

## Chapter 11

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# Commercial Buildings, Hospitals and Institutional Buildings

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### 11.1 Introduction

Commercial and institutional buildings – such as office buildings, shopping malls, universities, hospitals and prisons – can account for significant water consumption. In California, for instance, 27% of the State’s urban water supply (of 7 million acre – feet (8633 GL/yr)) is used by the commercial and institutional sectors, which is nearly three times that of the industrial sector [1]. The World Business Council for Sustainable Development states that buildings are one of the largest end users of energy; in OECD countries, the building sector accounts for 25–40% of the final energy demand and this demand is expected to grow by 45% by 2025 [2]. Out of this, 33% is used by commercial buildings.

Therefore the commercial and institutional property sector needs to respond to these needs by becoming energy- and water-efficient. Most of the fixtures in commercial and institutional buildings are similar (with slight variations) and are therefore considered together in this chapter. The solutions for water savings are similar for hotels (in most cases) and (where applicable) the reader is referred to the relevant sections in Chapter 10.

### 11.2 Commercial Property – Office and Retail

#### *11.2.1 Industry Structure and Water Usage*

The commercial property sector consists of offices, shopping centres (retail), industrial parks, hotels and car parks. Trusts known as Listed Property Trusts (LPT) or Real Estate Investment Trusts (REIT) own the majority of the premier locations.

LPTs are often keen to reduce their water and energy consumption as a result of market pressures. These may include the following:

- Customer demand – More than half of the world’s 500 largest corporations issuing sustainability reports in 2005 say that they want to build and occupy real estate that reflects their values [3].
- Market attractiveness. The green building sector is one of the fastest growing sectors within the commercial property sector.
- Pressure from institutional investors such as pension (Superannuation) funds.
- Regulatory pressure – Many governments are requiring that building managers and owners have well-developed water and energy management plans.
- Reporting requirements such as in the European VfU reporting requirements for the finance, banking and insurance sectors and Global Reporting Initiative (GRI).
- Inclusion in Sustainability indices such as the Dow Jones Sustainability Index and RepuTex.
- Competitive advantage – to have a green portfolio and this requires that the building are rated according to industry rating tools such as The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ or National Australian Built Environment Rating System (NABERS).
- To minimise current and future costs, liabilities and risks.

The average breakdown of water usage in an office complex is given in Figure 11.1

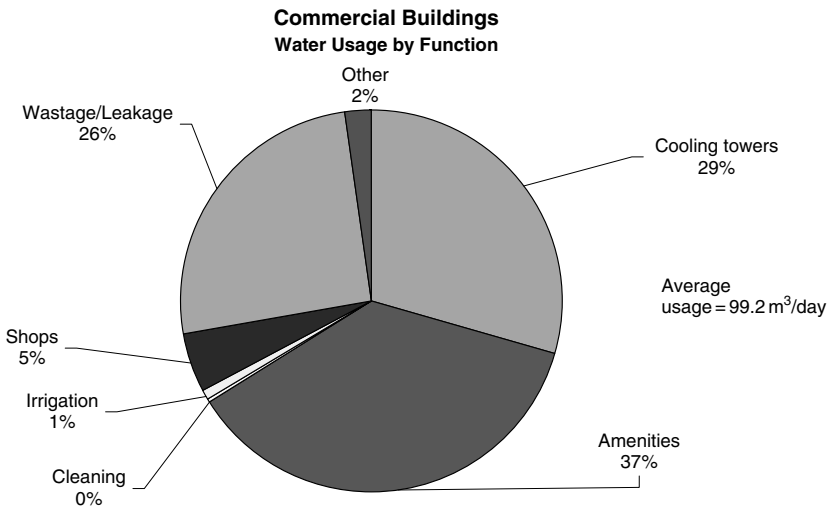


Figure 11.1 Water-usage breakdown in an average office building.

Courtesy of Sydney Water

The chart in Figure 11.1 shows that an average office building's water use can be minimised by one-third by arresting leaks. Cooling towers account for 29% of water usage. There are opportunities to save water in cooling towers and in amenity blocks, where the majority of water leaks occur.

### 11.2.2 Water-Usage Benchmarks

Water use in office buildings and consequently benchmarks are dependent on a number of factors:

- square area
- number of employees or tenants
- number and type of retail facilities
- type of water using facilities and efficiency
- climatic conditions.

Commonly used indicators to benchmark water use in commercial buildings are

- Water usage per square area –  $\text{m}^3/\text{m}^2/\text{yr}$  (USgal./ft<sup>2</sup>/yr)
- Water usage per employee/day – L/employee/day (US gal./employee/day)
- Water usage per annum per employee –  $\text{m}^3/\text{yr}/\text{employee}$  (Thames Water, UK).

In Australia, Sydney Water developed a best practice water use benchmark of  $0.8\text{m}^3/\text{m}^2/\text{yr}$  ( $19.63\text{ US gal./ft}^2/\text{yr}$ ) – based on over 30 comprehensive audits in large office buildings. This translates to  $22\text{m}^3/\text{day}$  for  $10\,000\text{m}^2$  of floor space. However, this figure is only applicable if there are cooling towers in the building. If the building has air-cooled chillers, then the water use will be less. A study conducted by the Australian Department of Environment and Heritage [4] has identified that water usage in office buildings within Australian capital cities can vary from  $0.4$  to  $3\text{m}^3/\text{m}^2/\text{yr}$  with a median of  $0.91\text{m}^3/\text{m}^2/\text{yr}$ . Using statistical analysis it also concluded that the most reliable indicator was  $\text{m}^3/\text{m}^2/\text{yr}$  (after correction for cooling degree days which takes into account the heat rejection via cooling towers in warmer climates) rather than occupancy-based benchmarks.

In the United Kingdom, the government took the initiative (under its Watermark Program) to set a target of reducing water usage in government departments from  $11\text{m}^3/\text{person}/\text{yr}$  to  $7.7\text{m}^3/\text{person}/\text{yr}$  by 2004. For new buildings (built after 2002) the benchmark is set at  $7\text{m}^3/\text{person}/\text{yr}$  [5]. A best practice figure of  $6.4\text{m}^3/\text{person}/\text{yr}$  has been established. Thames Water has also established benchmarks for office buildings that ranges from  $6.8\text{m}^3/\text{person}/\text{yr}$  for buildings larger than  $1000\text{m}^2$  to  $4.4\text{m}^3/\text{person}/\text{yr}$  for buildings less than  $1000\text{m}^2$ , and additional 1.5 to be added if there are catering facilities available [6].

**Table 11.1 Environmental performance benchmarks for corporate ecology**

	Water usage	Water usage	Electricity	Heating
	Litre/employee/day	m <sup>3</sup> /m <sup>2</sup> /yr	Usage	Energy
			kWh/employee	kWh/m <sup>2</sup>
Ellipson Best Practice Benchmark	47	0.7	3,706	119
Ellipson Standard Practice Benchmark	104	1.7	6,955	135
The best company performance	30	0.5	2,562	61
The average performance	104	1.7	6,955	135
The worst company performance	135	2.2	10,228	289

Adapted from Muller K, Sturm A. *Benchmarking Corporate Ecology of the Finance and Insurance Industry in Switzerland, Germany and Austria*.

\* Based on UK average office space per employee of 16.3 m<sup>2</sup>.

According to a study conducted by the University of NSW [7] in Australia, the average office space per person is 20.6 m<sup>2</sup>, while in the UK it is 16.3 m<sup>2</sup>.

On this basis the Water Mark target of 6.4 m<sup>3</sup>/person/yr equates to 0.4 kL/m<sup>2</sup>/yr.

In using the square area figure, care needs to be taken to ensure that the reported area is nett or gross surface area. In the United Kingdom and in Australia, office space is reported in Nett Lettable Area (NLA) otherwise known as nett internal area.

In Europe, the Finance and Insurance sector in Germany, Switzerland and Austria publicly reports environmental benchmarks under the VfU Guidelines. These are reported in L/employee/day. Researchers Muller and Sturm of Ellipson [8] have used this data to calculate water and other environmental best practice indicators for this sector. Table 11.1 shows water and energy usage per employee and if the average UK office space is used as a guide the expected water usage per m<sup>2</sup>.

#### 11.2.2.1 Energy Consumption

As a group office buildings are the largest energy user within the commercial property sector. In a typical office building lighting, heating and cooling represent more than 50% of total energy use. Office buildings in the United Kingdom (with air conditioning) will consume the following [9]:

Total annual consumption MJ/m <sup>2</sup> /yr	Good	Typical
Gas or oil	349	641
Electricity	<u>461</u>	<u>814</u>
Total	810	1455

Therefore water conservation strategies need to be geared towards reducing energy consumption which will result in a stronger business case.

#### 11.2.2.2 Shopping Centres

Shopping centres play a major role in the OECD countries economies. For instance, in Australia there are 1338 shopping centres ranging from large regional centres of more than 100 000 sq m of retail space and generating sales of around A\$500 million a year down to smaller, supermarket-based centres of around 5000 sq m generating sales around A\$30 million. Cumulatively they generate \$51 billion in retail sales each year [10].

From Table 11.2 it is evident that the trend in shopping centres is to build larger and larger shopping malls resembling mini-cities with thousands of shops, catering and other facilities. Eight of the ten largest malls in the world were in Asia by early 2007 and several more mega-malls in China and the United Arab Emirates are under construction. It is predicted that within the next few years, seven of the ten largest shopping malls in the world will be in China alone. The Australian company Westfield Group is the largest shopping mall owner today.

The results of six water audits conducted by Sydney Water, in six shopping malls (with an average gross lettable area between 23 000 and 116 000 m<sup>2</sup> (0.25–1.25 million ft<sup>2</sup>)), and with an average water consumption of 120–660 m<sup>3</sup>/day (32 to 127 thousand US gal./day), identified that leakage accounted for (on average) 32%.

Water usage in shopping centres is shown in Figure 11.2 with most of the leakage occurring in restrooms and cooling towers.

**Table 11.2 Largest shopping centres in the world sorted by gross lettable area\***

Mall	Location	Size (millions of square feet)	Size (square meters)
South China Mall	Dongguan, China	7.1	660,000
Aeromall ( <i>under construction</i> )	Caracas, Venezuela	6.7	620,000
Golden Resources Mall	Beijing, China	6	560,000
Central World	Bangkok, Thailand	5.8	550,000
Mall of Arabia ( <i>under construction</i> )	Dubai UAE	5.6	520,240
Seacon Square	Bangkok, Thailand	5.5	500,000
Runwal Arcade	Mumbai, India	4.25	425,000
SM Mall of Asia	Manila, Philippines	4.2	386,000
West Edmonton Mall	Edmonton, Alberta, Canada	3.8	350,000
SM Megamall	Manila, Philippines	3.6	332,000

Source: Eastern Connecticut State University, USA.

\*Gross lettable area (GLA) is the total area of floor space leased for retail shops, consumer services, and entertainment, including restaurants. GLA is less than total area.

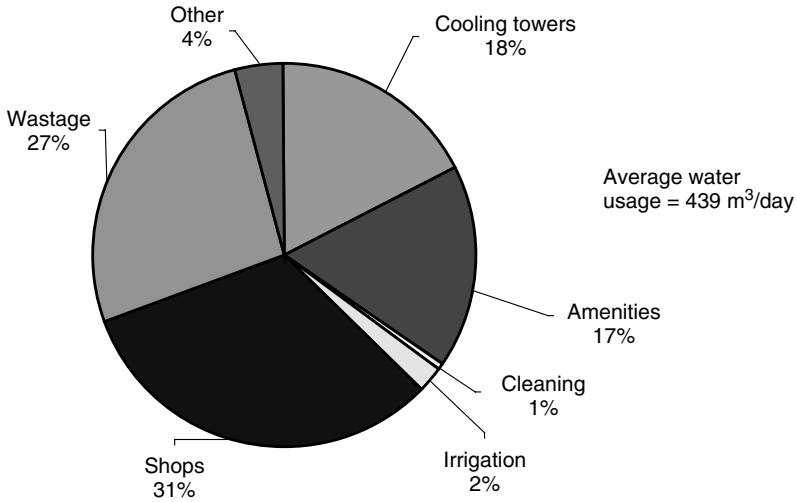


Figure 11.2 Breakdown of water usage in shopping centres

Courtesy of Sydney Water

From an energy-consumption perspective, in a typical retail building in the United States, lighting, cooling, and heating represent 69 and 84% of total energy use depending on the climatic conditions. Out of this, lighting accounts for 42–61% of consumption. Cooling represents 5–24% of total energy consumption and water heating varies from 1 to 7% [11].

### 11.2.3 Water-Saving Opportunities

Given that leakage accounts for a large part of water wastage, water efficiency can be improved with some easy steps before considering complex solutions.

Here are some suggestions.

1. Monitor water usage per square area per annum or per employee per day.
2. Carry out a site-wide assessment of other sub-meters available on site. Ensure that these are in working order.
3. Repair leaks.
4. Inspect all toilets and replace gravity type toilets with dual flush 6/3 L, 4.5/3 L or high-efficiency toilets, pressure-assisted toilets as discussed in Chapter 10. The reduction in water usage from a 12 L/flush to 4 L/flush using a dual-flush toilet is 51 L/day [12].
5. Inspect urinals. If they are the 'flush and fill' type, replace them immediately. Check timing cycles and volumes discharged. The calculation below shows how much of water (and dollars) go down the drain.

- Assume the cistern is a ‘flush and fill’ type which fills every 2 minutes. The capacity of the cistern is 6L and the number of persons using the urinal is 50/day.
  - The water consumption is 1576 m<sup>3</sup>/yr (416 thousand US gal./yr). This would cost \$2/m<sup>3</sup>–\$3153/urinal. Now assume that there are at least 10 of these in the building. The cost and water wastage now becomes significant. By installing a sensor that operates the urinal (based on movement) the water usage could be reduced to 0.2 m<sup>3</sup>/day (52 US gal./day) – easily justifying the cost of replacement.
6. Replace showers with water-efficient models (9 L/min) maximum.  
 An office building with a floor area of 30,000 m<sup>2</sup> has 2000 employees (based on 15 m<sup>2</sup>/person). Ten per cent use the showers daily for an average of 8 minutes. The office is used for 5 days/week.

	Conventional	Water efficient showers
Water usage	15 L/min	9 L/min
Number of showers/day	200	200
Total water usage kL/day	24	14.4
Annual usage, kL	6,240	3,744
Total saving, kL		<b>2,496</b>
Total saving, %		<b>40.0%</b>

7. Install water-efficient aerators in taps. Typical taps discharge 15–18 L/minute. An ultra low water-efficient aerator has a flow rate of 1.7 L/minute. At the very least, a 6 L/minute should be the maximum allowable.  
 For hand washing a 1.7 L/minute pressure-compensating flow controllers have proven to be adequate. Pressure compensation is essential to ensure that all taps have the same flow rate. Lack of pressure compensation may lead to an imbalance in water flow rates in fixtures, even though they are connected to the same pipe. For more details, refer to Chapter 10.
8. Convert once-through cooling water systems to open recirculating cooling water systems or reuse the water elsewhere. Refer to Chapter 5.
9. Consider air-cooled or hybrid cooling systems when replacing cooling towers Refer to Chapter 6. Hybrid systems save energy and water.
10. Install conductivity controllers in the cooling tower and boiler blowdowns to ensure that the correct conductivities are maintained and blowdown frequencies are not too frequent. Refer to Chapter 5.

11. Optimise usage of steam boilers and minimise blowdown as per Chapter 7.
12. Use trigger-operated nozzles on all hoses. Details are given in Chapter 12.
13. For irrigation of lawns and ornamental plants, use drip irrigation.
14. Check sprinkler systems and timing devices regularly to ensure that they operate properly.
15. Capture rain water if possible and reuse for irrigation, cooling tower makeup and toilet flushing.
16. Connect the water meters to the building management systems.
17. Capture condensate from air-handling units and reuse it for toilet flushing or as cooling tower makeup.
18. In kitchens, use pre-rinse spray valves for cleaning dishes before loading the dishwasher.
19. In shopping malls, individually meter the large retailers and issue bills according to actual water usage.
20. Cooling water treatment contracts to include water efficiency and penalty clauses for poor performance.
21. When testing fire water pumps consider reusing this water.
22. Only operate water features during working hours.
23. Initiate a tenant and employee awareness campaign. Contact the local water authority for assistance.
24. Request suggestions from employees.

**Case Study: Jessie Street Centre Parramatta, Sydney.**

Jessie Street Centre in Parramatta is a multi-storey office block in Parramatta, Sydney.

Sydney Water commissioned an audit and achieved water savings of 24 000 m<sup>3</sup> in 6 months. The following initiatives were carried out to realise these savings:

1. Continuous flushing urinals were replaced with sensor-operated ones.
2. The irrigation of the building's garden was adjusted to eliminate excess watering.
3. All 324 toilets were modified to reduce their flush volumes.
4. A monitoring programme was put in place.
5. Initial capital outlay \$40 500. Cost savings \$95 000. Payback – 6 months.

Adapted from: *Sydney Water Fact Sheet – Jessie St Centre, Parramatta.*

## 11.3 Hospitals

Hospitals are large users of water and energy and emit a significant amount of greenhouse gases. It is also one of the largest employers in a country. For instance, in Australia nearly 220 000 people are employed in 1052 public and private hospitals [13,14].

Ageing populations, high cost of providing in-patient care in a climate of reduced budgets, provide the business case for hospital administrators to champion water- and energy-efficiency best practice and thus reduce these costs. According to the American College of Healthcare Executives, 67% of Chief Executive Officers list financial challenges as their number one concern. Every dollar saved in minimising water and energy usage is another dollar for patient care and a win for the environment.

Increasingly hospitals are also responsible and accountable to a range of stakeholders who use, render, regulate and benefit from hospital services. Therefore it is in the hospitals' best interests to promote best practice resource efficiency and communicate this to all stakeholders to minimise costs and budget cuts.

There is a direct link between healing the individual and healing this planet... We will not have healthy individuals, healthy families, and healthy communities if we do not have clean air, clean water, and healthy soil.

**Lloyd Dean, MA CEO Catholic Healthcare West, October, 2000.**

Source: Energy Star. Making the Business Case for Energy Management Healthcare.

Hospitals can be classified as in-patient, day-hospitals and community-based hospitals. The water usage in hospitals depends on

- the number of patients being treated
- number of beds
- type of hospital (teaching and research or community hospital)
- age of the hospital
- type of medical treatment provided
- and the types of facilities available in these hospitals – such as the presence of on-site laundries.

The major water-consuming areas in hospitals are

- domestic water use for toilets, wash basins and urinals
- medical equipment, X-ray processors, dialysis machines, sterilisers, autoclaves and vacuum systems
- on-site laundry

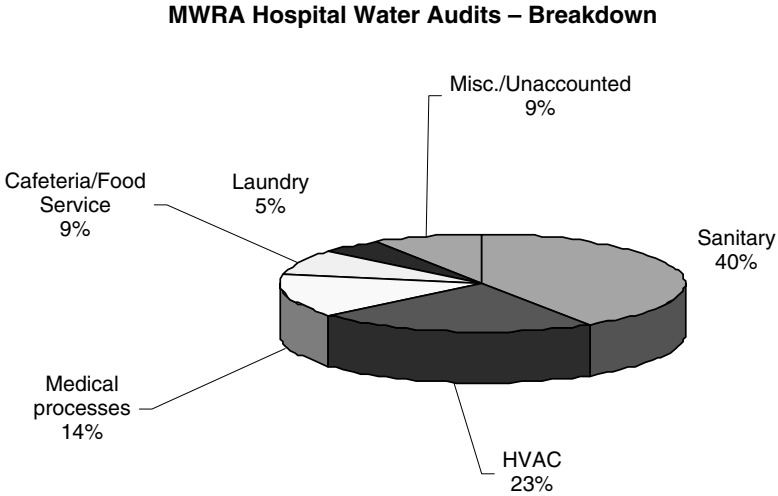


Figure 11.3 Average water usage in seven hospitals [15]

Courtesy of Massachusetts Water Resources Authority.

- laboratories
- air-conditioning and refrigeration systems
- reverse osmosis systems for dialysis machines
- boilers or hot water generators
- kitchens and cafeterias
- landscaping
- leakage.

Figure 11.3 shows the average water used in hospitals within the Metropolitan Boston area, derived from the water audits of seven hospitals, ranging from 138 to 550 bed capacities. These had a water usage ranging from 155 to 700 m<sup>3</sup>/day (15–67.2 million US gal./yr) [15].

### 11.3.1 Benchmarking Water Usage

Two common water usage benchmarks for hospitals are

1. Water usage per area – m<sup>3</sup>/m<sup>2</sup> (US gal./ft<sup>2</sup>)
2. Litres/bed/day (US gal./bed/day)

Table 11.3 shows water usage guidelines developed for UK hospitals [16, 17]. Table 11.4 shows the U.S. Department of Energy’s rough estimates of water usage for hospitals [18].

### 11.3.2 Benchmarking Energy Consumption

All hospitals are unique in design and the services they provide and also have special requirements unlike other buildings. For instance, indoor temperatures may be slightly higher to maintain patient comfort levels. Seventy-five per cent of energy consumption in hospitals is for lighting, ventilation, space heating and water heating.

A 1997 study conducted by the European organisation, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), concluded that there was a large discrepancy in electricity consumption amongst the six countries that participated in the survey [19]. For instance, electricity consumption per bed varies from 5.1 MWh (Italy) to 28.1 MWh (Australia), with an average consumption of 16.1 MWh (58 GJ/bed/yr). This is explained by a variety of factors such as climatic conditions, prices, age of equipment and insulation in buildings that can impact on electricity consumption. On the other hand, thermal energy consumption per bed is more uniform, varying between 23.3 MWh (Italy) and 42.8 MWh (Canada) with an average of 33.9 MWh (122 GJ/bed/yr).

However, similar to water consumption benchmarks there are large variations between acute, teaching and small hospitals.

Electricity consumption per floor area varies between 61 kWh/m<sup>2</sup>/yr (Switzerland) and 339 kWh/m<sup>2</sup>/yr (Canada) with an average consumption

**Table 11.3 Water usage guidelines for hospitals in the United Kingdom by usage per patient bed-days**

Type of hospital	Litres per patient bed-day			
	Very poor	Poor	Average	Good
Acute > 100 beds	1138	711–1137	531–700	< 530
Long stay > 25,000 patient days per year	690	412–689	331–411	< 330
Long stay < 25,000 patient days per year	380	298–379	218–297	< 217

Courtesy of Thames Water, UK.

**Table 11.4 Water Usage Guidelines for hospitals in the United States**

Unit	Range	Typical
US gal/bed	80–150	120
L/bed	303–568	454
US gal/employee	5–15	10
L/employee	19–154	38

Adapted from U.S. Department of Energy – Energy Efficiency and Renewable Energy – Federal Energy Management Program – Water use indices [18].

of 145 kWh (522 MJ/m<sup>2</sup>/yr). Thermal consumption varies between 168 kWh/m<sup>2</sup>/yr (Sweden) and 690 kWh/m<sup>2</sup>/yr (USA) with an average of 367 kWh/m<sup>2</sup>/yr (1321 MJ/m<sup>2</sup>/yr).

### **11.3.3 Water Conservation Opportunities**

Water conservation opportunities in hospitals are similar to those mentioned previously for commercial office buildings and shopping centres. Some specifics relating to hospitals are given below.

#### *11.3.3.1 Monitor Leakage*

Many hospitals have sprawling infrastructure and leakage in underground pipes is common. Sydney Water monitored 15 hospitals' main meters electronically for a 2-week period. It showed that close to 50% of hospital water usage was due to water leaks – known as base flow. Lack of adequate monitoring equipment makes it hard to notice these leaks. Given the number of toilets, urinals and wash basins generally available in these facilities, having a good leakage minimisation programme will be a good starting point to reduce on-site water usage.

#### **Rule of Thumb for checking for leaks**

If the base flow rate is significantly greater than 10% of the peak flow rate, then this could be because of leakage.

#### **Case Study: Westmead hospital, Sydney, Australia**

Established in 1978, it is one of the largest specialised referral hospital in Australia. It services a population of over 1.5 million people and occupies over 130 000 m<sup>2</sup> (1.4 million ft<sup>2</sup>).

Sydney Water with the assistance of the Department of Commerce identified leaks of 50 000 m<sup>3</sup>/yr which was a saving of A\$ 80 000/year. The hospital has set itself a target of reducing water consumption by 25% through a range of initiatives such as:

Installing water efficient showers and taps including 5800 flow restrictors, replacing flush valves on all toilets, with an expected savings potential of 50 000 m<sup>3</sup>/yr and a monetary saving of A\$ 100 000/year.

Other initiatives under consideration include use of ground water as make-up water in cooling towers which could save another \$100 000/yr.

Since 2001 Westmead hospital has reduced overall water consumption from 420 000 m<sup>3</sup>/yr to 333 000 m<sup>3</sup>/yr.

Adapted from: *Sydney Water. Hospitals Saving Lives and Water. The Conserver. Issue 6. December 2004 [20].*

#### 11.3.3.2 Air-conditioning and Refrigeration Systems

Air-conditioning systems in hospitals in comparison to other building types have an added complexity for medical requirements that

- the air movement needs to be restricted between buildings to prevent the spread of disease causing germs
- stringent requirements for ventilation and air filtration. For an example, air changes can be as high as 20/hr in operating theatres.
- different temperatures and humidity requirements for different hospital areas.

The water conservation opportunities are similar to those found elsewhere. Refer to Chapter 5 and 6.

Common actions are

- eliminate once-through cooling
- eliminate leaks and overflows
- minimise blowdown and drift
- recover condensate from air-handling units (given the high rate air changes per hour)
- use alternative supply sources
- replace old or inefficient cooling towers with hybrid cooling towers
- investigate heat recovery options in HVAC units.

#### 11.3.3.3 Steam Systems

Steam is used extensively in hospitals for heating, to sterilise medical equipment, in absorption chillers, in laundries, for food preparation and so on. Maximising return condensate, minimising boiler blowdown and having a well-designed maintenance programme will reduce water and gas usage and costs. For more details, refer to Chapter 7.

#### 11.3.3.4 Taps, Toilets and Urinals

Taps refer to Chapter 10 for a discussion on flow restrictors and pressure-compensating aerators. Replace flush and fill urinals with water-efficient models. Replace single flush gravity toilets with dual-flush models as discussed in Chapter 10.

In hospitals apart from gravity flush toilets, flush valve-operated toilets are common. The 'flushometer valve' is directly connected to the water supply plumbing. The valve controls the quantity of water released over time by

each flush. These valves need a minimum water pressure of 200–237 kPa (30–35 psi) which is significantly higher than the gravity-operated ones which only require a pressure of 4 kPa (0.6 psi) to work effectively. Flush volumes are nominally rated at 6 L/flush (1.6 US gpf) or 13 L/flush (3.4 US gpf). The flush volumes do not change with changes in pressure according to a study conducted by Veritec Consulting [21]. The study found that the flush volumes can be changed in some models from 6 L to as much as 18 L by replacing the diaphragms and piston valves, adjusting the adjustment screw, changing internal O-ring or control stops.

#### 11.3.3.5 *Food Preparation*

Hospitals have large kitchens which are high water-using areas. Water is used for preparing food and washing equipment and containers. These have been discussed in Chapter 10.

Water savings can be made by

- installing pre-rinse spray valves
- inspecting dishwashers and ice-making machines
- considering foot-operated taps for wash basins
- not defrosting food done under flowing water
- minimising water usage to flush out potato peelings
- using a broom first before washing of floors
- using a hose with a water-efficient trigger gun.

#### **Case Study: John Umstead Hospital, North Carolina, U.S.A**

John Umstead Hospital in Butner, North Carolina is a 593-bed psychiatric hospital for patients older than six years.

A water conservation programme identified that it had five ice-making machines in the kitchen and four of them had single-pass cooling, consuming a total of 1623 m<sup>3</sup>/yr (429 000 US gal./yr). The hospital staff consolidated the ice-making machines and piped it into an existing cooling tower, saving that much water.

*Adapted from: North Carolina Division of Pollution Prevention and Assistance Case Study – John Umstead Hospital.*

#### 11.3.3.6 *In-house Laundries*

Hospitals have either in-house laundries or a central laundry that provides a service to a number of hospitals within its geographical locality. Refer to Chapter 15.

### 11.3.3.7 Medical Equipment

#### i) X-ray processing equipment

Medical facilities commonly have X-ray film processors operating 365 days of the year. Most have more than one processor. X-ray processing equipment uses water to rinse chemicals from the film before it reaches the dryer section of the machine and to cool the equipment. The rinse section receives a constant supply of water. The published water usage rate is estimated to be around 0.94–9.4 L/minute (0.25–2.5 US gpm) [22]. In older machines this water is rarely captured and reused. Moreover, in practice, it has been found that the water flow rates are one-and-a-half times (to twice) this amount. They therefore have the potential to waste large quantities of water as seen by the case study.

The X-ray film development process in brief is as follows. The process consist of developing, fixing, washing and drying of the film. The X-ray film goes to a tank which holds the developer chemicals which is maintained at a constant temperature of 35° C(95° F). The film then passes through rolls to remove excess water before being exposed to the fixer chemicals. The fixation process stops the development chemicals from over-exposing, after which the film is washed or rinsed with flowing water to remove excess chemicals. After the excess water is removed the film is then dried. The water-saving opportunities are

- Install a sub-meter to monitor the supply line flow received by the rinse water.
- Install a control valve to adjust the flow rate to the manufacturer's recommended flow rate.
- Install a solenoid valve to shut water supply to the rinse tank and cooling water pipes when the unit is not in use.
- Install squeegees to squeeze the maximum amount of liquid to minimise carryover as the film travels from one tank to another. (This reduces wash water requirements.)
- Recycle the rinse water. Water Saver/Plus™ units have been installed in California in many older units with considerable success. These units costs US\$4000–5000 and operating costs are US\$1300 [22].
- Shut off all units not in service.
- Replace old machines with digital imaging processors. They provide better images and at lower unit cost is more cost effective over the long term and does not use water.

#### **Case Study: Water Saver/Plus™**

Irvine Ranch Water District in California installed 38 Water Saver/Plus™ units in 7 hospitals to recirculate the water from the X-Ray machines.

Water Saver/Plus™ consists of a small reservoir with a capacity of 56 L (15 US gal.), a pump and an algaecide dispenser. A water meter and a data logger were installed prior to the units were installed to log water usage data for one month before and after installation of the Water Saver/Plus™. A timer releases a set amount of fresh water per hour for temperature control. The results showed that the device saved 4.5 m<sup>3</sup>/day (1183 USgal./day) or 1.63 ML/yr (1.33 acre ft/yr) – a 97% reduction in water usage.

Adapted from: *Water Conservation News* January 2003 [23].

ii) Steam sterilisers and autoclaves

Steam sterilisers (also known as autoclaves or pre-vacuum sterilisers) are used in hospitals and other institutions requiring sterilisation of medical equipment in the manufacture of pharmaceutical products – for the total destruction of microorganisms. The most common type of steriliser is the steam steriliser.

Steam sterilisers use water for jacket cooling and for generating a vacuum using steam ejectors (vacuum type sterilisers).

The process is as follows: Medical equipment, after going through a washing process, is placed in the steriliser. The sterilisation process consists of removing air to create a vacuum seal and injecting low-pressure steam at 134° C (273° F) into the chamber for about 4 minutes. After sterilisation the vacuum seal is broken to start the drying process. The whole process takes usually 35 minutes to complete. The steam condensate leaves the steriliser at around 80° C (176° F). Before discharging this water to the sewer, it needs to be cooled below 38° C (100° F) to comply with trade waste regulations (since water authorities prohibit the discharge of water at temperatures above 38° C (100° F)). Steriliser jackets are also kept warm by maintaining a flow steam to the chamber to minimise steam condensation on the walls and minimise start up times. This water is sent to the drain. At 11 L per minute the water wastage during one cycle is around 418 L.

Water conservation opportunities are

- Jacket and chamber condensate cooling modification [22]  
Steam that is condensed from the jacket during the 'standby' mode is discharged to the sewer. Therefore, cool potable water is typically used to mix with the hot water before discharging to the sewer. No attempt is used to conserve this water and it runs continuously. Flow rates of cool potable water wasted are in the range of 11 L/minute.

The condensate can be modified to collect the jacket water in a tank, and letting the ambient air circulating around the tank to cool it first before discharging to the sewer. When the temperature rises above the legally permissible temperature of discharge to the sewer, a thermostatically actuated valve opens to inject the minimum quantity of potable water which is added to cool the condensate temperature below the set point. The whole unit is small enough to fit in space-constrained areas. This measure has the potential to reduce the water usage by 85%.

- Ejector water modification  
Potable water is used as the driving force to create a vacuum in the sterilisation chamber. The potable water is traditionally wasted. The modification consists of collecting this water in a tank and then using it in place of fresh water as the driving force for the vacuum. The principle is based on the ambient air cooling the water in the tank below 49°C (120°F). When the temperature exceeds the set point, cool fresh water is used to cool the tank water below the set point.
- Use chilled water for cooling of hot condensate, liquid ring vacuum pump or steam ejector water and reusing it. The chilled water is circulated in a closed cooling coil, cooling the condensate before discharging it to the sewer [24]. The relatively warm chilled water returns to the chiller. Read the case study below for more details.
- Shut off all units not in service.

#### **Case Study: Western Health Victoria retrofits steam sterilisers and reaps a quick pay back**

Western Health Victoria retrofitted 9 of their steam sterilisers which included a chilled water loop to cool the condensate to save 20 235 m<sup>3</sup>/yr at a cost of A\$60 400. The payback was 2.4 yrs.

Flow rate of cooling water	22 Lpm
Time for each cycle	35 minutes
Number of cycles per day per unit	8
Number of units	9
Quantity of water used and saved per year	20 236 m <sup>3</sup>
Cost of water and sewerage	A\$24 950
Capital cost	A\$60 400
Payback	2.4 yrs

Adapted from: *Water Saving Sterilisers, Western Health, Smart Water Fund, Melbourne, Victoria* [24].

## iii) Medical pumps and liquid ring vacuum pumps

Liquid ring vacuum pumps and steam jet ejectors are used in hospitals to create a vacuum in sterilizers and in laboratories. These can waste significant quantities of water. Details on vacuum pumps are given in Chapter 13. Solutions are to recirculate the cooling water or replace the pump with an oil ring or a dry vacuum pump. The case study given below illustrates the point.

**Case Study: Royal North Shore Hospital (RNS), Sydney replaces liquid ring vacuum pumps and reaps the rewards**

RNS is a 740 bed acute general teaching hospital. The hospital received a subsidy of A\$104 025 from Sydney Water to replace their medical suction and laboratory vacuum pumps with dry running pumps. Since then RNS is saving 100 000 litres of drinking water daily. The annual savings in water charges alone exceeded \$60 000. The project had a simple payback of less than two years.

Adapted from: *Sydney Water. The Conserver issues August 2005 and December 2005.*

## iv) Hemodialysis units

Water used in hemodialysis units is purified beforehand in reverse osmosis systems (RO). The reject water from the RO system is usually sent to waste. If the TDS is not excessive this water can be used as cooling tower makeup or for flushing of toilets. Consult the cooling water chemical treatment supplier for advice. For details on RO systems refer to Chapter 8 and cooling systems refer to Chapter 5.

**Case Study**

East Kent & Canterbury Hospital is one of the three main hospitals in the East Kent Hospitals Trust. The Trust has a duty to promote the efficient use of resources. It identified an opportunity to save water and money at the Renal Unit at East Kent & Canterbury Hospital.

The project involved recycling the wastewater that had been sent to drain by the Reverse Osmosis (RO) plant. The RO plant is used to separate specific calcium ions in the water and purify it for use by the renal unit. The new initiative diverted water to a holding tank via pipe work and then subsequently to a larger redundant tank in a separate plant room. This water was then re-used to flush all the toilets and urinals in the main operating theatres and the accident centre areas. Mains water is used as a top up when required.

The initial set-up costs included a feasibility study, materials (piping and one holding tank) and installation costs. The annual maintenance costs of the system are minimal.

The Trust aimed to recover the costs of the project in less than three years. They based this on their calculations for wastewater passing to drain and subsequent savings on WC/urinal usage at the prevailing water and sewerage rates. This target was achieved with a 38% reduction in the use of mains water and on-going annual financial savings of £7000.

*Courtesy of Environment Agency UK.*

#### 11.3.3.8 Increase Staff Awareness

Given the large number of employees, increasing staff awareness will play a significant factor in reducing water usage.

#### 11.3.3.9 Floor cleaning

Floor cleaning is an essential part of a patient care program to minimise the spread of pathogens. In conventional wet mopping of floors, cotton mops are used. A disinfectant is added to the water and after every 2–3 rooms the water is discarded. At the end of the shift the mops are sent to the laundry for washing and drying.

Microfibre mops are considered to be more water efficient than the cotton mops. Constructed from nylon and polyester fibres, they are approximately 1/16 the thickness of a human hair. The density of the fibres enables it to hold six times its weight in water. As a result for a hundred room hospital it only requires 19 L (5 US gal.) of water as against 397 L (105 US gal.). The microfibrils are split and they also carry a positive charge which enables them to attract dust particles and thereby increasing the cleaning efficiency. The mops also can withstand 300–500 washings as against 55 for cotton mops.

According to a study carried out by the University of California Davis Medical Centre, the microfibre mops are about 5–10% cheaper than using cotton mops. The studies concluded that microfibre mops reduced water and chemical usage by 95%; Lifetime cost savings by 60%; Labour saving by 20% and were ergonomically better for the janitors due to less lifting [25, 26].

## 11.4 Correctional Centres

Prison populations are increasing with newer prisons being built by the public and private sector. For example, in the United Kingdom there are 135 prisons with a current prisoner population in excess of 65 000 whereas in 1985 there were only 41 500 prisoners [27]. Given the increase in prisoner populations (in most countries) both energy and water usage is increasing the cost of maintaining prisoners, stretching the limited budgets of state and local governments.

Prisons are categorised as high security, local, open, women's or juvenile offenders' institutions. The prison category influences the water usage. In high-security prisons usually there will be a higher staff /prisoner ratio. In New South Wales, Australia, the staff to prisoner ratio is around 2–3. Open prisons may have low occupancy levels during the day when prisoners work off-site. On the other hand, these may have other water-using facilities such as farms, dairies and vegetable canning works.

### **11.4.1 Water Usage Benchmarks**

The water usage benchmarks for correctional centres are expressed as:

Water usage per floor area –  $\text{m}^3/\text{m}^2/\text{yr}$

Water usage per prisoner –  $\text{m}^3/\text{prisoner}/\text{yr}$  or  $\text{m}^3/\text{prisoner}/\text{day}$ .

Due to the occupancy characteristics, water consumption in detention and correctional facilities is high. Kitchens, laundries and shower facilities require large volumes of hot water. Inmate areas require special plumbing fixtures to minimise vandalism and suicide attempts. These aspects are seen from the high water-usage figures per prisoner. The UK Watermark Project [27] has established the benchmarks shown in Table 11.5. An international comparison is given in Table 11.6.

### **11.4.2 Water Conservation Opportunities**

Prisons are not dissimilar to other institutions, except that they have special requirements. With traditional plumbing fixtures prisoners have full control over lavatories, toilets and showers. This can lead to a variety of problems, such as intentional flooding through simultaneous flushing and constant

**Table 11.5 Water consumption for UK prisons**

Category	Typical $\text{m}^3/\text{prisoner}/\text{yr}$	Best Practice $\text{m}^3/\text{prisoner}/\text{yr}$
Prisons with laundry	143	115.3
Prisons without laundry	116.6	92.4

Source: Environment Agency UK.

**Table 11.6 Water Consumption for prisons – international comparison**

	NSW Australia	USA	UK
Typical water usage $\text{m}^3/\text{inmate}/\text{day}$	0.32–1.29 [29]	0.30–0.57*	0.32–0.39**

\* Adapted from The US Federal Energy Management Program (FEMP) water indices data gives a figure 80–150 US gal./prisoner/day.

\*\* Adapted from Table 11.6.

running of showers and lavatories. To overcome these problems as well as minimising water usage, more attention needs to be given to the planning aspects (as well as remote monitoring of fixtures) through innovative use of technology and the installation of purpose-built fixtures.

Some suggestions are given below.

- Install sub-meters.
- Data log main and sub-meters to identify water leakage. It is preferable that the dataloggers are connected to the building management system.
- Install systems that enable the shut off of individual or group plumbing fixtures in a cell (or cells) rather than shutting down the entire domestic water system.
- The main use of water is for toilet flushing and washing. Install movement-detection sensors to prevent wastage when the toilets are unoccupied.
- Conceal flush valves and infra-red detectors to prevent them being tampered with.
- Use electronic controls to prevent inmates wasting water by programming the number of flushes within a specified time frame. This also allows the staff to monitor the frequency of toilets usage. When inmates try to flush the toilet more than the specified number, the toilet is locked out. In one instance, a prison had a problem of trying to prevent inmates flushing sheets and clothing down toilets and blocking toilets. By monitoring the frequency of usage, staff are able to detect the problem in time and prevent flooding of cells.
- Use integrated sink and toilets with push button controls to minimise vandalism.
- Replace water guzzling toilets with 13 L/flush (3.5 US gpf) with vacuum toilets that use only 1.2–2 L/flush (0.3–0.5 US gpf). Vacuum toilets have long been used in the aviation and marine industry. There is anecdotal evidence to suggest that prisoners tend to flush toilets 15–20 times a day [30]. With a vacuum toilet the water used is only 40 L/day (10.6 US gal./day) as against a conventional toilet using 13 L per flush wasting 260 L/day (70 US gal./day). When the cost of water and sewage is considered this could result in considerable savings – as seen from the example below.

The other advantage of vacuum toilets is that if an object was too large to pass through the bowl into the vacuum tubes, computer sensors would shut down the affected toilet and alert a system operator to the problem, as well as pinpoint the culprit. During cell inspections for contraband, security staff can use the computer-control network to shut down toilets in specific prison cells or to shut down the entire system, making it difficult for prisoners to flush away contraband.

**Worked example**

Number of inmates	500
Number of toilets	500
Number of average flushes per day	15
Water used with conventional toilet having 13 L/flush	$13 \times 15 \times 500 = 97,500 \text{ L/day} = 97.5 \text{ m}^3/\text{day}$
Water used with vacuum toilet	$2 \times 10 \times 500 = 10,000 \text{ L/day} = 10 \text{ m}^3/\text{day}$
Cost saving at \$4/kL for water and sewage	$\$4 \times (97.5 - 10) \times 365 = \$127,750$
Plus other productivity savings from reduced maintenance over a 10 year period.	$\$127,750 \times 10 \times 1.50 = \$1.9 \text{ million}$

The other benefits of vacuum systems are that the pipe diameters are smaller than for conventional gravity systems and therefore can be easily routed around beams and ventilation ducts.

- Install vandal proof fixtures (such as aerator spray heads) that are secured with a key. Shower heads that do not protrude from the walls are therefore difficult to tamper with.
- Follow other recommendations similar to hospitals for the kitchen and laundry.
- Consolidate individual laundries with one central laundry.
- Practice smart irrigation practices. Refer to Chapter 10.

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