HOSPITALS

&

SUSTAINABILITY

BY

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Introduction

Hospitals may be thought of as an icon for pain, sickness and distress, but they are also icons of healing, life, family and hope. They are important buildings for any community and "the way we design, construct and operate these buildings has a profound impact on our health and the health of the environment." (Guenther and Vittori, 2008) It would therefore seem logical that our healthcare systems and even the buildings where we humans seek healing are built and operated with our environmental health and our future generations in mind. Sadly however, this is rarely the case, and even today in the beginning of the twenty-first century we still live, work and even attempt to heal ourselves in buildings that use vast amounts of our dwindling resources and even impact negatively on our environmental health. This scoping study is aimed at highlighting the possibilities for a sustainability focused hospital. For any newly constructed hospital should be a hospital of the 21st century and utilize our innovations, technologies and increased understandings of community and healthier environments.

Structure and Purpose

This scoping paper is aimed at highlighting the innovations and technologies available for hospital stakeholders in their pursuit of a sustainability focused hospital. The paper is divided into five themes: Energy, Waste, Water, Transport, Digital Management and Human Dimensions. Throughout each of these themes specific hospital case studies, research literature and interview data has been used to briefly investigate sustainability features and concepts that could be used in the construction of any new hospital. As many of these features are part of complex and interdependent systems, much of the highlighted options would require further analysis by engineers and professionals. Where possible the paper attempts to indicate the Australian or Perth applicability of the relevant sustainability feature. Ultimately, the purpose of this scoping study is to develop specifications for which areas of further research is needed for the advancement of sustainability in hospitals.

THEME I

ENERGY

Hospitals use vast amounts of energy, as they operate 24 hours a day and all year round, irrespective of holidays. Victorian public hospitals consume 60% of public sector energy in the state (Gelnay, 2006); in Western Australia they consume around 45% (Katscherian, 2009). Hospitals are in a position to address this energy use in two ways: either increase the efficiency of the facility, thereby consuming less energy, or supplement their primary consumption and back-up energy generation with viable alternatives.

Part I: Energy Efficiency

To address the demand side of energy, hospitals can install system-wide energy conservation programs and materials to reduce energy consumption and increase system efficiency. Most of these installations are cost-effective and with varying payback periods. Installing these systems makes economic sense, especially considering energy costs are certain to rise in the future. The following figure 1 below is a pie chart that shows the different sources of hospital energy consumption in two major Australian cities, Brisbane and Melbourne. Throughout this energy theme, case studies are given to show how hospitals around the world and Australia attempt to reduce these components shown in the diagram.

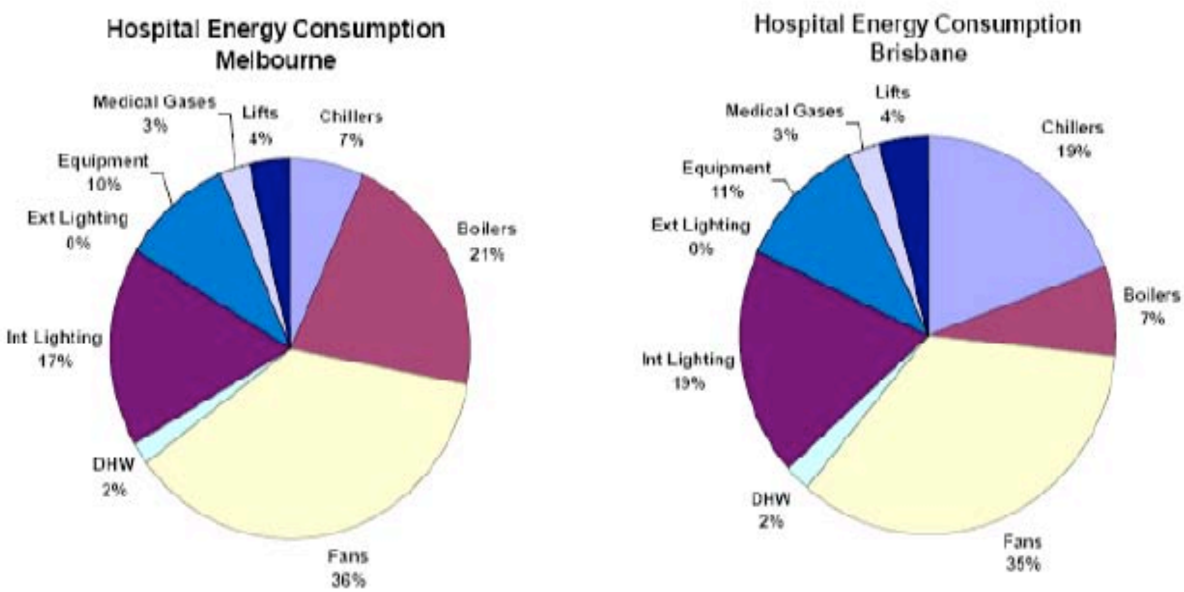


Figure 1: General energy consumption according to equipment/processes in hospitals in Melbourne and Brisbane. The highest energy consumer, in both the Melbourne and Brisbane charts, is from fans with 36 and 35 percent respectively. Source: Harris, B. 2009

Lighting: Natural Daylight

Maximizing the amount of natural daylight helps reduce the amount of artificial light the building needs to produce. This saves on energy costs for lighting and, depending on the climate, also helps with temperature control. For hospitals there is the added benefit of natural light creating a healing environment and a welcoming atmosphere to work and reside in. Sunlight in healthcare facilities is associated with substantial reductions in medical costs (Heerwagen, 2007). Evidence from studies assessing the role of natural light in buildings suggest that the lighter and brighter sunlit rooms contribute to stress reduction and shorter hospital stays in patients with depression and bipolar disorders, whilst reducing symptoms in cases of seasonal depression (Heerwagen, 2007). A study by Beauchemin and Hays showed a reduced mortality rate amongst heart attack victims when hospitalized in bright, sunny rooms (Beauchemin 1998 in Heerwagen 2007, p33). Through these psycho-physiological benefits, hospitals can inadvertently lower overall medical costs by improving the wellbeing of patients, saving thousands if a patient is discharged early and/or with less medication required.

Maximizing the amount of daylight the hospital receives is usually addressed during the design and construction phase of the hospital, but increasing sunlight can also be done through redevelopments or refurbishments to existing hospitals. A challenge for hospital designers is to incorporate natural lighting along with the thermal control systems of the hospital. For example, if a hospital is fitted with an entirely glass façade, built for complete natural light exposure, it may be uncomfortable if the facility is located in an extreme hot or cold climate area. Some of these concerns can be alleviated with “smart” thermal design strategies such as adjustable shading to reduce heat, double pane glass glazed with low-emittance film to retain heat. While these features are relatively expensive initially, the savings resulting from reduced patient care, temperature control and energy costs for lighting will pay the cost back. These and other features will be discussed later in this theme.

Case Study I:

THUNDER BAY REGIONAL HEALTH SCIENCES CENTRE

(Ontario, Canada)

The hospital features an elongated three story wood and glass concourse that intentionally curves to follow the path of the sun, allowing light penetration and enhancing the comforting perception of the hospital (Tye Farrow, 2008). Using the passive solar energy means that the concourse "uses virtually no fossil-fuel generated energy for cooling or heating in the summer or winter" (Guenther and Vittori, 2008). This is an achievement considering the extreme climate variance of Ontario, Canada.

Further natural lighting features of the hospital include external sunshades and frosted glass that reduce glare in summer and also allow full sunlight in winter. All public areas were designed to receive sunlight. The main corridors across and down the T-shaped building are constructed in such a way as to look out to daylight and the hospital grounds. "Day light enters all patient rooms and areas such as the neo-natal unit, where exposure to the natural light cycle helps premature babies develop. Daylight even penetrates radiation treatment bunkers and is brought to nurses' stations in the interior of each floor plate" (Tom Kelly, 2008). Thus the floor plates are direct-light skylights, bringing daylight to aid in the patients' therapeutic experience.

Digital Management for Energy Efficiency

During the design phase of the hospital, digital management technologies allow stakeholders to digitally model the future building with natural lighting schemes in mind. These digital technologies are collectively known as Building Information Modelling. With the importance of the psychological and therapeutic effects of sunlight on patients and staff being highlighted in recent healthcare design and construction literature, digital management programs can be extremely useful. There is also operational cost saving benefits from maximising natural daylight realized from decreasing the need for energy-intensive artificial lighting and thermal control. Therefore, using such programs can lead to substantial saving over the life cycle of the hospital. Figure 2 is an example of such a program that models the solar thermal performance of a building over the course of a day.

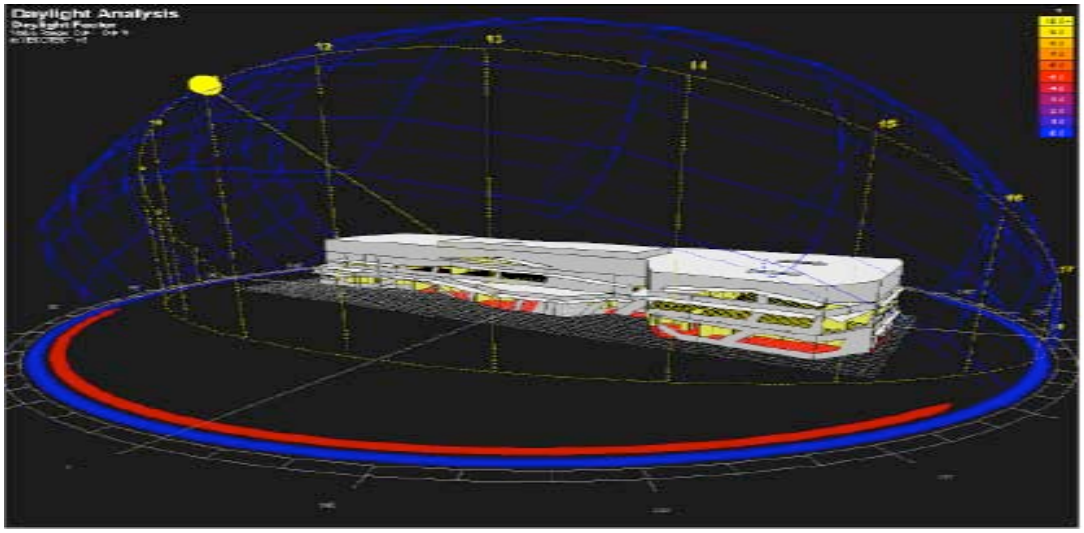


Figure 2: This is an example of digital management software which projects solar paths and the accessibility of daylight into a building. There are numerous applications of this technology from heat indicators or maximizing daylight hours (even in different seasons), to the efficient use of rooms which use natural lighting. Source: Kluske, 2009

For any modern building operations, digital management plays a vital role in the efficient control of the multitude of electronic systems used throughout the building. Moreover, digital control systems lead to operational cost savings. Artificial lighting can be monitored and controlled by management systems to minimize use and thus energy demand. Electronic sensors can use programmable timers and/or motion sensors to control lighting fixtures so that they switch off when not in use. As such, the information digital management programs collect can be useful in assisting operations during the entire life cycle of the building to the extent that specific areas can be monitored for their energy use and once information is gathered, possible measures taken to reduce energy demand. For example, the heating ventilation and air conditioning (HVAC) system's energy demands in specific rooms may be noticeably higher in certain rooms, perhaps due to the room's position or solar heat intensity. Possible action to address these problems, such as window glazing, may be pursued. Since information can be collected in BIM, even before construction, steps can be taken to maximise efficiency and use environmental innovations where they would be most applicable and cost effective.

Lighting: Artificial Lighting

Installing energy efficient lighting fixtures is another possibility for saving on energy and maintenance costs. Many of the modern high efficiency lights last longer and are more energy efficient, thus reducing operating expenses and realizing further savings on replacement costs. There are numerous case studies in Australia, where changing older lights to more efficient models has resulted in considerable savings. For example, Royal Perth Hospital was able to realize a savings of approximately $50,000 in a project that installed 180 lighting circuit power reducers, and 9000 fluorescent lamps (Sustainable Energy Development Office n.d.).

In large atrium areas, new lighting technologies such as efficient microwave sulphur lamps, which produce light by microwaving argon and sulphur gases, can be considered because they are capable of lighting immense areas. The visible light output from these sulphur plasma lamps mimic sunlight better than any other artificial light source which, if the psycho-physiological benefits correlate, would be ideal for the healing environment for the reasons discussed in the previous section, in addition to any cost savings. These lamps are still very new, and more research needs to be done to examine life cycle costs.

Part II: Ventilation & Temperature Control

Federal law in Australia requires that the indoor temperature of any hospital has to be constantly maintained at 23°C all day. Unfortunately, although slight variations of a degree or so is hardly noticeable for patients and staff, flexibility in temperature according to seasons or day and night is not allowed; if changed it would save large amounts in energy costs (Humphrys, 2009), but this is simply not possible. Until there is a change in this law (an unlikely occurrence), hospital ventilation and temperature systems must achieve the constant temperature of 23°C and also provide the high levels of indoor air quality for health safety reasons. This creates challenges for the ventilation and temperature control systems in green hospitals, and it also means that certain green initiatives, such as natural ventilation in urban areas with low air quality, are not always viable for hospitals.

The ventilation systems used in a green hospital thus have to attempt to improve their energy efficiency while maintaining the building's precise temperature control, as well as the highest possible indoor air quality. Traditional heating, ventilation and air conditioning (HVAC) systems are energy intensive and can be responsible for over 40% of the hospital's energy requirements. HVAC systems are responsible for most of the energy used by the fans, chillers and boilers represented in figure 1, found at the beginning of this theme. Nevertheless, some of the older overhead HVAC systems, through a process of diluting stale air by mixing it with fresh air from above, result in somewhat poor indoor air quality. The following figure 3 is from a paper by Dr Rod Escombe from Imperial College London, *Natural Ventilation of Health Care Facilities,* it provides a useful example of a mechanical ventilation system or traditional HVAC system commonly used in hospitals. Of course these systems vary greatly from hospital to hospital.

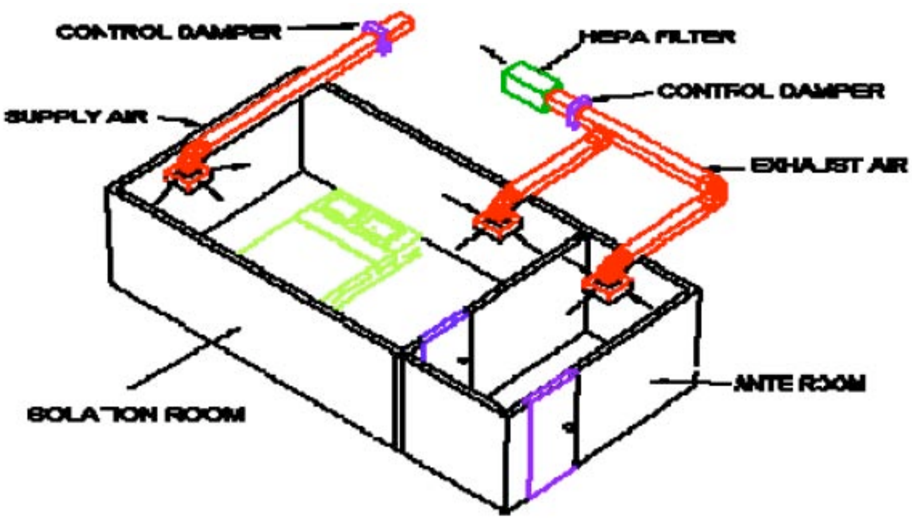


Figure 3: This is an example of a traditional heat ventilation and air conditioning system or HVAC, It is important to note that while most hospitals have these features installed; the parts and features can easily be altered and replaced with more advanced and efficient technologies. Source: Escombe, 2008

There are alternative HVAC systems such as displacement ventilation, active chilled beams , natural ventilation (Passive) and other hybrid systems available that offer greater efficiency and improved air quality. These systems are worth individual mention in this theme and further research into their use in Australian hospitals would be advisable. For “the type of HVAC system installed can have a profound effect on both performance and energy efficiency” (Karolides, 2008) in the system that contributes the highest percentage of any hospital’s energy consumption.

Displacement Ventilation

In displacement ventilation, outdoor air is pumped in at floor level. The cooler air will force the warm air already present in the room up towards the ceiling and exhaust system. A simplified picture of this process can be visualized in figure 4. This system is favourable for maintaining cooler, more comfortable air at the occupied zone in the room. "A displacement ventilation system can greatly improve air quality (compared with an overhead ventilation supply system) while also reducing energy use" (Karolides, 2008). The air quality is improved as pathogens and contaminants are not recirculated throughout the building, but rather the air is contained in the room and then exhausted immediately. At this stage very few hospitals have installed displacement ventilation systems, as continued studies into their effectiveness are still ongoing. However, some hospitals have installed displacement ventilation in specific areas. For example in the U.S. the exam rooms at the Center for Health and Healing, at Oregon Health Sciences University (OHSU). And in Australia, the Royal Women's Hospital in Melbourne uses displacement air-conditioning in the hospital's inpatient wards.

Figure 4: A metaphoric comparison between the so-called 'dilution' and the 'separation' systems of air ventilation. According to the image, the separation model is superior in that heated and 'dirty' air leaves the room at the top, while cold clean air enters from the bottom and is not circulation or 'diluted' with used air. Source: Kluske, 2009

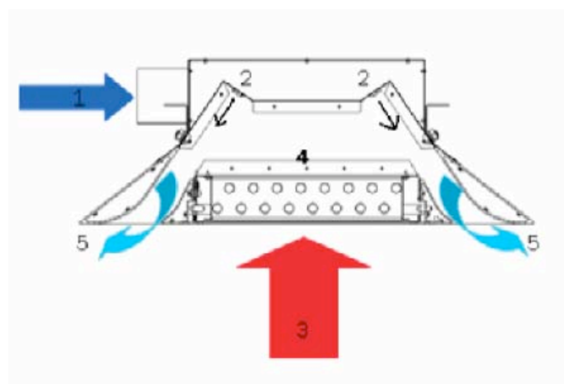
Active Chilled Beams

An alternative to conventional HVAC systems in a hospital is a system using active chilled beams. "An Active Chilled Beam is an air-water system that uses the energy conveyed by two fluid streams to achieve the required cooling or heating in a space" (Dadanco, 2009). Figure 5 provides further description of how an active chilled beam system works.

AECOM

Active Chilled Beam – How it Works

Primary/ventilation air **(1)** is introduced into the active chilled beam through a series of nozzles **(2)**. This induces room air **(3)** up into the active chilled beam and in turn through a secondary water coil **(4)**. Induced room air is cooled and/or heated by the water coil to the extent needed to control the room temperature. Induced room air is then mixed with the primary/ventilation air and the mixed air **(5)** is discharged into the room.



Source: Harris, 2009

The advantages of an active chilled beam system are realized through the superior properties of water as a heat transfer medium compared to air, as well as the ability to have individual control units. For hospitals, having individual active chilled beam units ventilating outside air into each room assists in improving indoor environment, as the air in the room is not mixed with air from other spaces and recirculated. The thermal properties of water allow active chilled beams to be more energy and space efficient compared to traditional HVAC systems.

Natural Ventilation

Natural ventilation may be the ‘old practice’ of simply having a building with lots of windows and areas that are naturally ventilated by the outside air (wind). However the use of natural ventilation in some area’s of a hospital, such as entrance foyers, waiting rooms and office spaces, is still common, especially in developing nations. The benefits of natural ventilation are realized in reduced operation costs and energy usage and in some cases increased air-quality. As noted in a case study of Washington State Veterans Home in *Sustainable Healthcare Architecture* by Robin Guenther and Gail Vittori, the authors note that the facility, which features natural cooling and operable windows, has an annual energy reduction of 50% below a standard, mechanically cooled long-term facility. They also point out that reliance on natural ventilation in many of their international case studies, featured throughout their book, is a “striking energy performance differentiator between American hospitals and those abroad”. (Guenther and Vittori, 2008, p310). As North American Hospitals are some of the most energy intensive hospitals in the world, in fact their energy consumption levels “are at least twice those of other industrialized nation” (Guenther and Vittori, 2008, p285) then consideration of natural ventilation should be on the agenda. The reduced costs associated with natural (passive) ventilation are realized by not having to mechanically move air through the building’s ventilation system, thus reducing the energy consumption and maintenance costs associated with fans and ducts.

Depending on the climate, these systems also save on heating or cooling costs. The other benefit of natural ventilation is the air-quality depending on the outside air quality “since ventilating with polluted outdoor air can itself produce deteriorated indoor air quality”. (Levin, 2008, p309). The other factor determining whether natural ventilation can improve air quality is the extent of the pressure control. In a study by the previously mentioned Dr Rod Escombe and other colleagues that examined the effect of natural ventilation in eight hospitals in Lima, Peru, natural ventilation was found to have provided 28 air changes per hour compared to 12 in negative pressure rooms (Wilson, 2007). Negative pressure is associated with traditional mechanically driven HVAC systems in hospitals, in an effort to have complete control of the hospital’s air flow. Thus natural ventilation may have potential in increasing the air quality of a particular building, but this will depend on how much buildings need to have tight pressure controls as well as the regional climate and the outdoor air quality.

Before opting for natural ventilation systems research into the factors of air quality and climate compatibility must be undertaken, as was the case before the construction of Washington State

Veterans Home. This presents an opportunity for digital modelling programs to help in the decision-making.

Digital Management for HVAC

Digital management can assist hospital developers in selecting the correct heating, ventilation and air conditioning (HVAC) system for their hospital. This is achieved through the use of modelling programs that simulate the effects of HVAC systems. One such modelling program is called Computational Fluid Dynamics (CFD), which can be described as a “computer based simulation tool for the analysis of complex systems” (Partridge, Groenhout and, Al-Waked, 2005). It can be used to model and predict airflow, humidity, air quality and temperature within a space. Figures 6,7 and 8 are examples of a CFD program measuring the velocity profile of air particles. From these models the capabilities of different HVAC systems can be modeled and hospital stakeholders can make more informed decisions.

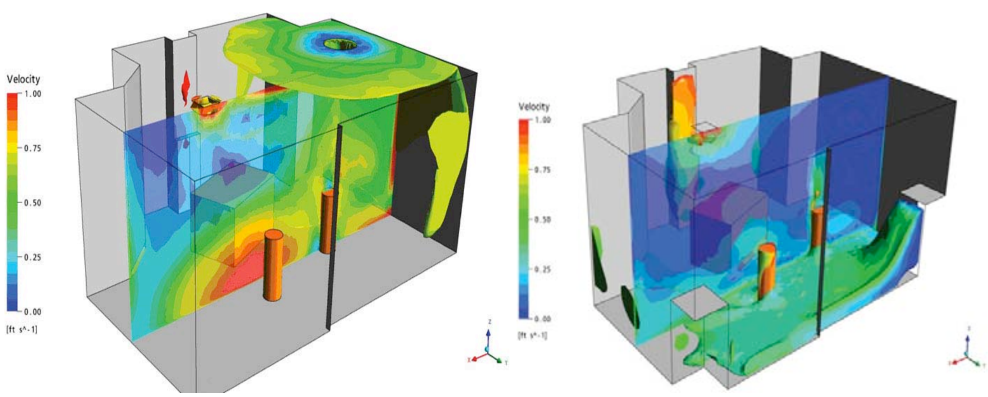
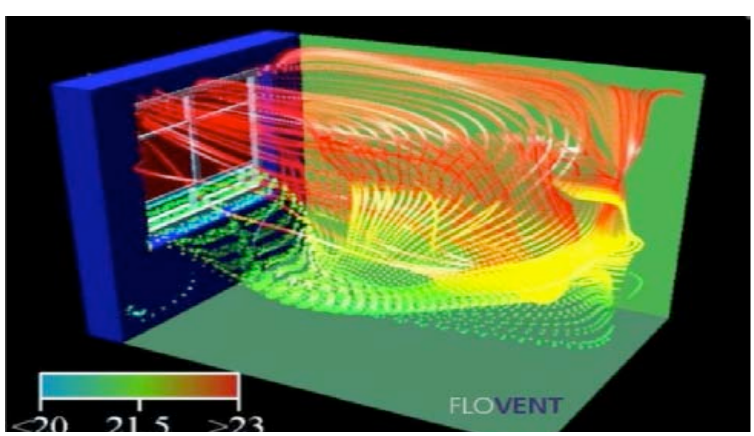


Figure 6 & 7 : Examples of modeling programs used to investigate the differences in air quality using an air particle velocity profile of the a room using overhead ventilation (left) and same room using displacement ventilation (right). Source: Gulick, 2007

Figure 8 is a similar modeling program used to study the thermal comfort of a room using natural ventilation. Source: Kluske, 2009



Other programs such as the Indoor Air Quality (IAQ) Estimator from the CRC for Construction Innovation enable building designers to estimate the impacts on indoor air quality of different materials, finishes and office equipment as well as ventilation practices. The program allows for the modeling and selection of different scenarios, the possibility of IAQ goals being exceeded can be understood, different strategies can be adopted (short-term increase in ventilation, delayed occupancy) and pollutant exposures can be reduced (Tucker et al 2004).

Part III: Energy Sources

Hospitals by law have to be able to generate their own base load power, in conjunction with or as a back up for the main electricity in the event of an unexpected loss of electricity and/or emergency situation. Though hospitals have these unique energy requirements, such as constant and reliable mains power and instant back up complementary power, it is important to note how alternative energy can still play a useful and cost saving role.

Co-generation Plants

Gas-fired generators are common for electricity generation in hospitals, with many new hospitals around the world featuring co-generation gas-fired plants when feasible (some countries do not use natural gas as an energy source). Co-generation plants not only produce electricity, but can also, by using excess heat supply, provide energy for the hospital's hot water, steam for sterilization, and space heating. The possibility of tri-generation generators exists, but these systems are rare because they are new. The tri-generation system uses the remainder of the excess heat in absorption chillers to create cold water that can be used for air conditioning or general cooling. The diagram 1 below from Umow Lai Engineering, provides an excellent outline of how a co/tri-generation system works, with the absorption chiller section representing the tri aspect of the system.

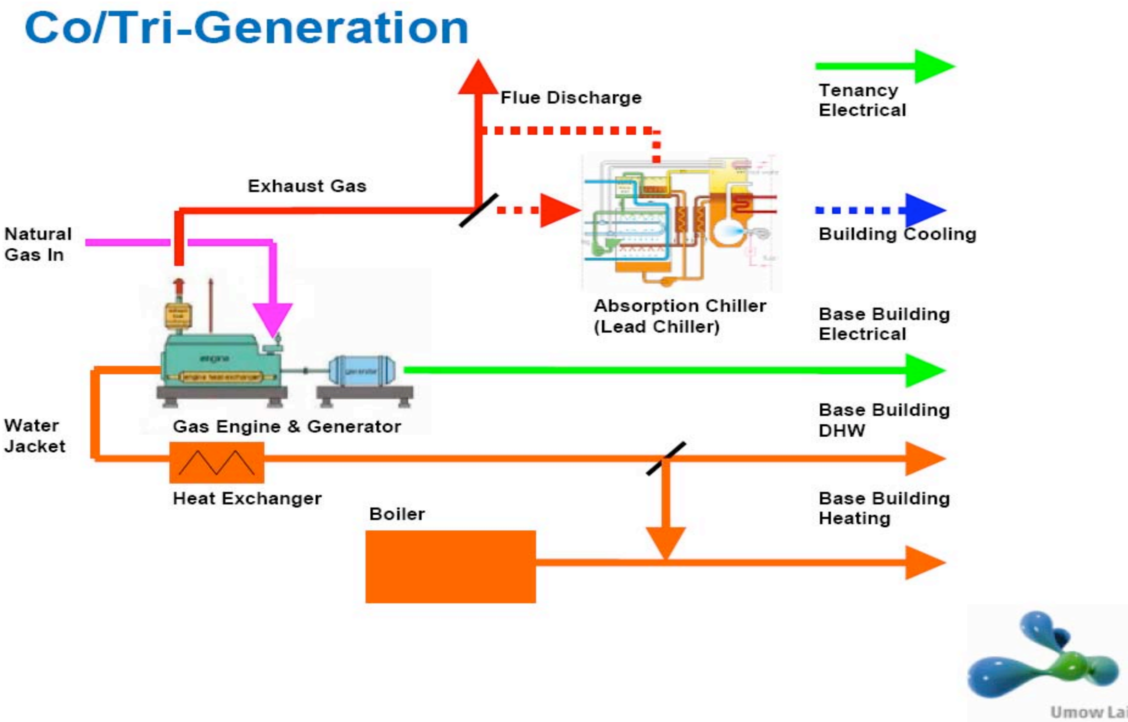


Diagram 1: Processes involved in Co/Tri-Generation. Highlighting how the use of excess heat from the gas engine can generate electricity (green), heat (orange) and cooling (blue). Note the ingenuity of this system in that it that uses the engine's hot exhaust gas (red) to cool the building it is powering. Source: Harris, 2009

Co-generation for hospitals in Australia

Currently there are a number of hospitals in Australia that employ gas-fired electrical and/or co-generation plants, such as Redcliffe, Toowoomba and Townsville Hospitals in Queensland, Geelong Hospital in Victoria, and Griffith Hospital in NSW. These facilities are mostly smaller scale and do not provide the hospital with its complete electricity requirements. However, many future large Australian hospitals, either in the conception and design phase or under construction are opting for gas fired co-generation plants for their electrical and heating needs. In Western Australia, both the Fiona Stanley Hospital and in Queensland the Gold Coast University Hospital are committed to co-generation plants.

Within the context of Western Australia, gas-fired co-generation plants seem to be a reasonable option, since the state holds 80% of the nation's total gas reserves and produces 66% of its natural gas (Energy WA, 2006). A further investigation would be required to assess how a large gas fired plant would affect the regional transmission grid. There is also the possibility of regional power utilities such as Western Power and Synergy being invited into a public-private partnership with the hospital, noting the following case study of Dell Children's Hospital in Austin, Texas, USA.

Case Study II:

DELL CHILDREN'S HOSPITAL

(Austin Texas, USA)

Dell Children's Hospital in Austin TX opened in June 2007, and it is one of only two hospitals in the USA to achieve LEED Platinum status with the Green Building Council of America. A major feature in achieving this high rating is the on-site, 4.3 megawatt (MW) natural gas fired power plant. A local energy firm, Austin Energy, built, owns and operates the plant, which is called the Mueller Energy Center. The power is supplied to the hospital at existing electricity rates and the chilled-water and steam rates were negotiated.

The gas fired power plant provides 100% of the hospital's electricity needs. Also, the heat exhaust from the generator is used to produce steam which is used for its sterilization systems and general heating (Health Facilities Management, 2009). The steam is also used in an "absorption chiller" where, through a chemical process, the heat energy is used to chill water to

40-42ºF (4-6ºC). The chilled water is piped to the hospital and funnelled through coils in air handlers. Air is blown across the coils to provide air conditioning to the building (AustinEnergy, 2006).

To ensure this system is not overloaded during peak operating hours, the plant also incorporates a 3.3 million litre on-site water storage tank. This allows water to be chilled overnight (when electrical supply is abundant) and stored. The chilled water in the tank can then be used to meet air conditioning needs throughout the day, and is especially helpful during peak operating hours. The plant also has backup electric chillers. (AustinEnergy, 2006)

At full operation the power plant can produce about twice as much power as the hospital requires, with its peak load of 2.3 MW. The plant thus exports power to the grid, and if the grid goes down, an emergency generator will blackstart the plant to provide power to the hospital in island mode.

One of the attractions of natural gas fired power plants and its use for powering hospitals is the reliable and consistent energy it provides, even if used as a backup system. This has benefits often not even considered. Joe Kuspan, the director of design for Karlsberger architecture firm in Columbus, OH, and the lead architect on the Dell Children's Hospital project explains, "The IT department has already taken note of the fact that their equipment is not breaking down. There are no power spikes, which shorten the life of high-technology equipment. When you think of a hospital, which has $2 million MRIs and other incredibly sensitive equipment, you want to have reliable power"(Sandrick, 2009).

Australian Case Study:

GRIFFIN HOSPITAL

(New South Wales, Australia)

Griffith Base Hospital is a 100-bed regional base hospital in New South Wales. The hospital features a small gas-fired cogeneration system that provides both electricity and heat for steam boilers. "The boilers produce heat for the laundry as well as the hospital's air conditioning, kitchen, heating, and domestic hot water systems" (SEDA NSW Government, 2003). The co-generation system has reduced the hospital's energy bill by over $100,000 and has cut greenhouse gas emissions by over 1,000 tons per year, the equivalent of taking 240 cars off the road. The system does not however provide the hospital with its full electricity requirements and there is "an alternative diesel fired generator available as an emergency back up" (Butt, 2003).

Heat Pumps

Heat pump and heat exchange technologies can be used effectively to achieve constant temperatures throughout hospital complexes. They can use thermal sources as varied as sewage, out-going air from ventilation ducts, excess heat from machines, solar energy and more. In addition a ground-source (geothermal) heat pump is also a possibility where available.

Geothermal

The following excerpt from Space Conditioning Goes Underground to Beat Operating Costs provides an excellent description of a geothermal heat pump and how it works utilizing a large body of water as a thermal ground source.

> *There are several different types of ground-source geothermal heat pump systems but two general categories: open loop and closed loop. The most popular system is a closed-loop system where a heat exchange fluid is circulated through polyethylene pipes that are laid underground or at the bottom of a large body of water and returned to heat pumps located within the facility. Open loops draw water from underground or aboveground, an example of an open loop system is the geothermal water heating system at Challenge Stadium in Perth.*
>
> *The system is simple and efficient. The heart of the system is in the heat exchange process. The heat exchange fluid - water or water with glycol - absorbs heat from or transfers it to the earth.*
>
> *The fluid returns to the heat pumps, which utilize a refrigerant cycle to take the fluid's low quality heat and concentrate it; the process is reversed for cooling. Air passing over coils is distributed by fans. The heat pumps tend to be rather small - one- to three-ton capacity pumps are typical, with the largest around 50 tons.*

(Space conditioning goes underground to beat operating costs. 2000)

Case Study IV:

GREAT RIVER MEDICAL CENTER

(West Burlington: Iowa, USA)

Great River Medical Center in West Burlington, Iowa, is one of the most energy-efficient hospitals in the U.S. The community medical care campus features over 1200 rooms and is powered by one of the world's largest lake-coupled geothermal heating and cooling systems (Geothermal in Action: Commercial n.d.). "The system is capable of producing more than 1,500-tons of cooling, enough energy to serve the equivalent of 500 single-family homes (KJWW n.d.)." The medical centre has recorded a 37% reduction in annual energy costs since its opening, compared to similar sized hospitals using conventional systems. The geothermal system utilizes a 14-acre, 13-foot-deep man-made pond as its heat exchange field. Through a piping system, the heat exchange fluid (water with glycol) is pumped throughout the hospital, passing through the centre's 768 heat pumps. These heat pumps, through the system described above, regulate temperatures in offices, patient and treatment rooms. Each patient room, office and treatment room has its own individual temperature controls that maintain the room's temperature to within 4°F of the setting. Each suite has individual room temperature control and a sensor to reduce ventilation when unoccupied in order to conserve energy (KJWW n.d.).

Figure 9, 10: Artificially constructed lake in West Burlington that acts as the 'heat exchange field' for the Great River Medical Centre's geothermal heating/cooling system. While still in construction phase, the devices shown on the lake floor are the grids and pipe coils, or heat exchangers, which will ultimately transfer heat from the water at the bottom of the lake to supplement the centre's heating/cooling requirements. Sources: 9, Alliant Energy n.d 10, Sherman Health n.d.

Perth Context

There is potential for any hospital constructed in Perth to opt for a geothermal heating or cooling system, however, more detailed research is required. "In Perth, thick, highly permeable, hot aquifers are already known" (Larking, 2009). An example of a geothermal hot water system in Perth, at Challenge Stadium, utilizes a ground source (borehole) as the heat exchange field for the system. Diagram 2 from Sustainable Energy Development Office and Parsons Brinckerhoff , the engineers for the project, shows how the geothermal system at Challenge Stadium works. This particular system at the stadium provides the energy to heat the four of the five pools that make up this large indoor and outdoor facility. However, by adapting the technologies highlighted in the case study of Great River Medical Center for use in a ground source geothermal system, a hospital in the Perth area could potentially operate its HVAC system with geothermal energy.

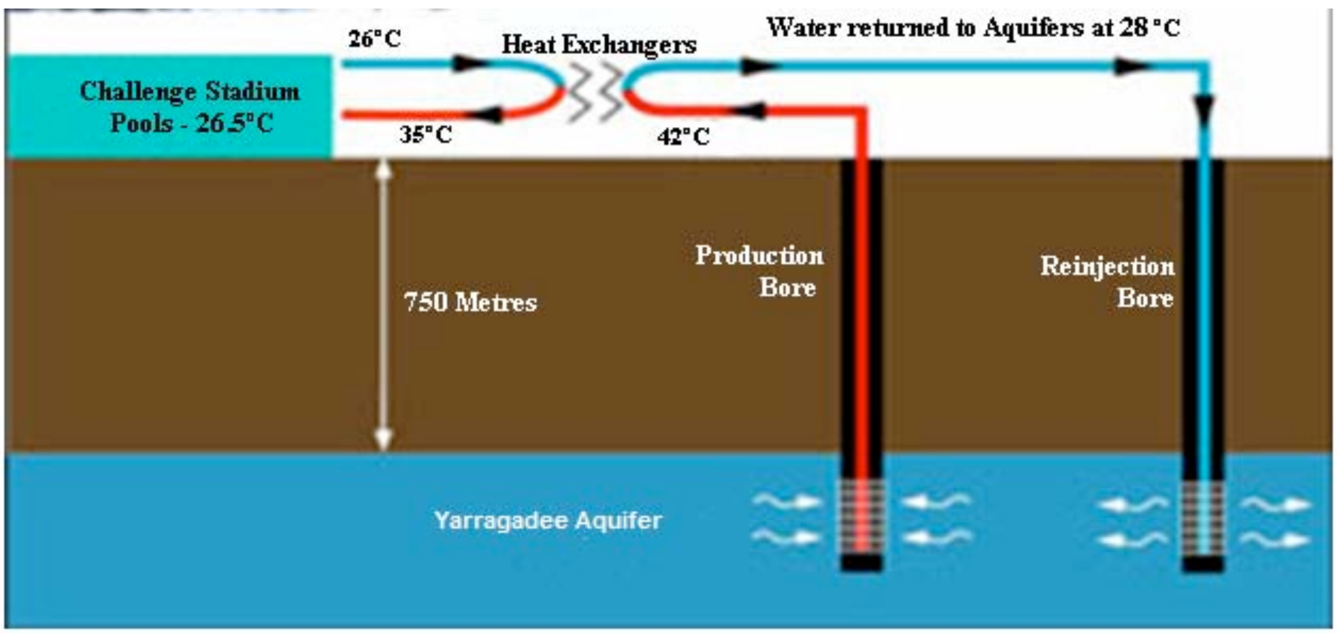


Diagram 2: For the Challenge Stadium in Perth, a geothermal system is used to warm their main pools. By pumping hot water from the Yarragadee Aquifer to heat exchangers, thermal energy is transferred to closed pipes leading to the stadium. The cooled water is then returned via a 'rejection bore' to the aquifer. Source: Sustainable Energy Development Office (SEDO) n.d.

Wind Power

The need for hospitals to have continuous and reliable power means that using wind power as a sole source of energy is not reasonable at the moment, or rather, not reasonable with the current technologies. However wind power can supplement a hospital's energy portfolio and assist by providing a carbon free source of renewable energy.

Case Study V:

ANTRIM AREA HOSPITAL

WIND TURBINE

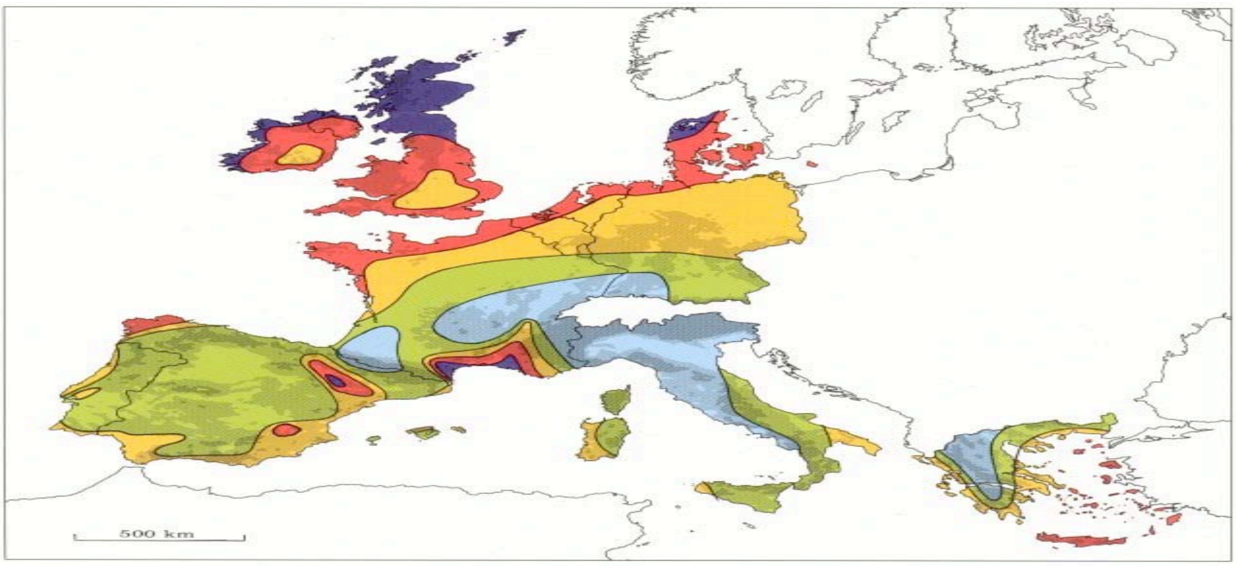
(Antrim, Ireland)

Figure 11: Antrim Area Hospital's V47 660 kW Vestas wind turbine. As suggested by its model number, V47, this particular Vestas turbine has a rotor diameter of 47m. Source: Sustainable Development Commission n.d.

Antrim Area Hospital is an acute care hospital with 350 beds in Northern Ireland. In the beginning of 2005, the hospital started electricity generation from a 44-ton and 40m hub-high 660kW Vestas wind turbine. The electricity from the turbine is used as a base load replacement and, depending on wind speed and consistency, has the potential to provide enough electricity for the hospital during the night, and two-thirds of its needed power during the day (Sustainable Development Commission n.d.). The project cost approximately £500,000 ,and since the hospital is a public sector building, they were able to secure a £400,000 grant from the Northern Irish government's Central Energy Efficiency Fund. Without the grant, it was projected that the turbine would take five years for the initial cost to be repaid, at least at 2005 energy prices (Sustainable Development Commission n.d.). As such, in the first two years of operation between 2005-2007, the turbine enacted a cost savings of over £140,000, effectively repaying initial cost less the grant, and from now on significantly decreasing the hospital's dependency on conventional energy (Action Renewables n.d).

Perth Context

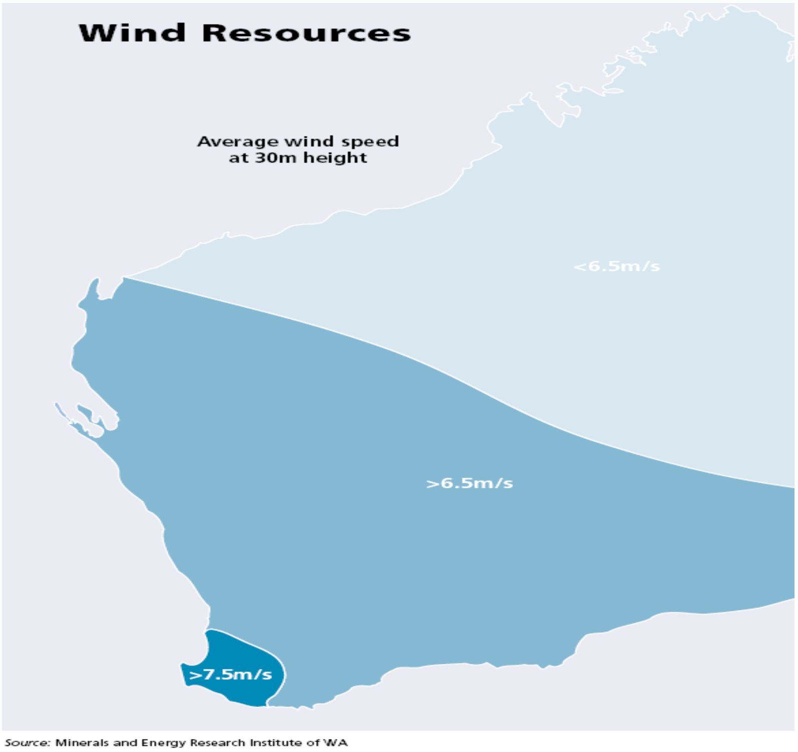
Perth is generally considered the windiest major city in Australia. The following maps 1 and 2 are wind atlases of Europe and Western Australia. From the two atlases a conclusion can be drawn that there are indeed good, if not comparatively better, conditions for a wind turbine at a newly built Perth-area hospital. There are even further wind technologies such as wind pods shown in figure 12, developed in Western Australia, which could be incorporated into the design of a hospital as an exemplar project. More precise research and measurements would need to be taken, but through a casual comparison between Perth and the levels generated in Europe, where it has been an efficient means of energy production, wind turbines and associated technologies seem a promising possibility for hospitals to reduce costs.



Wind resources[1] at 50 metres above ground level for five different topographic conditions										
	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700

Map 1: Detailed profile of European wind speed in relation to five different topographic conditions. The figures are measured 50m above ground level and represented in two ways, meters per second (i.e. $m.s^{-1}$) and expected power generation (in watts) per meter squared (i.e. $W.m^2$).

From the *European Wind Atlas*. Copyright © 1989 by Risø National Laboratory, Roskilde, Denmark.



Map 2: Basic profile of Western Australia's average wind speed in meters per second: $m.s^{-1}$. Note the height at which these speeds were measured, 30m, is approximately 20 meters lower than the European figures in Map 1 and is, assumedly, averaged according to topographical conditions.

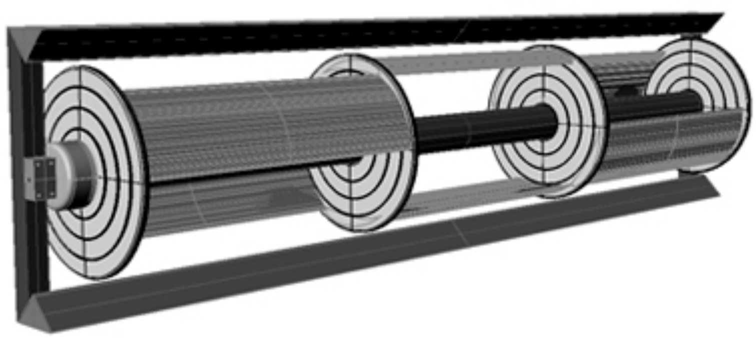


Figure 12: Computer generated model of a Windpod. The advantages of Windpods is that they can operate vertically, horizontally or any angle in-between where wind is at highest concentration, they have low noise and vibration levels and excellent power production per dollar of cost. See www.windpod.com.au

Solar Photo-Voltaic

Solar PV is rapidly becoming cost efficient and is the chosen renewable energy device in many new green buidings around the world. PV is growing worldwide at around 40% per year due to its simplicity of operation and long life (around 50 years). For any government hospital the pressure to provide PV energy on their building will grow as climate change debates give way to firm commitments such as the 20% renewables by 2020 which now challenges Australia.

Case Study VI:

LEWISHAM HOSPITAL

(London, England)

The new Riverside wing of the Lewisham Hospital (NHS Trust), in London, England, contains over 400 beds in single rooms and four-bed units. The Riverside was the first new hospital building in England to utilize solar panels to provide a proportion of the hospital's energy needs. Through the installation of 110m^2 of photovoltaics on the roof (72 panels), an impressive 10,300kWh per annum are generated, with a peak output of 13.7kW (Simpson, V., 2007). An exciting feature about this solar initiative is that in the reception area there is a display showing how much of the building's energy the solar PV system generates. The panels become part of the discourse between the community and NHS and their commitment to sustainability. The photovoltaic system cost £79,846, which was paid for by a grant from the Energy Savings Trust.

An exciting case study for dual purpose solar PV is how it is used in Oregon Health Science University (OHSU), whereby the solar PV installations in this facility act as both sun shades and electricity generators.

Case Study VII:

OREGON HEALTH SCIENCE UNIVERSITY

INTEGRATED SOLAR SHADING

(Oregon, USA)

At Oregon Health Science University (OHSU), the building's sunshades on the south façade are architectural features that serve both mechanical and electrical purposes. The sunshades, which in addition to their obvious function of blocking sunlight and thus lowering cooling requirements during summer, have also been layered with solar PV panels, with a capacity of 60kW, in order to generate electricity. Thus the shades work proportionately too: when sunlight is at its most intense and demanding of air conditioners, the shades not only block the sunlight but harness it, allowing the university to direct the acquired energy to cooling. The more intense the sun, the more energy provided to counter its unwanted effects.

Figure 13: Photo of the south façade of the Centre for Health and Healing at OSH, with its sunshades that incorporate solar PV panels.

Perth Context

Perth is the sunniest major city in Australia, receiving an average of 8 hrs of sunlight a day. Solar PV systems in Perth can realize increased performance in comparison to similar systems in the cities of Northern Europe, whereby on average, the latter receive far less sunlight. It is useful to note that many established and emerging local Australian solar companies are available to deliver and maintain solar PV systems and one, SunGrid, has become a major exporter of its services. While federal and state government rebates exist for installing solar systems, the possibility also exists for partnerships between local energy utility companies, such as Synergy, and hospital stakeholders.

Solar Hot Water

Heat pumps and heat exchangers have made solar hot water systems increasingly efficient over the last few decades. Combined with digital management these systems can either complement existing hot water systems or, by using heat capture technologies, provide continuous hot water itself. At this stage, solar hot water systems are mostly used as an additional heating source to gas and electric systems, helping to reduce overall energy use and costs. Hospitals throughout Australia are installing gas-boosted solar water heating systems. For example the largest solar hot water system in South Australia has been installed at Flinders Medical Centre. The following is a case study of Repatriation General Hospital in Adelaide, South Australia.

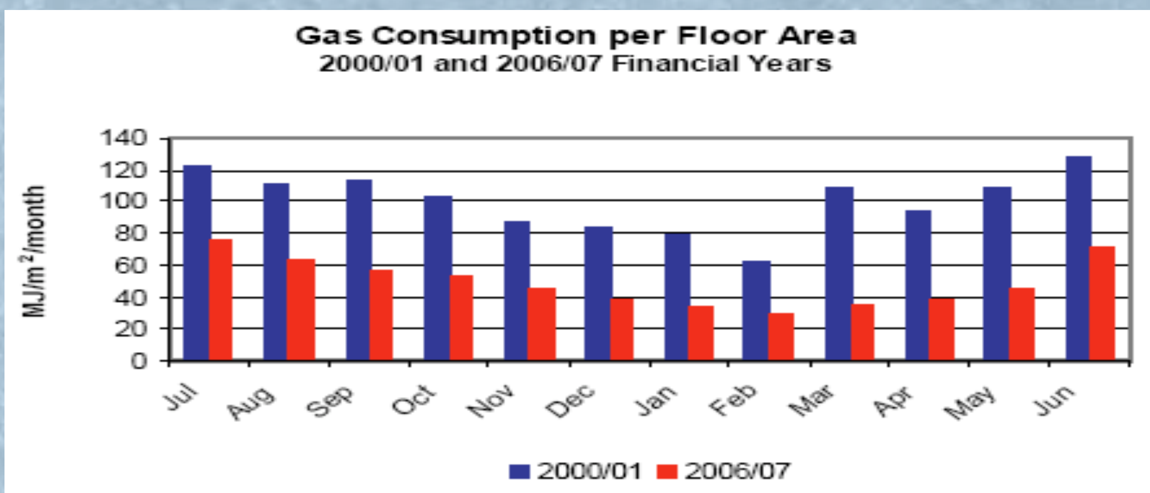
Case Study VIII:

REPATRIATION GENERAL HOSPITAL

(Adelaide: SA, Australia)

Figure 14, 15: Solar assisted hot water systems for the Repatriation General Hospital in Adelaide. Through these solar collectors (left) and other initiatives such as natural gas burners, 56% of the hospital’s heating requirements are now powered with alternative energy.

At Repatriation General Hospital in Adelaide, South Australia, two of the hospital's wards had solar-assisted hot water systems installed. These systems involve 100-panel-type solar collectors, expansion tanks, solar pre-heat tanks, natural gas-fired burner units and an intelligent control system (System Solutions Engineering 2006, 1). It is estimated that the solar heating system contributes to approximately 56% of the hospital's water heating requirements. This has led to gas energy cost savings of $119,410 per annum, resulting in a payback period of less than five years, surpassing the original expectations (McGowan, 2007). The "greenhouse gas savings are also significant, with the site reducing its CO_2 emissions by 37% to 783 tonnes per annum. This is the equivalent of removing 178 cars from Adelaide's roads" (McGowan, 2007, p12). The following graph from the engineering firm involved in the project, System Solutions Engineering, shows that RGH has achieved a reduction of 51% gas energy reduction per floor area in 2006/07 when compared to 2000/01 (System Solutions Engineering 2006).



Graph 1: Six year comparative study, for one financial year, on gas consumption per square meter per month for the Repatriation General Hospital in Adelaide. (Source: System Solutions Engineering 2006)

Perth Context:

Since the 1950's solar water systems have been heating the water of homes throughout Western Australia and have become a growing alternative to similar electric and gas systems all over the world. Solar Hart, Solar Beazley and Solar Edwards are all Western Australian firms that began in Perth from small plumbing firms that wanted to make use of the sun to help ease the high electricity costs in WA (Newman and Burger, 2009). Therefore any hospital constructed in Perth would have an experienced industry available to pursue solar hot water systems.

Solar Cooling

Absorption chillers can be used to heat exchange and feed refrigeration technologies to harness solar thermal energy to be used in temperature control systems such as air conditioning. There are many advantages to using this technology, as it has a renewable energy source and thus no greenhouse gas emissions. The system forms part of the solar hot water system and has a significant advantage over some renewable sources in that the system peaks in performance when demand for cooling is at its highest, namely, during the hot days when there is maximum solar thermal energy.

Case Study IX:

IPSWICH HOSPITAL

(Brisbane: QLD, Australia)

The air conditioning system at Ipswich Hospital is supplemented by a 300kWr double-effect absorption chiller connected to a 255kWh thermal solar collector field. (EcoLibrium 2008, 24). 43 solar collectors are located on the roof of the hospital's multi-story car park. They are controlled by a computer program which monitors radiation levels and tracks to the sun as it travels across the sky (Health Matters 2007, 13). These collectors are "connected to the absorption chiller by two loops – one containing thermal oil, and another containing water" (Meadows, J 2008, 18). A heat exchanger is used to transfer the heat energy between the two loops, which then provides the absorption chiller with necessary heat energy to produce chilled water. "The chilled water is connected to the main chilled water circuit in a 'side stream' arrangement, which allows the absorption chiller to operate either in series or in parallel with the main chillers" (EcoLibrium 2008, 25). The hospital's building management system (BMS) controls the entire system, and when sufficient solar thermal energy is available the BMS uses the solar-assisted chiller as the lead chiller, thus maximizing the efficiency of the solar-assisted systems. (EcoLibrium 2008, 25). A $6m^3$ thermal storage tank is also included to extend the operational hours of the solar cooling system (Health Matters 2007, 13). Even though the solar-assisted absorption cooling system provides a proportion (300kwr) of the 4.5MWr cooling capacity, the case study is an example of the possibilities of solar cooling technologies.

Figure 16: The Ipswich Hospital thermal solar collector field is powered by 43 solar collectors on top of its parking facility. Weather dependent, the field generates approximately 255kW/h.

Perth Context

Given Perth's warm summers and abundance of sunlight, utilizing a technology such as solar cooling systems which takes "advantage of the correlation between available solar energy and the cooling load required by the building" would seem sensible (EcoLibrium 2008, 25).

Green Energy Purchasing

Purchasing green energy allows the hospital to reliably supply its energy needs with renewable energy. Often the purchasing of green energy is slightly more expensive depending on the regional power utility though the capital costs associated with providing renewable energy are then not incurred by the hospital itself. The big advantage of free energy after the pay-off period is lost however.

The term *green power* as defined by the U.S. Department of Energy "refers to electricity products that include significant proportions of electricity generated from energy resources that are both renewable and environmentally preferable" (U.S. Department of Energy 2004, 4). These renewable energy resources include solar, wind, moving water, organic plant and waste material (biomass), and the earth's heat (geothermal) (U.S. Department of Energy 2004, 4).

Case Study X :

YORK HOSPITAL

(York: Maine, USA)

In 2003 York Hospital in Maine entered into a contract with Constellation NewEnergy to purchase renewable energy to meet 100% of its electricity needs. Under this agreement green power supplied to the hospital incurs a premium cost that is less than 0.5¢/kWh higher than Constellation NewEnergy's standard electricity rate (Large Purchasers of Green Power 2003). As of 2008, 90% of the hospital's energy purchases still come from green power. Despite using 37% more energy than in 2000, through the purchase of green power the hospital has reduced its carbon emissions by 24% from 2000 to 2006, a decline of about 300 tons a year (Perry, H 2008).

Case Study XI

Providence Health System Medical Center

(Newberg: Oregon, USA)

Providence Health System's medical center in Newberg, Oregon is under agreement to purchase 183,294 kWh per month of renewable power from Portland General Electric (Providence Health & Services n.d.). Thus, 100% of all the hospital's electrical needs are met by purchasing green power (50% wind, 25% geothermal, 25% low impact hydro). PNMC is the only hospital in the nation to purchase 100% green power. By purchasing green power the hospital will offset the need for conventional power generation that would have sent more than three million pounds (1,600,780 kg) of carbon dioxide emissions into the atmosphere each year. The CO_2 emissions avoided will be equivalent to taking 273 cars off the road (Providence Health & Services, 2006).

Green Power Purchasing: Perth Context

The local utility provider of the greater Perth area is Synergy. The company does offer green power purchases to corporations under the product label "Natural Power". Therefore there is the possibility of a Perth-area hospital meeting a proportion of its energy need (or even 100%) with renewable energy by opting for green energy. As hospitals are such large consumers of electricity the green power provided will be a major boost to the renewable energy industry and will be a big assistance to WA as it seeks to meet its 20% renewables goal. It would also be a boost to the marketing of green power in WA as "in comparison to other states and territories, Western Australia has the lowest participation in Green Power in Australia" (State of the Environment Report 2007).

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THEME II

WASTE MANAGEMENT

In her paper, Preventative Medicine for the Environment: Developing and Implementing Environmental Programs that Work, Laura Brannen, executive director for Hospitals for a Healthy Environment (H2E) in the USA, asserts that "Waste is a measure of inefficiency" (2006: p95). She supports her claim by suggesting "the evidence of this inefficiency in healthcare institutions across the country (USA) is clear when looking at the materials that are being tossed every day that equate to tossing millions of healthcare dollars while at the same time negatively impacting the environment and health of the very communities in which they serve" (Brannen, L. 2006, p95). Many large buildings with environmentally focused waste management strategies attempt to implement the three R's Reduce, Reuse and Recycle, in an effort to minimize their waste to landfill and improve their efficiency. The ability of a hospital to implement this strategy depends on several factors, namely: the facility itself, the participation of its staff and the procurement policies of the hospital's administration.

Waste management and Design:
Better waste management facilities

There is a misperception that hospitals create an abundance of clinical waste that is hazardous and thus, opportunities for attempting the Recycling and Reuse aspect of the three R strategy is not possible. However, as Terry Grogan, of the US Environmental Protection Agency's (EPA's) Office of Solid Waste, points out "In the US only about 15% of the waste created by hospitals is considered hazardous, the remaining 85% is composed of paper, plastic, food and other materials that could possibly be recycled" (G r o g a n, 2003). For a hospital to attempt to manage the non-clinical waste (hospital waste not considered hazardous), the building must have the appropriate waste handling facilities and space to effectively sort, transport, compact and store waste for recycling. Therefore, the opportunities for environmentally focused waste management are greatly affected during the design stage of a new hospital. Spaces, areas and systems designated for waste management need to be planned during the design stage, not added on afterwards. This importance of space and better understanding of hospital waste is highlighted by the authors, Janet Brown, Laura Brannen and Sarah O'Brien in their work *Integrating Operations in the Design Process*, in which they argue that:

> Spaces themselves can help staffers engage in environmentally sound waste-management practices, but this requires an understanding of how hospitals generate waste, what kind of waste is avoidable, and what space is needed for optimal operational efficiency (Brown, Brannen and O'Brien, 2008)

Thus any new hospital must research its possible waste generation and design its spaces and waste management strategies accordingly. For hospitals in Australia, this waste management design has to work with current procurement practices of the governing health authority and agencies that handle the region's waste disposal. For example, Perth currently does not have glass recycling facilities as WA's last recycling plant closed in December 2003, so the city freights the material (glass) to O-I Australia's bottle plant in Adelaide, South Australia (Hatch, 2007). So, the more that glass is separated at source the easier it is for the local recycling facilities to economically manage glass. Most cities are increasing pressure for 'zero waste to landfill' as the key to the future in waste management so any new major facility like a hospital has to be designed with this in mind. Designing with the long term future in mind may also lead to the avoidance of costly additions or changes once the building is complete. Ultimately the main concern with waste management and design is researching and understanding the future hospital's waste generation and then designing the building with the appropriate spaces, areas and facilities to efficiently handle this waste in the most environmentally friendly manner.

Waste and Hospital Staff:

For any of the three R strategies to be implemented, the participation of hospital staff is essential. While good design should make it easier and more obvious how to handle waste materials, ultimately it is every staff member's responsibility to use materials responsibly and manage the waste that they incur (Brannen, 2006, p87). Laura Brannen goes on to suggest that training in better waste management by staff members doesn't stop at new employee orientation, but is a continuous program of improvement and education (Brannen, 2006). Updating, educating and involving hospital staff is crucial for continuing environmentally focused operations.

Waste and Hospital Procurement:

Another important aspect of waste management is the procurement of materials and products used in the hospital's operations. Consideration of the life cycles of these materials and products during their procurement has an enormous effect on whether hospitals can minimize waste to landfill, attempt recycling and effectively handle their waste with the environment in mind. To use another suggestion from Brown et al, they argue that:

> Making informed purchasing decisions through environmentally preferable purchasing (EPP) – the process of purchasing products and services that have a reduced impact on human health and the environment when compared with comparable alternatives – goes a long way to reduce waste and toxicity at its source and is gaining broad adoption in Healthcare (in the USA).
>
> (Brown, Brannen and O'Brien, 2008, p182)

The disposal of hazardous waste must be done according to the laws and regulations of the health authorities, thus there are limited opportunities for recycling once an item is deemed hazardous. It is well known in the healthcare industry that one of the most important issues regarding effective waste management is the hospital's operational procurement for medical products. For example, single use kits containing multiple tools are often opened for just a single item, meaning the entire kit has to be discarded as hazardous waste. These ongoing operating costs make up a substantial proportion of the overall costs of any hospital, whereby better procurement practices not only assist in reducing the amounts of waste created by hospitals, but often significantly reduce costs related to disposal.

Western Australia in Context

In a *Submission to the Productivity Commission: Public Inquiry into Waste Generation and Resource Efficiency***,** the Department of Health for the Western Australian government has recognised that waste from its approximately 70 hospitals across the State is an important contributor to the state's solid waste stream. The department has also noted there is potential to improve the use and disposal of recyclable and other materials from the clinical environment which would result in a substantial reduction of waste to landfill (Department of Health Western Australia n.d). Furthermore, national practices and mechanisms to support medical environments to reduce or redirect their wastes are needed to provide for consistent and cost effective approaches (Department of Health Western Australia n.d.). As such, any future Perth Hospital, if they are to agree with the principles of the Department of Health, should be designed in such a way that the building facilitates the best possible waste management strategy within the context of national practices. There are case study examples in Australia, such as the following Flinders Medical Center in Adelaide, where by hospitals have taken initiatives to minimise their waste and improve recycling even in the absence of national directives to do so.

Case Study I

Flinders Medical Center

(Adelaide, South Australia)

The Flinders Medical Centre (FMC) in Adelaide has a proud record in terms of environmental and waste management issues, having received national acclaim in past years for a variety of waste minimisation and recycling initiatives (Flinders Medical Centre 2008). The hospital's Healthy Environment Project was initiated in December 1991 and within a few years managed a 50% reduction in general waste and 35% reduction in medical waste volumes. These reductions resulted in cost savings of $300,000 per year (ACF / ACTU Green Jobs Unit, 1994).

To achieve these results a waste audit was undertaken, identifying and classifying the types of waste emanating from the hospital: solid, chemical, medical and liquid. From the audit it was established that cardboard and paper represents about 50% of FMC's general waste (ACF / ACTU Green Jobs Unit 1994). Taking action, FMC installed recycling stations in each of the wards and most other departments. The paper recycling program alone established 150 collection sites throughout the hospital and has lead to approximately three tones of paper been recycled per month (ACF / ACTU Green Jobs Unit 1994).

Along with the Environmental Service team, which includes around forty FMC staff members such as a professional engineer, technical/maintenance managers, plant supervisory staff, trades and support staff - the hospital is minimising its environmental impact by focusing on waste reduction and lowering both its energy and water consumption (Flinders Medical Centre n.d.). An additional programme on medical waste and correct segregation has also achieved significant savings and a reduction in the volume of waste incinerated by 35% (ACF / ACTU Green Jobs Unit 1994).

For hospitals and environmental waste management the main point for any future hospital is to research and understand the hospital's waste generation. Then, as mentioned above, the hospital can be designed with the appropriate spaces, area and facilities to effectively handle its waste in the most environmentally friendly manner. Once the hospital has the facilities to initiate environmental waste management programs it is up to the staff and operations personnel to commence and maintain these programs. The entire process must also tie in to, and can be improved upon through, the procurement strategies of the hospital's supplies. All of these waste management strategies must also work within the framework of national waste disposal guidelines and laws.

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THEME III

WATER

Hospitals use vast amounts of water, and as Laura Brannen, the executive director for Hospitals for a Healthy Environment points out, "healthcare institutions are consistently within the top ten water users in their communities" (Brannen, 2006). At present, the low cost of water in most developed countries means it occupies a small percentage of a hospital's operational costs and concern. This makes it difficult for organizations to justify major water conservation strategies from a cost savings point of view, as from a financial standpoint they would not be viable. This short-sightedness is obviously a barrier to adopting better water practices. Thankfully, there is a powerful environmental obligation that drives water conservation, especially in Australia. For hospitals, specific health related aspects obviously should be kept in mind when addressing water conservation strategies. In some hospitals even current potable water supplied by the local authority is passed through their own purification systems before use. Therefore water conservation strategies, such as dual system plumbing that uses rainwater or grey water for toilets, become a perceived health issue for hospitals. Depending on the type and size of a facility, hospitals typically use 25% of their water for domestic use (sinks, showers and toilets) and 75% for non-domestic (including boilers, chillers, food services, operating rooms, laundry facilities, sterile processing and radiology) (Guenther and Vittori, 2008 p270). As this theme will demonstrate, hospitals throughout the world have begun to adopt innovative water reuse and water use reduction strategies.

Case Study I:

CENTRE FOR HEALTH AND HEALING

OREGON HEALTH & SCIENCE UNIVERSITY

(Portland, Oregon)

The use of grey water and water recycling within hospitals is limited at present because of issues related to health safety concerns and water reuse. In an effort to conserve water, many hospitals obtain their water for grounds irrigation from cooling towers, fire suppression systems, and other water intensive devices located throughout the hospital. Rainwater reclamation systems that utilize water tanks are used in a few hospitals as a non-potable water source for the non-domestic requirements of the hospital where possible. However, "the broader application of municipal or on-site reclaimed water is subject to approval by local regulatory authorities or infection control professionals and lack of clear regulatory guidance has hindered industry-wide implementation to date" (Guenther, R. and Vittori, G 2008, 275). To date, one of the only hospitals to pursue such aggressive water management strategies is the Center for Health and Healing associated with Oregon Health & Science University (OHSU).* Because of its water-wise strategies, the centre realizes a reduction in potable water demand of 56% from a combination of rainwater collection, sewage treatment, and water-efficient fixtures (Guenther and Vittori, 2008, p277).

Rainwater and infiltrated groundwater is used for irrigation, fire water storage, cooling tower make-up water, cooling water for micro-turbines, cooling the radiant slabs in the building and supplying water to the centre's roof garden (Chappel, 2007). The roof garden, in addition to being an attractive building feature, provides insulation and effective temperature control. An on-site "blackwater" bioreactor treatment plant filters and recycles on-site waste water for use as non-potable water for certain plumbing fixtures such as toilets. Beyond water recycling, the hospital's water management system also includes water conservation strategies that reduce demand for both potable and non-potable water such as reducing faucet flow rates and incorporating lower flow toilets, showers and urinals throughout the building.

Case Study II:

IPSWICH HOSPITAL

(Brisbane, Queensland)

Rain Collection Tanks at Ipswich Hospital
Image from Health Matters 2007

* *Note: Please see figure 1 in Appendix. This diagram is from* Achieving Water Independence in Buildings*, which was compiled for the Central City Concern, a non-profit owner of affordable housing in Portland, OR. Firms involved in the OHSU water management system such as Interface Engineering contributed to this research project. The diagram has been included at the end of this theme because of the similarities to OHSU's water management system and the attention to the barriers facing the procurement of such a water system.*

Ipswich Hospital in Brisbane, Queensland has incorporated a rainwater harvesting system that has led to a 25% reduction (22,000 kilolitres) in water use. Four 30,000 litre water tanks collect rainwater from several of the hospital's buildings and roadways; this water is then used in cooling towers. Further water conservation efforts at the hospital include flow restrictors in water reticulation pipes and equipment, locks on outdoor taps, stopping horticultural watering and programmes to educate staff and visitors on water saving techniques. It has been estimated that in one year these conservation strategies saved over 13,000,000 litres of water (Health Matters 2007, p14).

Case Study III:

GEELONG HOSPITAL

UNIVERSITY OF MELBOURNE

(Geelong, Victoria)

There is a multitude of hospital-specific systems and equipment such as sterile processing, radiology, laundry facilities, laboratory equipment, dialysis, etc., which use vast amounts of water. Reducing the amount of water or reusing water in these systems is an effective method for improving the water efficiency of any hospital. The following example from the University of Melbourne's Geelong Hospital highlights their innovative process to reuse "reject water" from the dialysis process, a hospital-specific water conservation strategy.

Previously ''reject water'', is water that has already been filtered by reverse osmosis but still not considered clean enough for hemodialysis (HD) services, had been discarded into the sewer. But now the hospital's HD facility collects the reject water from its 8-station in-centre facility in a holding tank. It is important to note the reject water is a by-product of generating the high-grade water needed for dialysis and is easily drinkable. The holding tank consists of two 30,000-litre storage tanks; from these tanks the water is directed to a central sterilizing department where it is used to generate steam for hospital sterilizer units. Additionally, this water is used for janitorial purposes and as non-potable water for ward toilets. Any further surplus is then directed to watering the hospital garden (Agar et al 2009, p34).This innovative process at the hospital saves approximately 100,000 litres of water weekly. This is an exciting project, as currently in Australia the water consumption associated with HD services is around 0.55 gigalitres per year, where 1 gigalitre equals approximately 500 Olympic-size swimming pools (Agar et al 2009, p35). The cost associated with instigating this process is essentially insignificant, as this Geelong Hospital project was estimated to cost under AU$8,000 (Agar et al 2009).

Case Study IV:

WINSHIP CANCER INSTITUTE

EMORY UNIVERSITY

(Atlanta, Georgia)

Imaginative strategies for recycling previously used, process-specific water are not limited to the preceding case study and HD reject water reuse. There are many hospitals throughout the world that implement other process-specific water conservation systems. For example, the Winship Cancer Institute at Emory University uses chilled non-potable water in a recirculating system to cool condensing units throughout the building, as well as using condensation derived from energy-recovery dehumidification for the cooling towers' makeup water. Combined, these initiatives conserve 71.9 million litres of water per year (Guenther and Vittori, 2008, p143).

Most hospitals have landscaping, gardens, or surroundings that require irrigation and maintenance. As water resources become increasingly scarce, the use of potable water for the irrigation of these areas is undesirable. However, there are many opportunities for hospitals to recycle water for the purpose of irrigating these gardens. Furthermore, hospitals should consider changing the types of vegetation planted in these areas, and opt for native flora instead of water intensive foreign species. At the Winship Cancer Institute, the grounds were landscaped using native plants, and drip irrigation was used initially but discontinued once plants were established (Guenther and Vittori, 2008, p243).

Perth Context

Perth's potable water is sourced from dams, desalination and underground aquifers. The area also uses individually sunk boreholes as a major source of non-potable water, which is usually then used for irrigation or industry. Rainfall has been decreasing over the past 25 years in Perth so water conservation and recycling is clearly on the agenda. The large seasonal differences in rainfall mean South Western Australia receives the majority of its rainfall during winter months.[*] This, combined with easy access to local bores, contributes to lower rainwater tank use in Perth than in cities like Adelaide. Therefore, some aspects of the water management strategies highlighted in the OHSU and Ipswich case studies, such as rainwater collection, may not be viable for a potential Perth hospital. Hospital process-specific water recycling strategies, such as HD reject water reclamation and cooling tower condensation recycling, may be more appropriate for a prospective Perth hospital because they are independent of external factors like weather. However, several of these strategies are not without precedent in Perth: St John of God Health Care Subiaco has landscaped its grounds in native plants and less water-intensive grasses, replaced older sterilizing machines with new water-saving models, replaced regular toilets with dual-flush toilets, and educated staff on handwashing technique to minimize water waste (St John of God Health Care Subiaco, 2003). These are good steps, but more can be done. Ultimately, closely assessing hospital water usage for possible conservation opportunities and pursuing further research into all water conservation possibilities is necessary, considering the growing demand for water in Perth.

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[*] *Note: Please see figure 2 in Appendix.*

Curtin University of Technology

CRC Construction Innovation BUILDING OUR FUTURE

CRC AUSTRALIA

Appendix

Figure 1

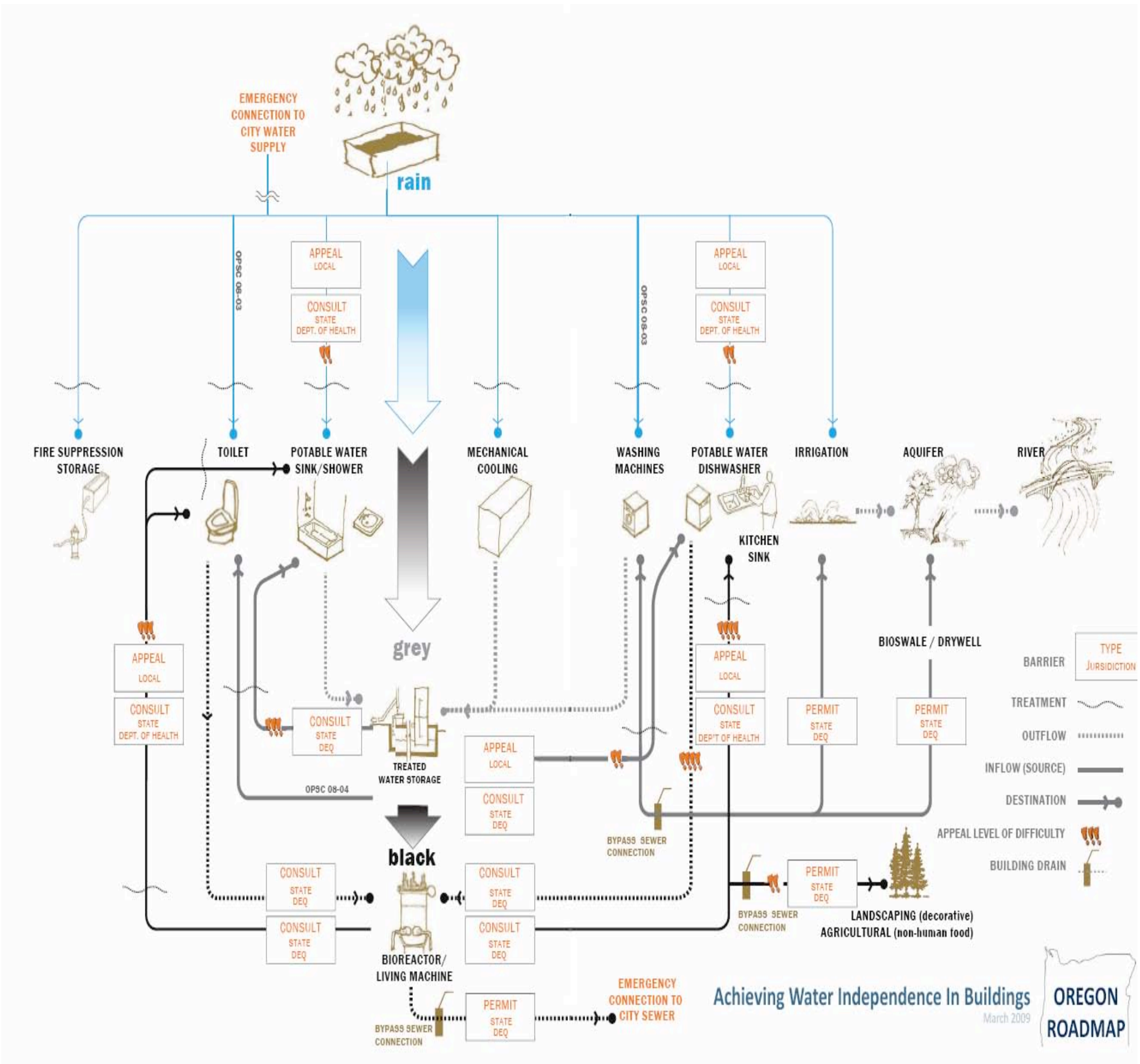
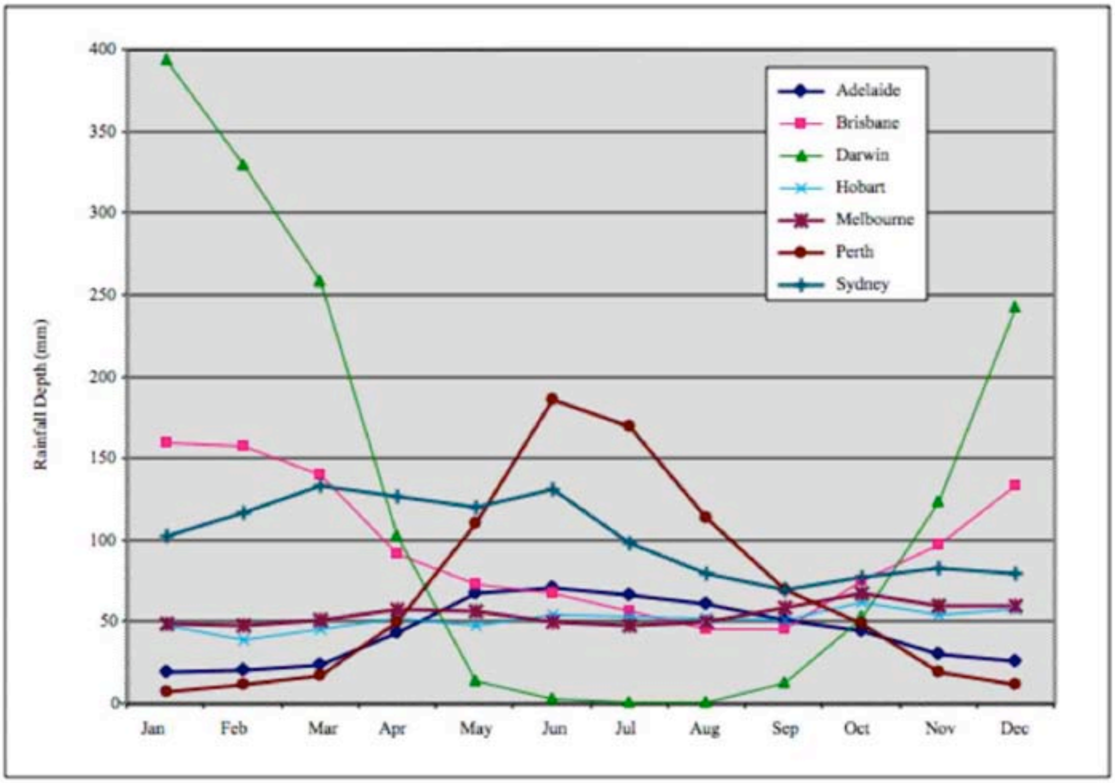


Figure 2



Average monthly rainfall (mm) for Australian capital cities.

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Appendix

Figure 1.

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Navigating the challenges of water reuse in Oregon. *Central City Concern*

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Figure 2.

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THEME IV

TRANSPORT

A large volume of traffic is generated by the 24/7 operation of hospitals. The health sector, with its "fleets of hospital vehicles, delivery vehicles, and staff and patient travel" (WHO & HCWH 2008, p18) is undoubtedly a transportation-intensive industry. As healthcare is increasingly related to aging, the need for people to reach the hospital other than by driving themselves is obvious. Therefore, harnessing alternative transportation and community-based travel programs is increasingly viewed as essential for healthcare industries, especially given the environmental impact of fossil fuel based transport. For example, the National Health Services (NHS) in the United Kingdom has estimated that 1 in 20 motor vehicle journeys are directly or indirectly related to health services. For any future hospital, it is important to note how transport infrastructure has as much to do with the location of the hospital in relation to public transport infrastructure as overcoming traditional hospital specific transportation issues. In general, these hospital specific issues can be divided into two main population groups: staff and hospital related services, and patients and visitors.

Part I: Staff and Hospital Related Services

The operations of any large hospital involve hundreds of staff members, from healthcare professionals like doctors, nurses and medical interns to the operational staff of cleaners, engineers and technicians. Since most hospitals operate 24 hours a day, 7 days a week, there is a scheduled, though paradoxically chaotic, flow of travel for this hospital demographic.

A few hospitals have encouraged public transport or alternative transport modes, such as bikes and car-pooling for their staff, but there are significant concerns to hamper progress, such as the varying times staff begin or complete their shifts. For example, a staff member who works a late night shift and finishes at 3am may be in a situation whereby the public transport services are simply unavailable, in addition to the safety concerns of travelling on public transport during these hours. Similarly, riding a bike or walking home in the late evening or early hours of the morning is less attractive than during the day, despite the obvious health advantages.

Nevertheless, it should be noted that the majority of hospital staff work regular daytime hours, particularly in administration, maintenance and generic clinical services. Hence, despite the understanding that night shift staff would require special alternatives, most traditional hospital transport initiatives are still viable for a significant proportion of any hospital's staff.

The following case studies highlight a few of these hospital initiatives.

Case Study I:

ADDENBROOKE HOSPITAL

(Cambridge, England)

According to a special report from the World Health Organization, in conjunction with Health Care Without Harm, "Addenbrooke's Hospital, part of the Cambridge University Hospital System, is reported to be the largest source of traffic in the county of Cambridgeshire" (WHO & HCWH, 2008). To counter this impressive, yet disconcerting, feat, Addenbrooke initiated a "travel plan" to encourage alternative transport, with a particular focus on aiding staff. As such, a bus was commissioned with assistance from the NHS to serve the hospital, and 1,300 bicycle spaces were made available. Staff specific incentives, such as interest-free loans for buying bikes, a car share scheme and 16 car pools were also offered in addition to favourable discounts on bus and train tickets. Other incentives were that staff cars' parking fees were linked to the cost of a return bus ticket, ensuring that public transport was cheapest. According to the Sustainable Development Commission, since 1999 the hospital's travel plans have returned promising results, and Addenbroke's car use has "fallen from 60% to 42%", bus use has "gone up from 12% to 23%", and lastly, "25% of staff now cycle to work" (Sustainable Development Commission, 2007).

Case Study II:

BOULDER COMMUNITY HOSPITAL

(Colorado, USA)

At Boulder Community Hospital, alternative transportation has been encouraged with a different focus: increasing infrastructure. Two new bus stops were built for easier public transport access for staff, patients and visitors. The staff have a further incentive to use public transport as this "service is paid for by the hospital" (Guenther, 2009). Assigned carpool spaces in the parking lot encourage staff to share rides. Bike racks, showers and changing facilities also encourage staff to bike or walk to work. The latter is a particularly attractive option since the hospital is linked to an existing bike path from the city of Boulder (Guenther and Vittori, 2008, p235).

Environmentally focused fleet management at hospitals is also an important aspect of sustainable healthcare, as private transport may be unavoidable for many of the hospital services, such as ambulances and patient house calls by medical staff. Certain hospitals have addressed this issue with initiatives specifically directed towards improving fleet management and control.

The following two case studies are brief examples of these programs.

Case Study III:

GREEN AMBULANCE PROJECT

(Stockholm, Sweden)

Ambulance drivers at AISAB, one of Stockholm's major ambulance service providers, receive intensive training in "eco-driving" (i.e. driving in a manner that reduces fuel consumption and wear on the vehicle). AISAB's drivers found that eco-driving reduced fuel consumption by as much as 10% with no increased risk to patients (Sustainable Development Commission, 2007). It is important to note that eco-driving does not mean slower driving, thankfully allaying patient fears, but rather incorporates improved planning of services ahead where possible, and training in order to drive more efficiently. As such, the project also resulted in 50% fewer insurance claims, with less wear and tear on ambulance tyres and brakes (SDC, 2007).

Case Study IV:

PITT COUNTY MEMORIAL HOSPITAL

(Greenville, North Coralina)

At Pitt County Hospital in Greenville, all 35 of the hospital's fleet vehicles, including ambulances and service trucks, run on B20, a blended fuel containing 20% biodiesel (SDC, 2007). To provide their fleet with this fuel blend the hospital has its own biodiesel fuelling station. (SDC, 2007)

Even though these projects may seem insignificant they are undoubtedly a step in the right direction. This becomes more apparent when one considers there are "10,500 respiratory hospital admissions in urban areas each year due to emissions from fuel burning in transport and industry" which, the Sustainable Development Commission goes on to argue, cost the UK's National Health Service "over £17 million annually" (SDC, 2007). A small underlying irony is that since "NHS staff, patients and visitors travel 25 billion passenger km per year in the UK" (SDC, 2007), the people caring for and visiting the sick are indirectly responsible for some of those healthcare problems. With visitors accounting for "70% of these passenger kms, patients 20% and staff 5%" (SDC, 2007), creating sustainable transport alternatives in the healthcare industry are valuable and cost effective steps towards preventing some of the illnesses their institutions are trying to treat.

Part II: Patients and Visitors

As the Sustainable Development Commission demonstrated, patients and visitors are responsible for the vast majority of transport associated with healthcare facilities (SDC 2007). While public transport, cycling and walking could significantly reduce this figure, obvious shortcomings arise from seriously ill patients, who almost by definition are usually not fit to use traditional alternative transport. Issues of mobility are also a clear difficulty, as well as patients who have contagious illnesses, as it seems unnecessary to detail the irony in encouraging a highly contagious person to take public transportation. Visitors or people accompanying patients may also prefer the convenience of private travel to the hospital, particularly during urgent medical situations, though this does assume car ownership, easy access by road and plenty of parking, all of which are increasingly difficult to provide in reality especially in big hospitals.

For regular visiting hours and non-urgent hospital related travel, public transportation should be encouraged, particularly when used in conjunction with transport management plans. These plans are often linked with other initiatives that promote sustainable transport options, such as Western Australia's Department for Planning and Infrastructure's *Public Transport Masterplan,* whereby a number of stakeholders, including two hospitals in the area, have resolved to improve the sustainable travel options for the public in the area. One such Australian example of a transport management plan designed to further incorporate larger travel plans is Queen Elizabeth II Medical Centre in Western Australia.

Case Study V:

QUEEN ELIZABETH (QEII)

MEDICAL CENTRE TRUST TRAVEL PLAN

(Perth, Western Australia)

In Western Australia, the QEII Medical Centre Trust joined the TravelSmart Workplace program in 2005 and with assistance from the Department for Planning and Infrastructure and their respective consultants, identified transport issues at the QEII Medical Centre and developed a plan to address them (Sustainable Transport Coalition [STC] WA, 2007). TravelSmart is an Australian program which has now spread worldwide, that according to their website, "aims to inform and motivate people for changing their travelling behaviour through personal choice" (Travelsmart n.d.). The QEII Trust assessed transport infrastructure and services affecting patients, visitors and employees. From the assessment, a plan was drawn up and adopted in 2007 that set targets for sustainable transportation and related behavioural change.

Based on their plan and subsequent action, QEII maintains they have already implemented the following steps towards sustainable transportation:

- A TravelSmart Coordinator employed to market travel alternatives to staff, thought to be the first such position at a health campus in Australia.
- A Bicycle User Group formed to promote cycling and advocate for improved provisions for cyclists.
- The travel plan and its targets have been incorporated into access and site structure plans, transforming what began as a voluntary undertaking into an important part of statutory approvals for the Department of Health's major redevelopment project.
- A Travel Plan Project Manager employed to oversee implementation of the Travel Plan.
- Development of a master plan for public transport improvements.

(Sustainable Transport Coalition WA, 2007)

Perth Context

By assessing current travel options and developing plans to encourage alternative transportation, the QEII Medical Centre Travel Plan is an excellent step in the right direction. Other hospitals have had great success with comprehensive incentive plans, yet it remains to be seen how effective and attractive the alternative transportation options are to staff at QEII as the hospital is not on a train line. Future plans ought to consider light rail as the hospital is already at maximum use of its site for car parking without going to expensive multi-storey buildings.

As seen in the case studies above, there are other opportunities for conservation besides encouraging bikes and public transport, such as the creative "eco-driving" training for ambulance drivers and incorporating biodiesel and hybrid fleet cars. And while most discussions regarding alternative transportation focus on hospital staff, because of the inherent difficulty in having seriously ill patients use public transportation, the Western Australia government in conjunction with hospital planning committees can devise easy-to-use transportation schemes to encourage those only mildly ill and visitors to use public options as well, like in the QEII Travel Plan.

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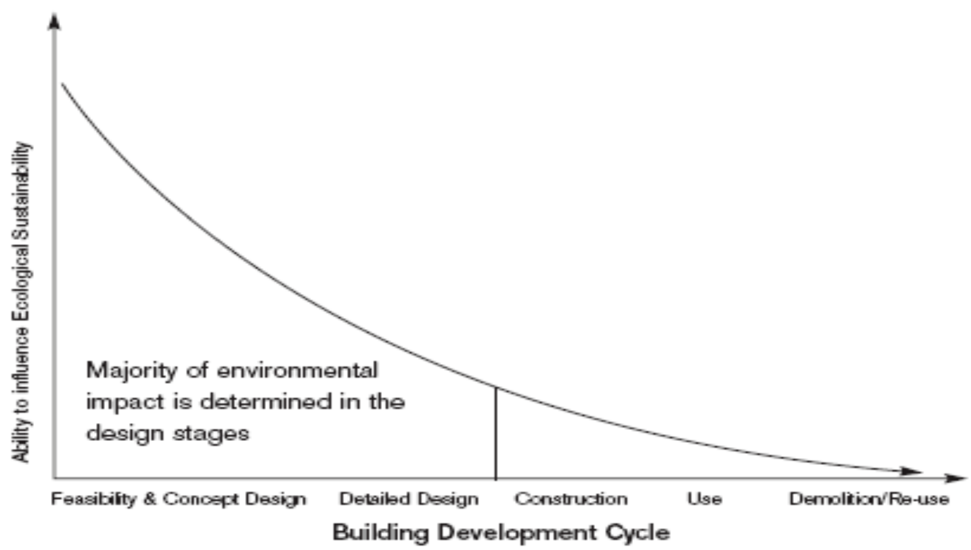
THEME V

DIGITAL MANAGEMENT

Digital management is crucial to hospital sustainability in two ways: first, by improving efficiency in the design and construction processes; secondly, for the hospital's ongoing operations.

Part I: Design and Construction:

When a building (or hospital) is in its design phase the opportunity to reduce and influence its environmental impact of the structure is at its greatest. The main reason being it is during this phase that all appropriate materials and operation systems are selected. Graph 1, taken from Dominique Hes's PhD thesis, *'Green' building: turning observation into practice,* provides a graphical layout of the diminishing influence over the ecological sustainability of a building during the building development cycle. In his thesis he also notes, "Design has the capacity to greatly affect the 'green' impact of the end product but it needs to be balanced with all the other demands of the project – aesthetics, client demands, functionality, cost, etc" (Hes, 2005, p111). Striking this important balance mentioned by Dr. Hes is where digital management plays its most important role.



Graph 1: The diminishing ability of influence over the ecological sustainability of a building project over its development cycle. (Source: Hes, 2005, p 22)

Digital management systems help stakeholders balance and correlate the ecological demands of their project with its other pragmatic concerns such as functionality and layout. This is done by using software to model several variations of the building during the concept phase of the hospital design and construction process. There is powerful design software available that allows for detailed building information modelling (BIM) with 3D modelling from concept design and production scheduling as well as the creation, management and communication of information about a building (CRC for Construction Innovation 2007). According to the CRC, the scope of this process is impressive, such that "a BIM carries all information related to the building, including its physical and functional characteristics and project life cycle information" (CRC for Construction Innovation 2007).

The advantages for developers of using BIM are the "improved efficiency and collaboration by reducing re-work and early detection of potential problems as well as improving the management and communication of information generated by the model" (Wakefield et al. 2005, p102). These programs can also be integrated with other software to digitally model ecologically sustainable or green features of a building. Another more financial contribution is the incorporation of cost benefit analysis software, so financial predictions can be modelled on different material selections, lighting fixtures, water fixtures and a host of other installations. These programs are known as eco-profiling software and their aim, and usefulness, is to address the traditional difficultly of selecting building materials and to show the worth of more sustainable options.

The following two case studies highlight possibilities of digital modelling and the use of such programs in hospitals. The first case study is Gold Coast University Hospital, demonstrating its extensive use of digital modelling and BIM by stakeholders to plan the construction of the new facility. The second case study is an example of eco-profiling software that has powerful applications for stakeholders, particularly when it assists their selection of eco-friendly materials and increasing understanding of environmental features.

Case Study I:

Gold Coast University Hospital

(Gold Coast, Queensland)

During a presentation for the Green Hospitals Conference 2009 in Melbourne, Mike Hill and Martin Tuktens of GCUH engineering highlighted the ability of digital models to assist developers in their decisions regarding design, material selection and the operating systems of the building. The following screenshots from their presentation and the explanations that follow show the remarkable potential of these programs. These digital models and programs were used for the design and planning of the future Gold Coast University:

Thermal Modelling

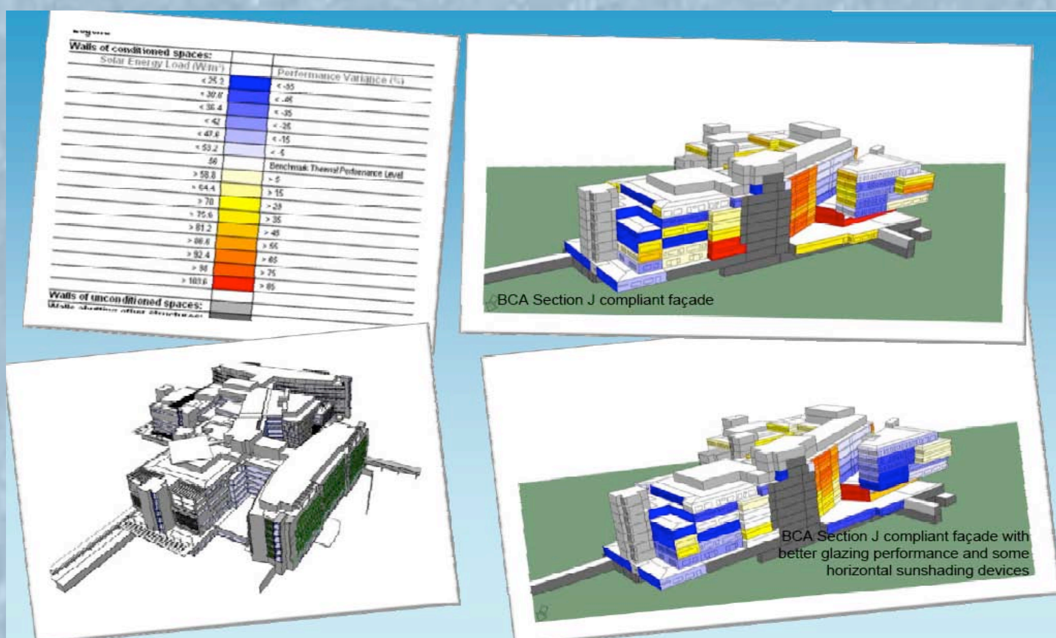


Figure 1: The top left frame in this screenshot is a table that features a scale of thermal performance levels (with white being the benchmark level), the bottom left frame is the digital model of the future Gold Coast Hospital, the two pictures on the right are the digital model of part of the building that incorporates the predicted thermal performance of the different areas of the building. Thus, the two models on the right offer a contrast between the hospital's thermal performance if it was constructed with basic compliance, and the bottom right if constructed with better glazing and sunshading devices. Note how much lower the thermal 'performance' is for the latter (Hill and Tuktens, 2009).

Daylight/light modelling

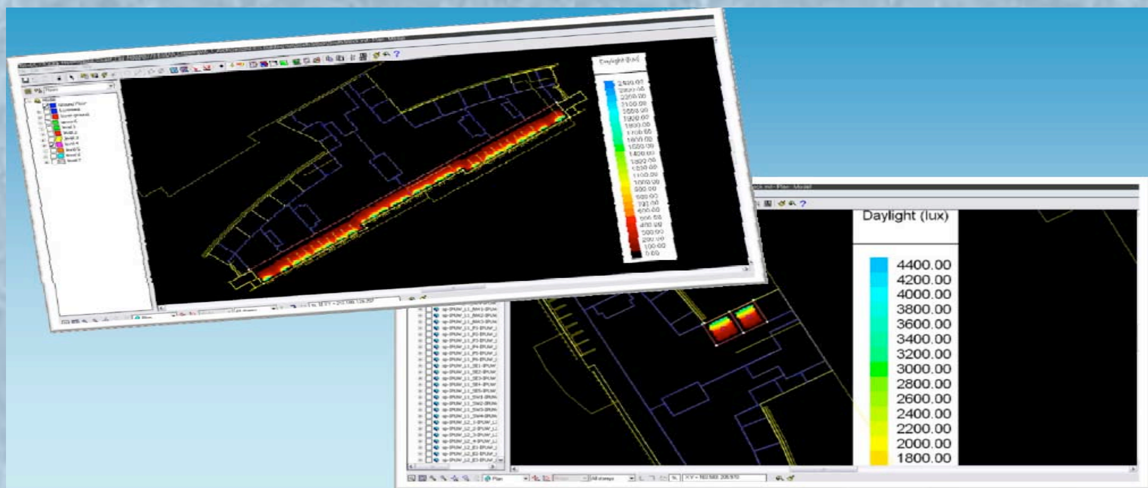


Figure 2: The two frames above show the use of a daylight modelling program; these programs use digital models to predict the penetration of daylight into parts of the future hospital wing. From these models stakeholders can accordingly design and construct the building to maximise sunlight throughout parts of the buildings and, assumedly, reduce the need for continuous artificial lighting (Hill and Tuktens, 2009).

Energy efficiency modelling

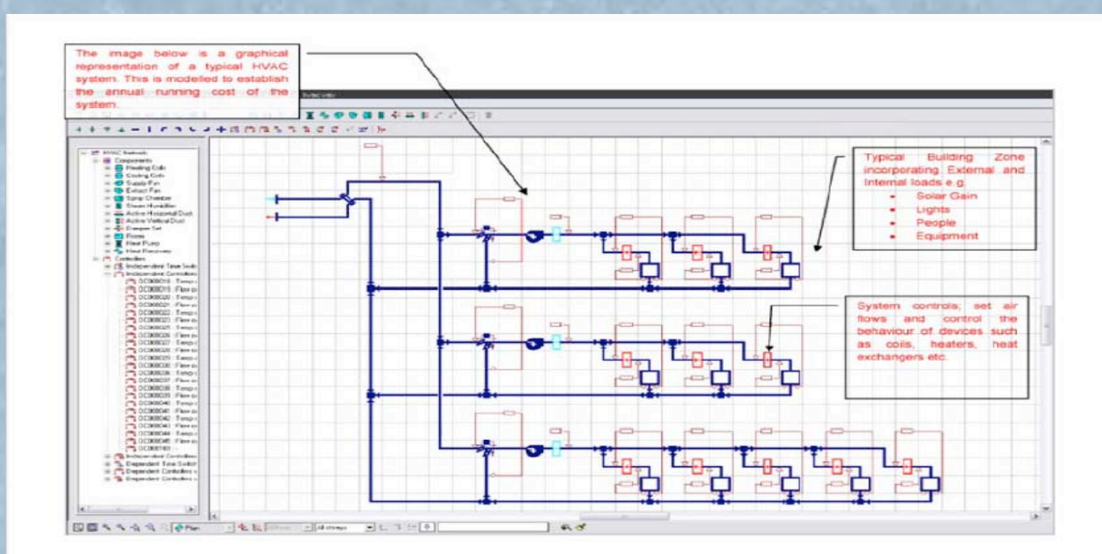


Figure 3: Is a snapshot of a program that models the energy efficiency of the future heating ventilation air conditioning (HVAC) system. Stakeholders can thus make changes to the modelled system to see the performance and costs of alternative HVAC systems or installations (Hill and Tuktens, 2009).

Case Study II:

LCADesign

(Eco-profiling Software)

LCADesign is an Australian developed eco-profiling software from the Brisbane based CRC for Construction Innovation. LCADesign is an acronym for Life Cycle Assessment (LCA) with Computer Aided Design (CAD) (Tucker, Seo and Ambrose, 2007). The LCADesign software package enables developers, building designers, architects, engineers, builders, manufacturers and government bodies to optimize the eco-impact of a building as the design model evolves. Building Information Models (BIMs), generated by 3D computer-aided drafting programs are then integrated with the National Australian Life Cycle Inventory (LCI), thus the environmental values and risks of materials in commercial buildings can be assessed. The life cycle inventory database includes "details of resource consumption and environmental emissions generated during the manufacture of building materials including embodied pollution and water, as well as energy. It also covers resource use and pollution from material acquisition and transport as is energy and water use in building operations." (CRC for Construction Innovation, 2008).

The CRC for Construction Innovation maintains that LCADesign users "can measure and compare changes to new and refurbished designs and compare eco-preferred and conventional product options, determining in seconds the impact of design improvements across human health, ecosystem damages, resource depletion and carbon impacts." (CRC for Construction Innovation n.d.). For any hospital this could be a highly beneficial program considering the vast amount of operating energy associated with hospital buildings and their design complexity, as well as the sensitive nature of a building designed for healing.

Diagram 1 is taken from *Selection of Sustainable Building Material using LCADesignTool* by Seo, S., Tucker, S. and Ambrose, M., from CSIRO Sustainable Ecosystems, it describes the principle aim of the eco-profiling software LCAdesign. The three main parts of the diagram are divided into input, analysis and improvement.

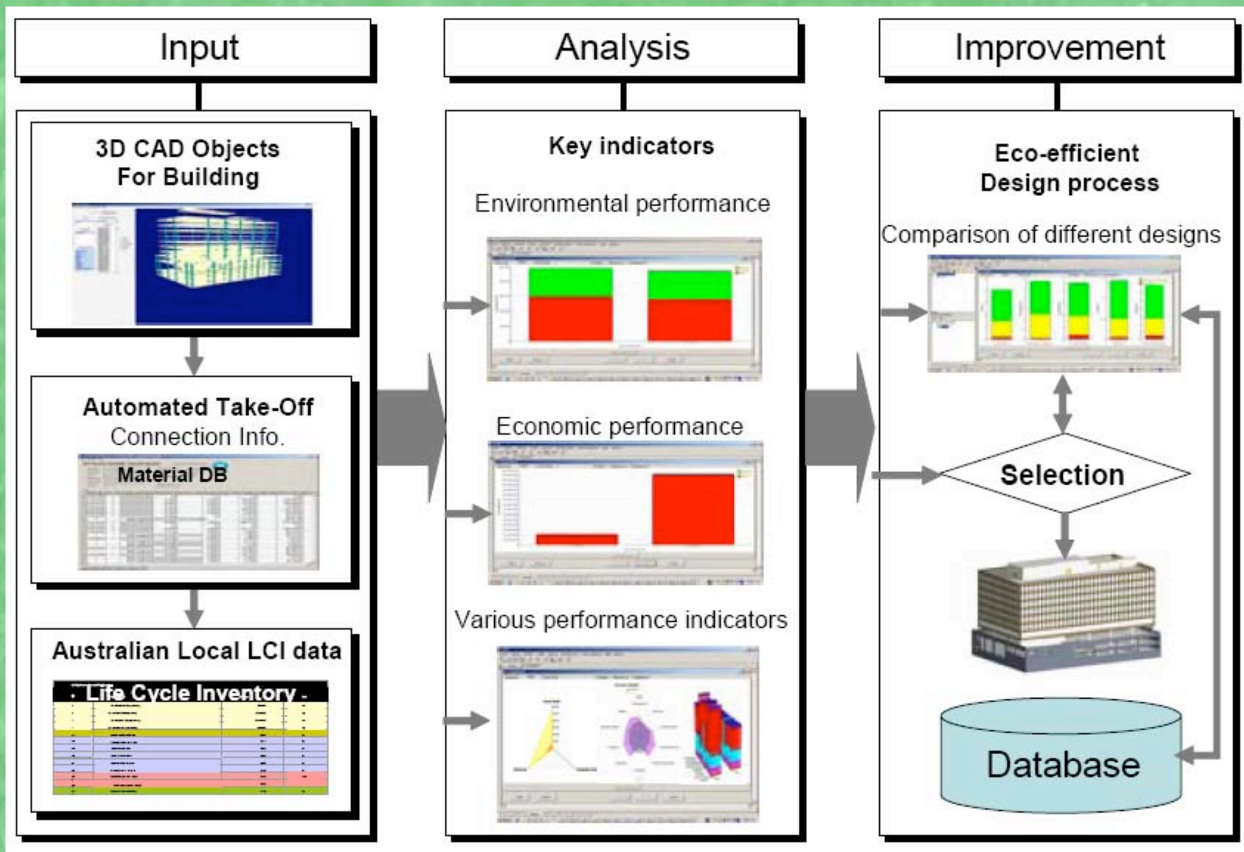
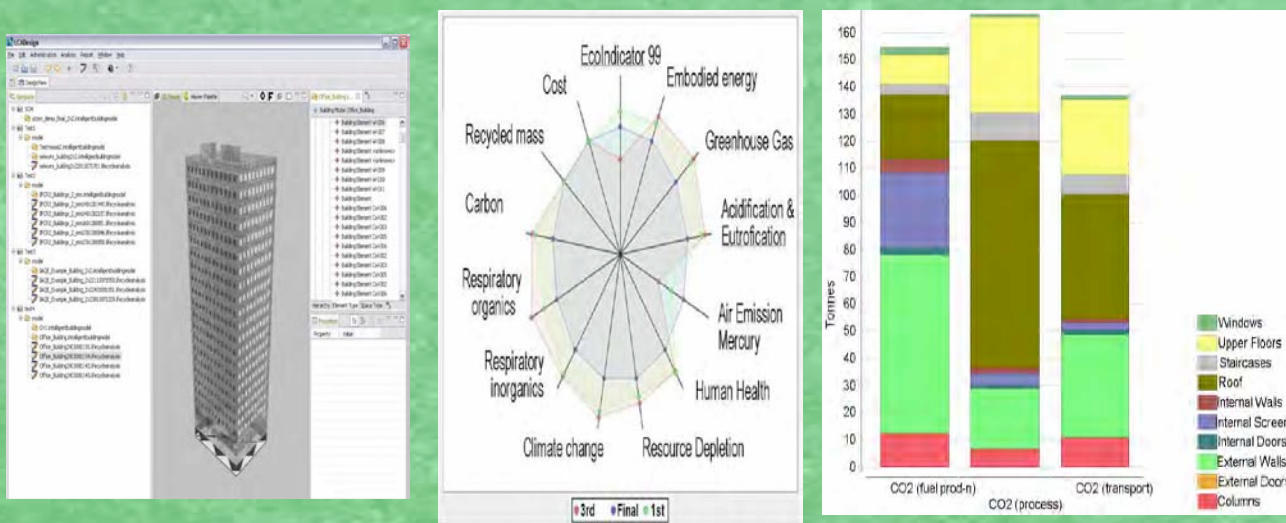


Diagram 1: The process of the eco-profiling software, LCADesign , which allows firms to optimise the environmental impact of a building during the design and planning stage through eco-preferred material selections. (Source Tucker, Seo and Ambrose, 2007, p2).

The first part, input, relates to the integration of 3D CAD modelling of a building and estimating quantities of all materials and products needed for the building with materials life cycle analysis (LCA) databases. The second part, analysis, is calculating and applying the information from the input modelling and databases. The third part, improvement, is the comparisons made possible from the information gathered form the first two parts and the creation of an eco-efficient design process, which could be continued as part of the buildings operational database.

The authors note that "Information for LCADesign flow seamlessly from the 3D CAD model to the evaluation stage without interruption or intervention from the designer or environmental assessor. Thus the designer can obtain almost instant feedback on whether the current building design under development is likely to produce a better environmental outcome." (Tucker, Seo and Ambrose, 2007, p4).

Figures 1,2 and 3 are screen shots of some of the tools available in the LCADesign program, they provide examples of the integration of the building's 3D information model and the tables and diagrams displaying the relevant project and environmental information.



Figures 1,2 and 3 The screenshots of the program LCADesign from the CRC for Construction and Innovation (Source: CRC for Construction Innovation, 2008)

Such a tool for hospital design and construction could be extremely beneficial for the stakeholder involved in any large hospital project. Currently, the Victorian State Government is piloting the application of LCADesign for use by their departments, such as the Department of Human Services, involved in hospital projects. (Humphrys, 2009) It would be prudent to utilize the potential of such a program in building operations systems and material selections for the development of a 21st century hospital focused on sustainability.

The improved design and documentation quality through the use of digital modelling and BIM software can lead to improved overall on-site efficiency, saving on construction time, operating costs and resource use (Scuderi, 2008). Since the phases of construction can be modelled beforehand, contractors and stakeholders can plan their operations accordingly and more efficiently. Figure 4 shows a screenshot of phased construction digital model of a hospital project in Charlotte, North Carolina. The program used in the screenshot is from Revit/Autodesk Software.

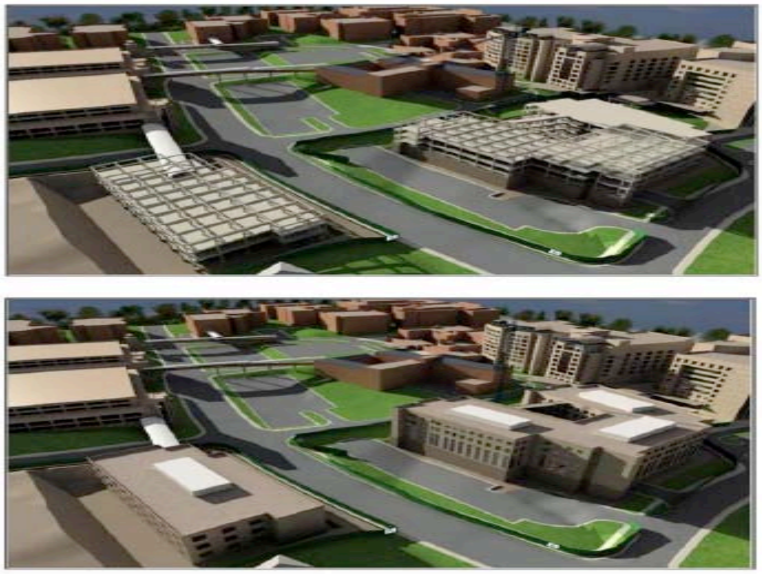


Figure 4: Using digital models the developers of a hospital project in Charlotte, North Carolina can plan their operations pre-construction, demonstrating not only what the hospital will look like in completion, but during construction and with scaffolding still in place. (Source: AutoDesk White Paper, 2005, 9).

Part II: Ongoing operations:

The operational costs of running a hospital form a large proportion of its expenses. By realizing more efficient building systems, digital management systems create a platform for better management in hospital operations and thus, can reduce costs, promote environmental management and even boost overall efficiency. These improvements are realised through digital management as "processes, [such as general maintenance, operations and systems management,] can now be carried out faster and more effectively because information is more easily shared, and can be value-added and reused" (Mitchell et al. 2007, p17). The following case study is an example of such a digital management system that can facilitate the on-going operations of any building.

Case Study III:

Facility Management Software

Efficiently operating a hospital requires the effective management of electrical and operational systems used throughout the building. Digital management is an effective solution to the management of such a facility and indeed, most modern hospitals have some form of digital management already in use. These management systems and their associated computer and software programs offer greater control for the building operation managers. Figure 4 is a screenshot showing a digital management software program from the CRC for Construction Innovation.

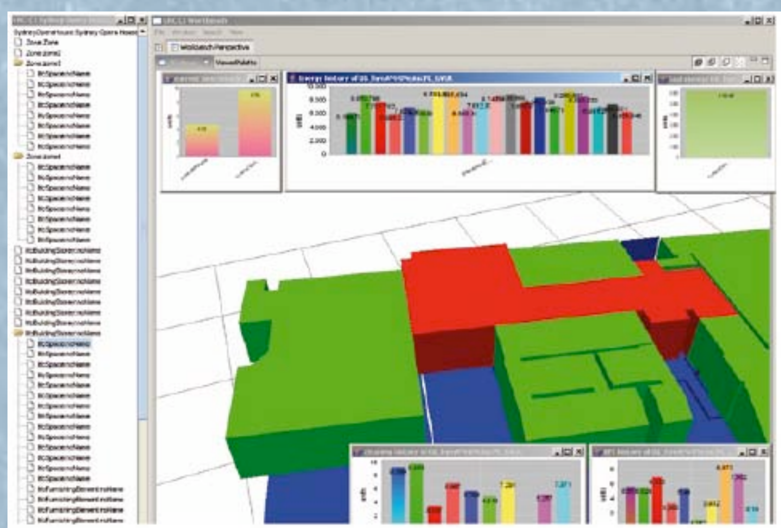


Figure 4: 3D digital model of a section of the Sydney Opera House and its energy consumption; just one of the functions of the management software, allowing operations managers greater security and cost-effective maintenance.

This particular software was developed for the Sydney Opera House and incorporates Building Information Modelling (BIM) and seven other existing digital information systems into one 3D digital management tool. The seven different and initially incompatible, due to the differing programs they were managed on, digital information systems manage functions as diverse as building maintenance, accounting, building presentation and asset value management. (CRC for Construction and Innovation 2008(2)) By bringing these information systems together, the building managers can align and confine these diverse operational processes into one program. As one could imagine, this could simplify operation procedures and dramatically improve operations efficiency.

Figure 5 is a flow diagram by Peter Scuderi from the CRC for construction and Innovation, detailing these different digital information systems and how they are pooled into one "digital model".

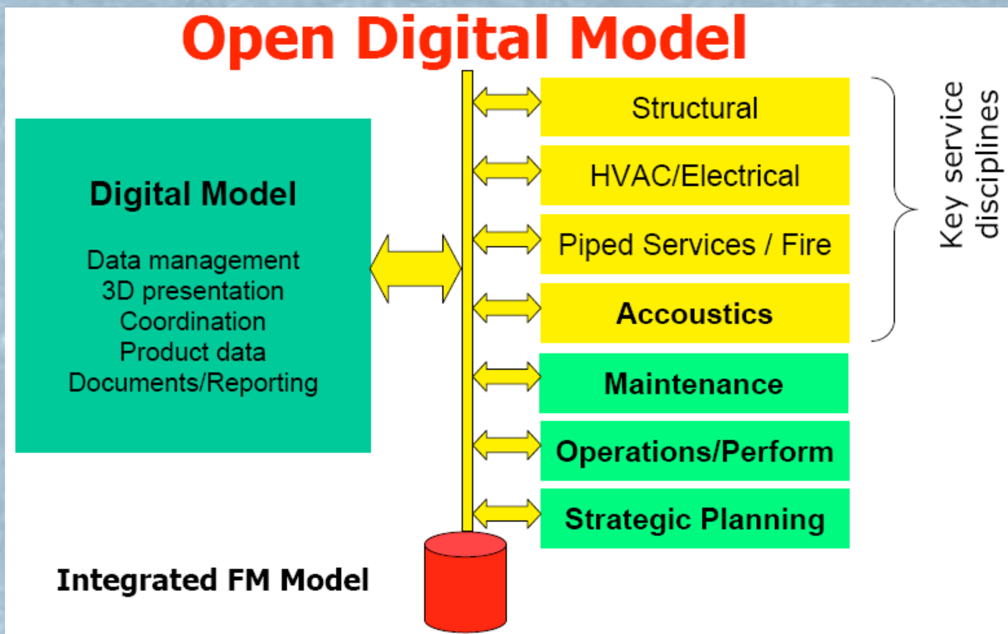


Figure 5 A diagram showing the strategy the CRC for Construction and Innovation's program used to integrate seven different facilities management system's information. (Source Scuderi, 2008)

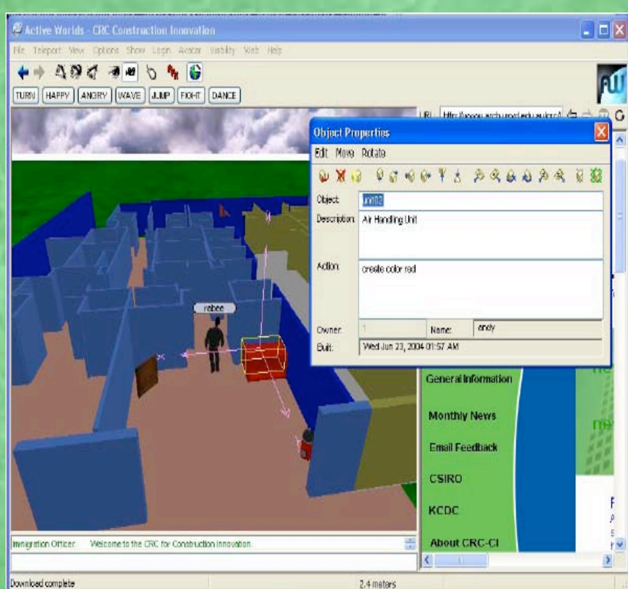
This figure highlights the potential for improvements in the building's systems management that can be achieved under an integrated facility management model. For any large building that is full of activity, "space planning and maintenance operations can benefit from integrated planning." (Mitchell et al. 2007, 10). Even though the software program was developed for the Sydney Opera house, it could easily be adapted for use in a hospital to enhance facility management to include all aspects of operations into one program. Another program from the CRC of Construction and Innovation, highlighted in this next case study, is an example of this adoption.

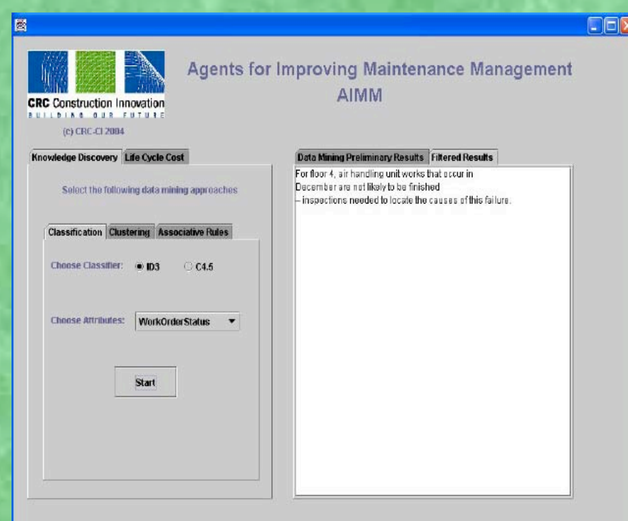
Case Study IV:

ROYAL PRINCE ALFRED HOSPITAL

(Sydney, Australia)

The CRC for Construction and Innovation's Agents for Improving Maintenance Management (AIMM™) prototype system provides a demonstration of a digital management program that could be used effectively in assisting the operation and maintenance of a hospital. Figures 6 and 7 are screen shots of this AIMM program, whereby a management system is integrated in to a 3D model of building No. 10 at the Royal Prince Alfred Hospital, Sydney. The program allows users to gather maintenance data in a virtual environment of the 3D model of the building. In the case of the screenshots the user selects the red Air Handling Unit (AHU), found in the virtual room (Left), which then pulls up the maintenance history of the unit (Right).





In technical report by John Gero et al. entitled, *Life Cycle Modelling and Design Knowledge Development in 3D Virtual Environments*, the authors note that, "facilities managers will benefit from such a [program] in terms of the feed back generated from identifying patterns and correlation in maintenance records that are presented as meaningful asset knowledge" (Gero et al, 2004, p47). Improved asset knowledge gained from such a program can lead to greater maintenance efficiency and savings in operational costs.

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THEME VI

HUMAN DIMENSIONS

Every practicing doctor takes an oath vowing to do no harm, and in the pursuit of healing, it seems only reasonable that our healthcare facilities would encourage wellness rather than hamper doctors' best efforts to aid the ill. However, until recently, this has not been the case. Antithetical to their very purpose, hospitals built with solely the financial bottom line in mind have not facilitated healthy day lighting, have used cheap, dangerous materials that, over the life of the hospital, cost far more than the initial capital required, and actively hurt patients, staff and the community at large. These environmentally harmful buildings use vast amounts of dwindling resources, from energy to water to oil for plastics. Yet, this does not have to be the case. Hospitals and health care facilities, because they are both physically large and also house large numbers of people, including staff and patients, have the ability to reap enormous benefits from environmentally friendly materials, and in doing so positively impact their communities. Hospitals do not have to be simply buildings to house the sick; they can be pillars of environmental stewardship and responsible community members. Three facets of the human dimension of sustainable healthcare will be discussed here: the economics of building green hospitals, the materials selected for use, and the sense of place a hospital can develop within its community.

Part I: Economics

Health is similar to sustainability in that it starts by providing an holistic opportunity for a better long term and short term future. It is not done to save money it is done because people want their health. In the same way people today are demanding a more sustainability-oriented future. Sustainability should feature in every aspect of a hospital and not merely as an additional expense or sidenote. Having said that it is also possible to say that sustainability like health has to benefit the financial bottom line as well. Hospitals benefit their communities by providing healthcare services, and as the world's resources come under increasing pressure, it is important that they minimise their burden on diminishing resources, as well as to do this in ways that can save financial resources. It would seem prudent that hospitals become focused on sustainability as a way to achieve savings in both resource use and also costs associated with future capital costs and maintenance.

Because of their immense size and the constant energy demands from technical equipment, hospitals require tremendous amounts of energy to maintain 24/7 operations. The Dept of Human Services in Victoria estimates that hospitals and health care operations consume 60% of the energy used by the public sector in the state (Gelnay, 2006). This is a tremendous burden on the Victorian community, and as both demand and scarcity increase in the coming years, the use of green building technology becomes almost imperative. By incorporating alternative energy sources and creative water management systems, hospitals can tread lighter upon their communities and not be scrambling to retrofit energy and water systems when prices rise. For example, although water is still relatively cheap today, Tiernan Humphrys, the Environmental and Sustainability Manager for the Victoria Department of Human Services, estimates that water prices will rise 48 to 60% in the next 4 years (Humphrys, 2009). Any prospective hospital in Australia would be wise to consider alternative energy and water conservation systems to save money in coming years.[*]

But beyond the obvious operational economics of green hospitals, there are unforeseen cost savings when sustainable materials are used, such as increased worker productivity and retention rates. Over the life cycle of a hospital, for every $1 spent on the initial capital for building, $5 is spent on operations and management (including energy and water), and $20 is spent on staff (Tiernan Humphrys, personal conversation, 2009). So, any effort to increase staff productivity would be very effective in saving money because staff composes such a large proportion of the hospital's lifetime costs.

Poor indoor environmental quality due to airborne chemicals and mould is the primary cause of Sick Building Syndrome (SBS) (Humphrys, 2009), a condition characterized by generalized fatigue and cold-like symptoms. The New South Wales government has estimated the cost of SBS in increased absenteeism and decreased productivity to the Australia economy as a whole

[*] *Please see Energy and Water themes for further discussion of energy options and water management.*

(not just healthcare) to be over AU$125m per year (Humphrys, 2009). When traditional, non-environmentally friendly building materials are used, they can emit volatile organic compounds (VOCs) into the air that trigger SBS and increase the number of sick days staff have to use (Rossi and Lent 2006). The common plastic PVC used extensively in hospitals can both give off VOCs, which are known to be associated with cancer, and also harbour mould, known to be an SBS trigger (Berry et al, 2004). By incorporating PVC-free and green building materials, hospitals can at the same time increase staff productivity and honour their commitment to healing by not exposing their workers to potential carcinogens.

Beyond improving indoor air quality to increase productivity, hospitals can incorporate natural lighting to improve morale and reduce turnover. By increasing daylight, hospitals can increase staff retention by up to 10% (Humphrys, 2009). In light of the current nursing shortage problems, this can be an important consideration.

In addition to reducing staff costs and increasing productivity, there are hundreds of hospitals all over the world that are realizing substantial reductions in operational and maintenance costs due to the savings that come with the implementation of sustainable practices and green technologies. Many of these technologies and practices have been discussed throughout the other themes of this scoping study. For one example "through implementation of Reduce, Reuse & Recycle initiatives the Royal Newcastle Hospital (NSW) has saved $60,000 per year" (Centre of Excellence in Clear Production, 2003), from reduced disposal and procurement costs.

Part II: Materials Selection

Because of the nature of hospitals' mission—to heal the sick—it seems ethically responsible for hospitals to opt for environmentally friendly materials to reduce exposure to potentially dangerous chemicals. An example of this can be found in the elimination of mercury products in the American healthcare sector. Although not yet complete, it is a powerful success story about how hospitals can collectively use their enormous purchasing power to reduce their environmental and public health footprint and also drive markets for safer alternatives to problematic chemicals and technologies (Cohen, 2006, p5) . This market manipulation through purchasing power could be extended to other areas in which hospitals are large customers such as food, energy, new building materials and indeed the purchase of any of the innovative technologies described above.

As mentioned above in the economics section, adopting new building materials, such as wheat- and strawboard instead of treated plywood, and incorporating PVC-free plastics will improve both employee and patient health. Traditional building materials, including finishing products like paint and flame-retardants, have long been known to emit VOCs, many of which are known carcinogens and biodisruptors (Rossi and Lent, 2006). Exposure to VOCs can cause respiratory health problems, asthma, cancer, and reproductive and development effects (Vittori, 2002). When PVC, a nearly ubiquitous plastic in medical supplies, is incinerated, it creates dioxin, the most potent carcinogen known. And chemicals added to PVC to increase flexibility can leach phthalates, potential hormone disruptors. These are clearly undesirable consequences, and hospitals should be leaders in choosing non-toxic materials wherever possible.

Case Study I:

Women's and Children's Pavilion at Hackensack University Medical Center HUMC

(Hackensack, NJ, USA)

One hospital, the Sarkis and Siran Gabrellian Women's and Children's Pavilion at Hackensack University Medical Center (HUMC) in Hackensack, NJ, is a leader in adopting non-toxic materials. Several years ago, discussions about cleaning products in the pediatric oncology unit led to a systematic assessment of traditional cleaning products. Many products contain carcinogens, endocrine disruptors, and neurotoxins, and it does not seem reasonable to use these products to clean the areas ill children occupy, as children in general are disproportionately susceptible to environmental contamination, and many children in this ward were immuno-compromised. A comprehensive cleaning protocol, "Greening the Cleaning", was developed to replace traditional cleaners with non-toxic, natural cleaning products.

When developing plans for the new Women's and Children's Pavilion, HUMC continued to assess the health risks associated with traditional building supplies. They opted for millwork that contained a wheat/strawboard core that eliminated the potential carcinogen formaldehyde commonly used in wood adhesive and finishes, wood veneers that are finished in low-VOC sealant, cotton insulation made from pre-consumer recycled denim, and synthetic rubber flooring that is not only free of phthalates, but can be maintained without waxing and stripping, making further chemicals unnecessary (Guenther and Vittori, 2008). And although PVC-free rubber flooring may have higher initial costs than traditional flooring, the life-cycle cost of the PVC-free floor is lower, due to minimized maintenance (Rossi and Lent, 2006). And, curiously enough, the rubber flooring has a higher coefficient of friction, which may reduce patient falls, reducing in turn further healthcare consumption and potential lawsuits (Rossi and Lent, 2006). Together, these choices demonstrate the excellent example HUMC has set in its commitment to both holistic health and sustainability.

When possible, hospitals should choose materials for construction, operations, and procurement that are non-toxic, bio-based, and recyclable. As hospitals begin to demand safe, PVC-free products, the market will move to provide them because of their tremendous purchasing power. When Kaiser Permanente, one of the largest managed care organizations in America, decided they wanted a PVC-free, recyclable, high-performance carpet, they went to the manufacturers and requested a new product. Over the course of two years, one company developed a low-emission, PVC-free carpet that met Kaiser Permanente's specifications, and was rewarded with a sole-source contract to distribute the new carpet in Kaiser Permanente's buildings (Guenther and Vittori, 2008).

Hospitals need to consider the entire life cycle of the materials they choose, from production to use to disposal, and other associated costs of materials. Many times, the environmentally friendly options that seem more expensive at the outset may actually cost less over the life of the material than the traditional option, such as the new PVC-free rubber flooring now available. And, hospitals have a responsibility to consider health damage done by using traditional materials.

Australian Context:

The effect of building materials' selection regarding hospitals in Australia is a recognized issue. Many future hospitals in Australia, such as Fiona Stanly hospital in Perth, have been planned to be constructed with low emission paints, adhesives, sealants, carpets and furnishings (Fiona Stanley Hospital n.d.). However, further investigations into materials selection are always warranted and examples from other countries are still relevant for Australian hospitals.

Part III: Sense of Place

Hospitals can be incredibly important community members by stressing health in all forms, not just personal health, since they interact with so many people. In the US, the healthcare industry employs one out of eight Americans, and composes 15% of GDP (Debra, 2006). By embracing a commitment to environmental health and recognizing the interconnectedness of people and their ecosystems, hospitals can encourage healthy living by adopting sustainable practices. By "redefining buildings through their life cycle as integral parts of a healthy regional ecosystem, and as environments that directly impact human health" (Vittori, 2002), we can see hospitals as more than buildings to house the sick; they become valued community members that establish a sense of place and communal welfare.

Hospitals throughout the world have begun to reassess their place in their respective communities. The following two case studies highlight the different ways a hospital can create a sense of place and positively impact the community.

Case Study II:

Rikshopitalet-Radiumhopsitalet Medical Centre

(Oslo, Norway)

The Rikshospitalet Hospital in Oslo, Norway, is a preeminent example of how a hospital can become a responsible community member. Completed in 2001, the hospital was not designed with sustainability in mind, but rather promotion of healing by incorporating extensive natural lighting, accessible architecture, and art (Guenther and Vittori, 2008). In essence, a hospital that does not seem like a hospital.

The hospital occupies a bowl-like site, allowing the building to have up to seven floors in some areas, yet maintain a façade that appears only two stories tall. By a neat use of landscape and space, the hospital is a more accessible, "human-sized" building that blends in with the surrounding areas (Guenther and Vittori, 2008, p323). Also of note, the Rikshospitalet Hospital utilizes its large and airy hallways to show pieces from its art collection, the largest public art collection outside of a museum in Norway (Guenther and Vittori, 2008).

Case Study III:

Kaiser Permanente

(USA)

Kaiser Permanente, one of the largest hospital chains in the United States, has generated much positive press due to their commitment to healthy foods and sustainable agriculture. In a paper titled First Do No Harm the co-executive director of Health Care Without Harm in the U.S., Gary Cohen, highlights the hospital chain that "has established farmers markets at the majority of its hospital campuses. In some locations, the Kaiser Permanente lobby is the only place to get fresh and organic produce in the community." Mr. Cohen then goes on to state that "[f]rom sponsoring farmers markets to adopting better procurement guidelines, hospitals can make a difference. And by supporting food production that is local, humane, and protective of the environment, healthcare providers can lead the way to more sustainable agricultural practices in their communities" (Cohen, 2006, p7) . Recognizing the need to address healthy food as a component of both healing and disease prevention would seem prudent for any futture green hospital.

Hospitals are therefore important players in sustainability and the community discourse regarding sustainability. The reason for this major role is because of the human dimensions of any hospital. For the purpose of this scoping study the human dimensions are composed of the economics of green hospitals and their benefit to the community, the choice of opting for better materials selections and its impact on hospital workers, patients and visitors and finally the hospital's ability to create a sense of place within the community. When each of these different facets is improved, they come together to create the humane, efficient healthcare system that people, and the planet, deserve.

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