# Flexible Delivery Flat-Pack Module

# An Overview Introduction to Energy Efficiency Opportunities in Environmental Engineering

*Produced by*

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

## The EEERE Project:

**E**nergy **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
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## 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

Environmental Engineers will be a key part of the World’s response to climate change, from the design of waste water treatment plants to assisting all other engineering disciplines to see natural features as design elements. Environmental Engineers have critical skills the economy needs to thrive in a carbon constrained future. The following learning points provide a summary of the Environmental Engineering video – our ‘Allen keys’ to building the flat-pack content!

Watch the ‘***Environmental Engineering***’ MMB

1. Ambitious global targets for greenhouse gas emissions reductions will see growing pressure for improved energy efficiency in the form of regulations, incentives, and consumer demand for products, processes and services that both improve economic development and reduce greenhouse gas emissions.
2. As energy plays a key role in many environmental issues this means that energy will become core business for Environmental Engineers, and the demand to deliver energy efficient design solutions will grow rapidly in the coming decade.
3. A key role for Environmental Engineers will be to contribute to conducting energy efficiency assessments that lead to the *identification, evaluation,* and *implementation* of energy efficiency improvements. Energy Efficiency Assessments create a range of possible options with the Environmental Engineer advising on which ones to implement based on a number of factors including: the amount of energy that can be saved, the co-benefits to the project or business, the level of difficulty and investment required, and the likelihood that the option will be implemented.
4. Carlton and United Breweries is an example of what is possible when energy and water are considered together. The Yatala plant was able to save an estimated $2-3 million per year by re-evaluating their requirements for electricity, steam, pumping, and water treatment. Increasing environmental and financial pressures stemming from a long-running drought caused the company to identify opportunities for treating their own water (rather than paying additional costs for council-treated water). Engineers at CUB ran a comparison of two types of technology and found that reverse osmosis was 40% cheaper. Not only did this save water from council supplies, but it also supplied the factory with demineralised water at the right quality needed for brewing.
5. In Australia the ‘Infrastructure Sustainability’ Rating Tool provides guidance as to how to improve the sustainability of projects and includes a focus on energy and climate change. For example the Whitsunday Regional Council commissioned an upgrade of two existing wastewater treatment plants by DownerTenix that utilised the tool in the design stage to identify and implement energy efficiency opportunities. The upgrade project utilised enhanced membrane technology, biological and chemical nutrient removal, mechanical sludge de-watering, more efficient aeration philosophy, and the most energy efficient pumps and fixtures available, in addition to reduced construction materials such as concrete and asphalt.
6. According to the Group Sustainability Manager for DownerTenix, Matthew Brennan, ‘*We set out to counter the common view that sustainability always costs more*, *what we actually found was that we were able to deliver better sustainability outcomes that will deliver savings across the projects lifecycle*.’

# 2. Energy Efficiency and Chemical Engineering

## 2.1. 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]

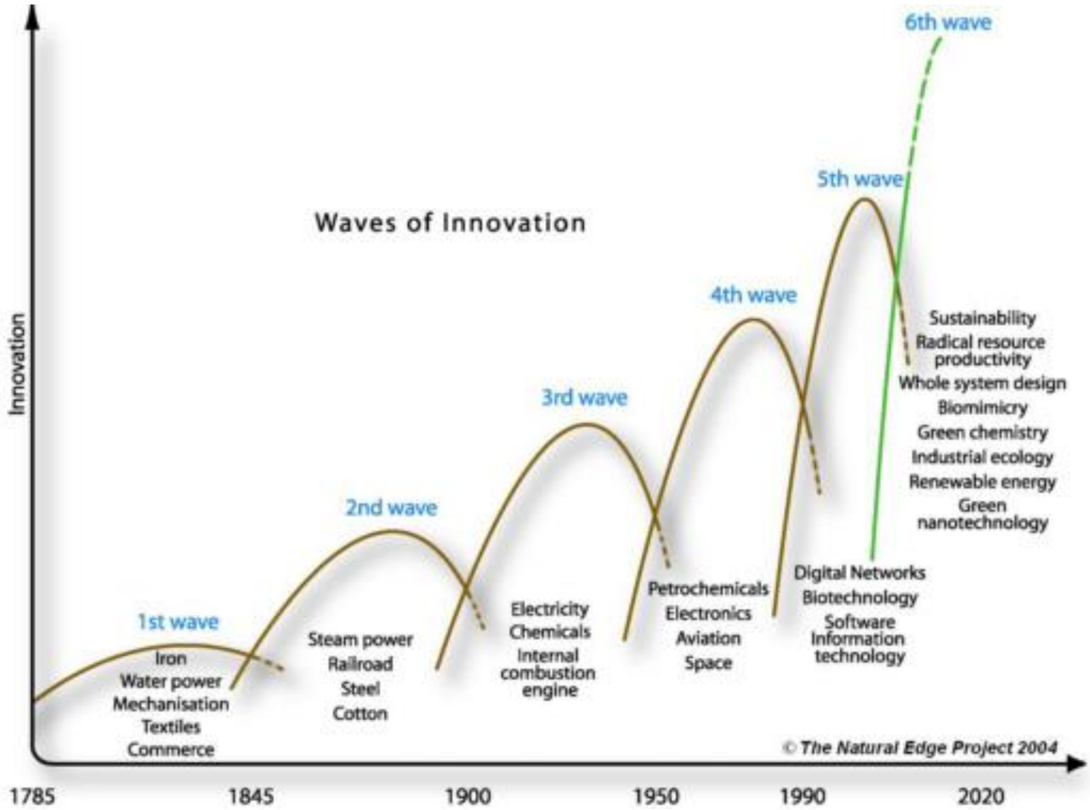


**Figure 1:** A stylistic representation of waves of innovation since the Industrial revolution[5]

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 Environmental 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 Environmental Engineers reduce greenhouse gas emissions?***

***How could energy efficiency provide benefits to Environmental Engineering firms?***

**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.

## 2.2. 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.

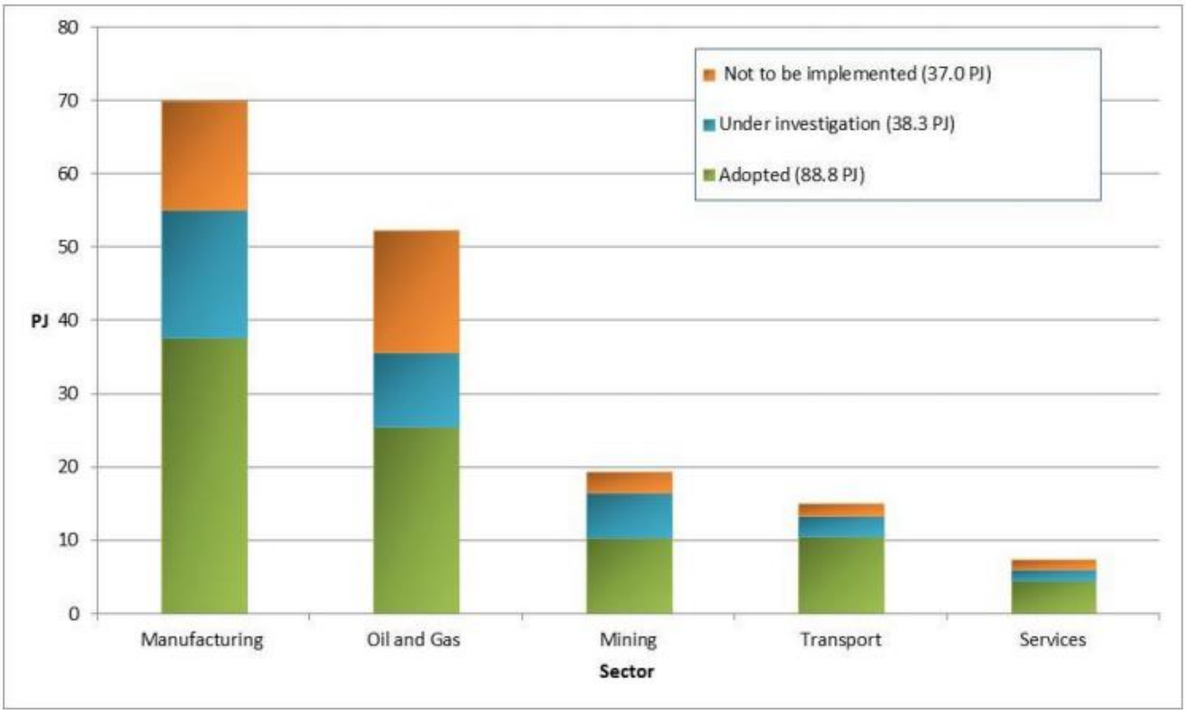


**Figure 2**: Summary of energy efficiency achievements in by participants in the Australian Government Energy Efficiency Opportunities (EEO) program (2006-11)[32]

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 of 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 Environmental Engineers to achieve energy efficiency improvements in each of the sectors involved in the EEO Program (Fig 1)***

## 3. Key Knowledge and Skills for Environmental Engineers

According to the Society for Sustainability and Environmental Engineering in Australia, '*Environmental Engineering is a rapidly growing, multi-disciplinary branch of engineering, concerned with devising, implementing and managing solutions to protect and restore the environment, within an overall framework of sustainable development*.'[35] As such, Environmental Engineering is in a position to make a substantial contribution to societies around the world achieving sustainability. Environmental Engineers can assist other engineering disciplines to identify opportunities to reduce greenhouse gas emissions through studying project design, construction and operation, and minimising any adverse effects that projects may have on the environment.[36]

Two main principles that underpin Environmental Engineering are particularly relevant to energy efficiency:

- **Sustainability**: Ensuring projects produce sustainable outcomes. This includes, but is not limited to: applying the precautionary principle; undertaking full life-cycle analyses; minimising impacts; using resources economically and efficiently, particularly non-renewable resources; and evaluating engineering outcomes using triple bottom line techniques.
- **Systems thinking**: Ensuring that natural and constructed systems, as well as engineering systems, are considered during the life of a project. This involves 'big picture' and holistic ways of thinking to ensure that impacts of the project on natural and built environments are minimised while opportunities provided by those environments are harnessed.

These guiding principles are included in the Australian Government's '*Define your discipline'* project (ALTC 2011), and are listed a number of times in the EA *Stage 1 Competency Standard*.[37]

Understanding processes and 'big picture thinking' is where Environmental Engineers can make the greatest contribution to improving energy efficiency. They have the potential to play the role of a solution integrator, and can adopt a larger, whole-systems perspective. Some of the 'soft' skills developed in this discipline are highly beneficial to making energy efficiency improvements. These skills include:

- Flexibility and interdisciplinary skills,
- Ability to understand and concentrate on the 'big picture' and 'whole system',
- Ability to asses multiple forms of environmental impact,
- Ability facilitate and integrate solutions involving inputs from multiple disciplines, and
- Ability to deal with clients and 'sell' greener solutions based on long-term financial benefits.

Environmental Engineers can contribute to increased energy efficiency in a number of industries, including mining, minerals processing, and buildings. There are opportunities for improving energy efficiency in these sectors through: impact assessment; the evaluation and design of equipment and processes for the treatment and safe disposal (or utilisation) of waste material associated with minerals processing; and the conservation and wise use of natural resources. There is also potential to make energy efficiency improvements through identifying low energy material options, water reclamation, waste treatment, and recycling. The 2011 European Union Energy Efficiency Directive includes changes to legislation regarding impact assessment, including balancing environmental objectives with competitiveness and energy security.[38] Considerations span assisting with a whole system approach to reducing energy demand from residential through to commercial and industrial applications, purchasing products, services and buildings with high energy efficiency performance, retrofitting existing building stock, developing energy management systems (augmenting existing ISO14001 documentation and utilising ISO 50001 as well as the recently released AS/NZS 3598:2014),), and energy performance contracting.

Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be 'learned', 'practised', and 'demonstrated' over the duration of environmental engineering undergraduate curriculum. Considering the graduate attribute of the "*Ability to Participate in/Contribute to Energy Efficiency Assessments"* there are opportunities for various parts of the curriculum – in particular the first and second years – to include related content, such as:

- Energy efficiency opportunities in the built environment,
- Variety of measurement tools or models available to quantify energy efficiency opportunities,
- Coordinate interdisciplinary teams of engineers,
- Communicate environmental, social and economic impacts and benefits of energy efficiency innovations, and
- Choose low embedded energy materials.

## 4. Energy Efficiency Opportunities in Environmental Engineering

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

READING

### 4.1. Energy Savings from Industrial Water Conservation

With a planned doubling of capacity and facing the prospect of greatly raised charges due to the increase in waste water volume in the Yatala Brewery (approx. AU$5-6 million annual cost), Carton & United Brewery's process team decided to install and maintain its own water recycling plant on site. The environmental and economic benefits are considerable and the move has been recognised by government for its role in a greater sustainability push that by 2005 saw the Yatala brewery having the lowest consumption of water per unit of beer produced nationwide.[39]

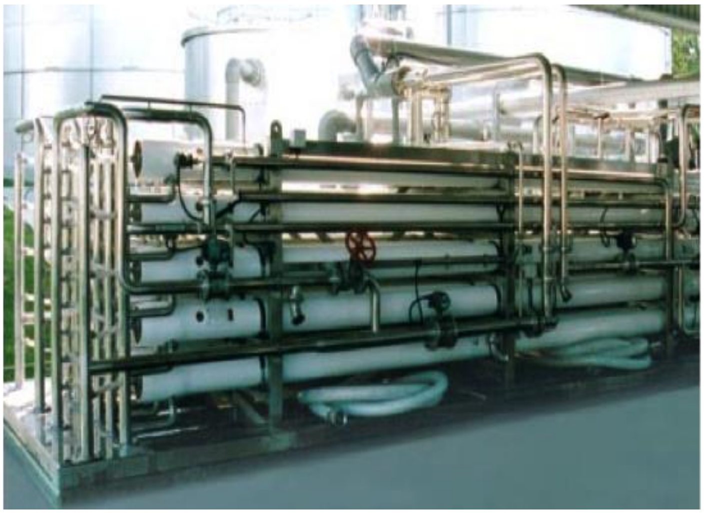

**Figure 2:** Reverse Osmosis Section of Treatment Facility

The plant installed a reverse osmosis system and achieved a treatment capacity of 2ML per day. The new facility produces higher quality water than the incoming supply from mains and is used in boilers, cooling towers, washing down, and various cleaning processes on site. The improvement in water quality has greatly reduced the need for, and costs involved with the addition of treatment chemicals and dissolved salts. A focus on water conservation has also delivered strong results given the regions vulnerability to severe drought conditions with overall production doubling and the resulting increase in water use of 10-15 per cent.[40]

Concentrated biogas is a by-product of the treatment cycle and has been used to supplement the fuel supply for the plants boilers. Some 90 per cent of the energy present in the waste stream is recovered in this manner and displaces natural gas volumes by around 20 per cent. This measure alone saves $400,000 per year. An analysis found that this method of onsite treatment uses less energy and produces less greenhouse gas emissions than the alternative of transport and treatment by council. Inherent with the reduced volume of water is the reduction in energy consumption associated with pumping and circulation. The economic benefits of the revised wastewater treatment scheme are saving the company $2 million per annum[41] and eliminated the energy costs associated with pumping its trade waste to the city's municipal plant.[42] Every kilolitre of water recovered presents a saving of $2 to the plant and is not trivial given the very high volumes of water used in the production of beer.

***Identify 3 options for water treatment suitable for a beer making facility and undertake a comparison of the energy demand of each.***

## 4.2. Energy Savings by Harnessing Underground Water

Approaching a design with environmental as well as financial targets can lead to innovative solutions that increase both energy efficiency and cost savings. British Telecom Italia undertook the design and construction of a new datacentre with the goal of reducing energy usage as a way of increasing financial and environmental sustainability, and made innovative use of the local environment, identifying a location for the structure that had a naturally replenished waterbed located onsite, under the building, which could be used in a sustainable cooling system for the hardware in the datacentre. The cooling system uses four wells which draw water from the underground reservoir, pumping it through pipes embedded in the walls of the building and into a heat exchanger allowing the water cooling stream to be completely separated from the equipment and generating cold air that is ducted into the hardware rooms to cool them. Because of the efficiency of water in storing heat, the underground water, which enters the system at 15°C, is only heated to 18°C when it exits the cooling system, and is used for irrigation of nearby farms. In winter the cooling arrangement is supplemented with fresh-air cooling, further lowering the energy usage of the facility. Through this setup, $CO_2$ emissions are reduced by 4,200 tonnes per year, and the company saves €9.6 million per annum in energy costs for the site compared to a conventional cooling arrangement.[43]

## 4.3. Energy Consumption in Sewage Treatment Plants

DownerTenix is an Australian construction company focusing on design, construction, and operation of infrastructure. In 2012-2014 DownerTenix upgraded two sewage treatment plants (STPs) in the Whitsundays, Queensland. The plants received Australia's first Infrastructure Sustainability rating, achieving an 'Excellent' rating level from the Infrastructure Sustainability Council of Australia.[44] Due to their proximity to the Great Barrier Reef, the plants were subject to stringent effluent discharge requirements. [45] DownerTenix went a step further by bringing sustainability measures to many aspects of the design, construction and operation of the plants to reduce their overall footprint and energy usage.

Sewage processed by the plants may contain a range of things that need to be treated and removed such as: organic materials and plant nutrients from body and food waste (nitrogen and phosphorus); disease containing pathogens (including bacteria, viruses and protozoa); oils and greases; runoff from streets, parking lots and roofs; heavy metals (including mercury, cadmium, lead, chromium, copper) and toxic chemicals including PCBs, PAHs, dioxins, furans, pesticides, phenols and chlorinated organic compounds. Detergents and washing powders used in the home often contain phosphates which are used to soften the water, as well as other toxic chemicals. While sewage is mostly water by weight (around 99%)[46], the impurities constitute a large amount of the volume. Treating water and wastewater is an energy intensive process. Energy is used in the water cycle from the sourcing point, to transportation, to treatment and distribution, and finally to the disposal or recycling point.[47]

In 2007 The United Nations Educational, Scientific and Cultural Organisation (UNESCO) estimated that only one tenth of the domestic wastewater in developing countries was collected and only one tenth of the existing wastewater treatment plants operated reliably and efficiently.[48] This suggests that many places in the world still require wastewater treatment plants, and thus there is great potential for Environmental Engineers to deliver significant value not only in treating water but also in reducing energy consumption around the world. In the case of the Whitsundays, energy usage of the Cannonvale and Prosperine sewage treatment plants was reduced by innovative and energy efficient focused design. An initial design proposal by the client was modified and simplified by DownerTenix resulting in plants which used 5000 tonnes less building materials during construction, had smaller site footprints, used less energy when operating, and had smaller carbon footprints.[49]

| Category/ Credit | Score | Achievements |
|---|---|---|
| **Management Systems** | 7.3/10.5 | • Good management systems integrating the IS rating tool into practices<br>• Knowledge sharing clearly demonstrated. |
| **Procurement and Purchasing** | 4.2/5.0 | • Strong commitment to and application of sustainable procurement including local procurement:<br>  • 50% of total spend in the Whitsunday region<br>  • 30% of total spend in greater Queensland |
| **Climate Change Adaptation** | 4.2/5.0 | • Did a thorough, formal climate change risk assessment and implemented controls to reduce 22 'high' or 'very high' risks to a 'moderate' or 'low' rating |
| **Energy and Carbon** | 5.1/10.5 | • 305 MWh electricity saved over operational life – thus a 14% reduction equating to $75,000 saving/year<br>• 14,000 $tCO_2$-e avoided over lifecycle<br>• Use of B20 Biodiesel avoiding 272 $tCO_2$-e (cost neutral) |
| **Water** | 3.9/7.0 | • 15% reduction in water use over lifecycle, with associated cost benefit |
| **Materials** | 7.0/7.0 | • Reduced the materials footprint by 25%:<br>  • Used 4,329 tonnes less concrete<br>  • Used 298 tonnes less steel<br>  • Used eco-cement with 30% fly ash<br>  • Eliminated asphalt from the design |
| **Receiving Water Quality** | 2.9/2.9 | • >75% reduction in N and >90% reduction in P (44 tonnes less nutrients annually) to the Great Barrier Reef Marine Park |
| **Ecological Value** | 2.0/2.0 | • Ecological value enhanced through >5,000 $m^2$ of regenerated native habitat and 1000 $m^2$ of wetland |
| **Innovation** | 5.0/5.0 | • World's-first trial of Parallel Nitrification & De-Nitrification (PND):<br>  • Significantly improves nitrogen removal<br>  • More compact<br>  • Less construction materials<br>  • More energy efficient |

**Figure 3:** Sustainability highlights of the STP designs[50]

The Cannonvale plant was designed as a membrane bio-reactor (MBR)[51] that involves a membrane filtration process and activated sludge treatment that results in an effluent of high quality. The plant has a compact design which contributes to the reduction in building materials. Pipe systems can also be shorter and more efficient, and consequently require less energy for pumping. Energy efficient air blowers and pumps, as well as an efficient aeration system, all contribute to reducing the energy requirement of the plant. The Prosperine plant uses a sequence-batch reactor (SBR) that involves an activated sludge process that utilises equalisation aeration and sediment settlement in a cyclic process. Real-time concentration profiles of the sewage being treated, coupled with automated control allows the plants system to perform more efficiently.[52]

Energy efficiency was also addressed in the plant construction phase. To reduce transport fuel costs, 80 per cent of construction materials were sourced from Queensland and 50 per cent from the immediate Whitsunday region.[53] The sites used 30 per cent fly-ash content 'green concrete', and the use of asphalt was eliminated from the site.

# 5. A Case Study of Environmental Engineering and Energy Efficiency

*Building on the multi-media bite on Environmental Engineering and energy efficiency the following example provides further details on the energy efficiency improvements related to Environmental Engineering. 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.*

## 5.1. Siemens

The drive toward increased energy efficiency is one of the primary goals for environmental engineering – going beyond regulatory requirements to deliver enhancements in sustainability, cost outcomes, and performance. The gains that can be made through the use of environmental engineering principles can be achieved at a number of levels, from distributed projects that provide incremental increases in energy efficiency, achieved through measures such as replacing existing system components with more efficient alternatives; through adoption of new processes and technologies to improve energy efficiency on a larger scale; to fundamental changes in project objectives which treat energy efficiency as a primary goal, which can enable large increases in energy efficiency, and significant cost savings, to be achieved. Small individual increases in energy efficiency can add up to significant savings across an organisation, as a number of examples from Siemens show. The company has partnered with a number of organisations in its role as an energy efficiency advisor, and in doing so has helped to achieve large efficiency gains through changes which may be small individually, but which have a large impact when applied over a large number of sites.

### The Challenges

1. In the case of Berlin, Germany, the state initiated an energy efficiency program in 1995, with the goal of increasing energy efficiency to reduce carbon emissions. The program looked specifically at 164 local buildings, including kindergartens, schools, universities, sporting facilities, and pools, and performance contracts between Siemens and the organisations running the buildings were set up, in which Siemens was paid based on the energy savings achieved.

2. In cases where more significant changes can be made, relative savings can be even greater – Siemens partnered with Glenbrook High School in the USA to work on redevelopment of their two campuses to cope with growing student numbers, with the goal of reducing energy costs and simultaneously increasing building performance, focusing on comfort, life safety, security, and air quality.

### The Solutions

1. Through a range of relatively small changes to existing infrastructure: more efficient lighting systems; water-saving technologies; regulated heat generation and distribution; updated HVAC technology; and systems for monitoring and control of energy usage. These measures resulted in 25% reduction in carbon emissions (approximately 29,000 tonnes annual reduction), and annual cost savings of €1.14 million per annum, against an investment of €28.5 million.[54]

2. A building automation system was installed to provide central control for each campus, which worked in concert with new security and HVAC systems, high-efficiency lighting, and new doors and windows designed for improved comfort and insulation, and the increased energy efficiency

equated to cost savings of $1.3 million per annum, against a total investment of $12.5 million, with increased integration of the system, when compared to the Berlin project, equating to greater savings per dollar invested.[55]

# 6. 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'.*[56]

## 6.1. The Australian Government

**Clean Energy Regulator Carbon Farming Initiative**: This resource provides emissions avoidance methodology for the capture and combustion of methane in landfill gas from legacy waste.[57] (See Resource)

## 6.2. The Natural Edge Project (TNEP)

**Transforming the Global Economy through 80% Improvements in Resource Productivity - The Pulp and Paper Industry**: This case study presents the potential for Factor 5 improvements in Pulp and Paper Manufacture resource productivity.[58] (See Resource)

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