Frey, C. and Kuo, P. (2007) 'Assessment of Potential Reduction in Greenhouse Gas (GHG) Emissions in Freight Transportation', Proceedings, International Emission Inventory Conference, US Environmental Protection Agency, Raleigh, NC, May 15-17, 2007.

[25] von Weizsacker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Improvements in Resource Productivity, Earthscan, London.

[26] Hargroves, K., and Desha, C. (2014) 'Energy Productivity and Decarbonization of the Global Economy: Factor Five Resource Productivity', Energy and Environment, WENE-217, Wiley Interdisciplinary Reviews.

[27] Romm, J. (1994) cited in Hawken, P., Lovins, A. and Lovins, H. (1999) *Natural Capitalism: Creating the Next Industrial Revolution*, Earthscan, London, Chapter 6:' Tunnelling Through the Cost Barrier'.

[28] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2008) Whole System Design: An Integrated Approach to Sustainable Engineering, The Natural Edge Project, Earthscan, London.

[29] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2008) Whole System Design: An Integrated Approach to Sustainable Engineering, The Natural Edge Project, Earthscan, London.

[30] Pears, A. (2004) *Energy Efficiency – Its potential: some perspectives and experiences*, Background paper for International Energy Agency Energy Efficiency Workshop, Paris, April 2004.

[31] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2008) Whole System Design: An Integrated Approach to Sustainable Engineering, The Natural Edge Project, Earthscan, London.

[32] Australian Government (2013) Energy Efficiency Opportunities Program, The First Five Years: 2006–2011, Overview., Commonwealth of Australia.

[33] Australian Government (2013) Energy Efficiency Opportunities Program, The First Five Years: 2006–2011, Overview., Commonwealth of Australia.

[34] Desha, C., Hargroves, K. and El Baghdadi, O. (2012) 'Review of Postgraduate Energy Efficiency Course Content and Recommendations for Use of Existing Course: Vocational Graduate Certificate in Building Energy Analysis (Non-Residential)', Report to the National Framework for Energy Efficiency, The Natural Edge Project (TNEP), Australia

[35] European Commission (2008) *Addressing the challenge of energy efficiency through Information and Communication Technologies*, Commission of the European Communities, p2.

[36] Engineers Australia website, www.engineersaustralia.org.au

[37] TNEP (2007) *Whole Systems Design Suite: Worked Example 3 – Electronics & Computer Systems,* The Natural Edge Project Engineering Sustainable Solutions Program.

[38] von Weizsacker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) Factor 5: Transforming the Global Economy through 80% Improvements in Resource Productivity, Earthscan, London.

[39] Fitcher, K., Stasinopoulos, P., Hargroves, K., Smith, M., Dunphy, D. and Benn, S. (2010) *Factor 5: Information and Communication Technologies Online Sector Study*, The Natural Edge Project, Australia.

[40] Carbon Trust (2006) *Heating, Ventilation and Air Conditioning (HVAC): Saving Energy without Compromising Comfort*, Queen's Printer and Controller of HMSO. Available at http://www.carbontrust.co.uk/publications/publicationdetail?productid=CTV003. Accessed 8 October 2007.

[41] Sustainability Victoria (2006) *HVAC Tips (Heating, Ventilation and Air Conditioning),* Sustainability Victoria.

[42] Jacobs, P. (2003) *Small HVAC System Design Guide: Design Guidelines*, California Energy Commission, p 63.

[43] Jacobs, P. (2003) *Small HVAC System Design Guide: Design Guidelines*, California Energy Commission, p 63.

[44] Jacobs, P. (2003) *Small HVAC System Design Guide: Design Guidelines*, California Energy Commission, p. 63.

[45] Architectural Energy Corporation (n.d.) *Design Brief: Integrated Design for Small Commercial HVAC*, Energy Design Resources, p. 17.

[46] Sustainability Victoria (2006) *HVAC Tips (Heating, Ventilation and Air Conditioning),* Sustainability Victoria.

[47] Architectural Energy Corporation (n.d.) *Design Brief: Integrated Design for Small Commercial HVAC*, Energy Design Resources, p 15.

[48] BuildingIQ (2014) What is Predictive Energy Optimisation?', BuildingIQ, California.

[49] Australian Greenhouse Office (2003) *Reference Manual – Motor repair and replacement*, AGO, Australia.

[50] Nadel, S. *et al* (2002) *Energy-Efficient Motor Systems: A Handbook on Technology, Program, and Policy Opportunities*, (2nd Ed), American Council for an Energy-Efficient Economy, USA, Chapter 1: Overview and Summary.

[51] Lawrence Berkley National Laboratories cited in Big Switch Projects (2004) *Data Centre Energy Efficiency Report*, Big Switch Projects. Sydney, p 2.

[52] Eubank, H., Swisher, J., Burns, C., Seal, J. and Emerson, B. (2003) *Design recommendations for high-performance Data Centers*, Rocky Mountain Institute, Snowmass, Colorado, p 15; Lawrence Berkley National Laboratory cited in US EPA Energy Star Program (2007) *Handout – Load Density*, US Environmental Protection Agency and US Department of Energy, p 7; US EPA Energy Star Program (2007) *EPA Report to Congress on Server and Data Center Energy Efficiency – Executive Summary*, US Environmental Protection Agency and U.S. Department of Energy, p 4.

[53]Big Switch Projects (2004) *Data Centre Energy Efficiency Report*, Big Switch Projects. Sydney, pp12-16.

[54] Rumsey Engineers (2006) *High Performance Data Centers: A Design Guidelines Sourcebook*, Pacific Gas and Electric Company, pp3-60.

[55] Zero Waste SA 2012, *Up Close,* Government of South Australia.

[56] Pangolin Associates (2012) *Case Studies: RM Williams,* Pangolin Associates.

[57] Energy Wise 2013, *RM Williams Case Study,* Pangolan Associates.

[58] Nair, J 2013, 'IT Value adding at Cook Medical', proceedings of CIO Summit 2013, IDG Communications Australia.

[59] Butschli, J (2013) *Cook Medical meeting global identification challenges,* HealthCare Packaging.

[60] Desha, C., and Hargroves, K (2014) Higher Education and Sustainable Development: A Model for Curriculum Renewal, Earthscan, Routledge.

[61] Energy Efficiency Exchange (2014), 'Heating, Ventilation and Air Conditioning', http://eex.gov.au/technologies/heating-ventilation-and-air-conditioning/, accessed 26 November 2014

[62] Energy Efficiency Exchange (2014), 'Pumps and Fans', http://eex.gov.au/technologies/pumps-and-fans-2/ , accessed 26 November 2014

[63] Energy Efficiency Exchange (2014), 'Motors and motor Systems', http://eex.gov.au/technologies/motors/, accessed 26 November 2014

[64] Energy Efficiency Exchange (2014), 'Waste Heat Minimisation and Recovery', http://eex.gov.au/technologies/waste-heat-minimisation-and-recovery/ , accessed 26 November 2014

65 Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007), *5.3-Opportunities for Energy Efficiency in the IT Industry and Services Sector*, The Natural Edge Project, Australia

66 Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007), *2.3-Opportunities for Improving Efficiency of HVAC Systems*, The Natural Edge Project, Australia

67 Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C., and Hargroves, S. (2007), *3.1-Opportunities for Improving the Efficiency of Motor Systems*, The Natural Edge Project, Australia

68 Fitcher, K., Stasinopoulos, P., Hargroves, K., Smith, M., Dunphy, D. and Benn, S. (2010) Factor 5: Information and Communication Technologies Online Sector Study, The Natural Edge Project,

Australia.