5 MINIMISING WATER CONSUMPTION IN TOURIST ACCOMMODATION

Tourism and water stress

A tourist's water consumption is higher than a resident's water consumption. A European tourist consumes around 300 litres per day compared with a European resident consumption of 100 – 200 litres per day, averaging approximately 150 litres (EEA, 2009; EC, 2009, Eurostat, 2011; Gössling et al., 2011). There are a number of reasons for higher tourist water consumption in accommodation enterprises, including maintenance of grounds (irrigation), daily room cleaning, daily laundry, maintenance of swimming pools, intensive kitchen activities, and a 'pleasure approach' to showers and baths (Eurostat, 2009). However, statistical data relating to water use in tourism are lacking (Eurostat, 2009; Gössling et al., 2011).

Tourism is highly concentrated in destinations, so that although tourism's share of global total water consumption is less than one percent (Gössling et al., 2011), tourism contributes significantly to water stress in hotspot areas, especially the Mediterranean within Europe (see section 1.2.2). The impacts of water extraction can be particularly high in sun destinations for the following reasons:

- water resources are more likely to be scarce;
- water demand is usually higher owing to the operation of large swimming pools and irrigation of green areas and golf courses.

According to Ringbeck et al. (2010), average tourist water consumption in European sun-holiday destinations in 2007 ranged from 149 L per guest-night on the Spanish Balearic Islands to 450 L per guest-night on the Greek Agean islands, but water consumption up to 880 L per guest-night is quoted for luxury tourists on Majorca (UN, 2004).

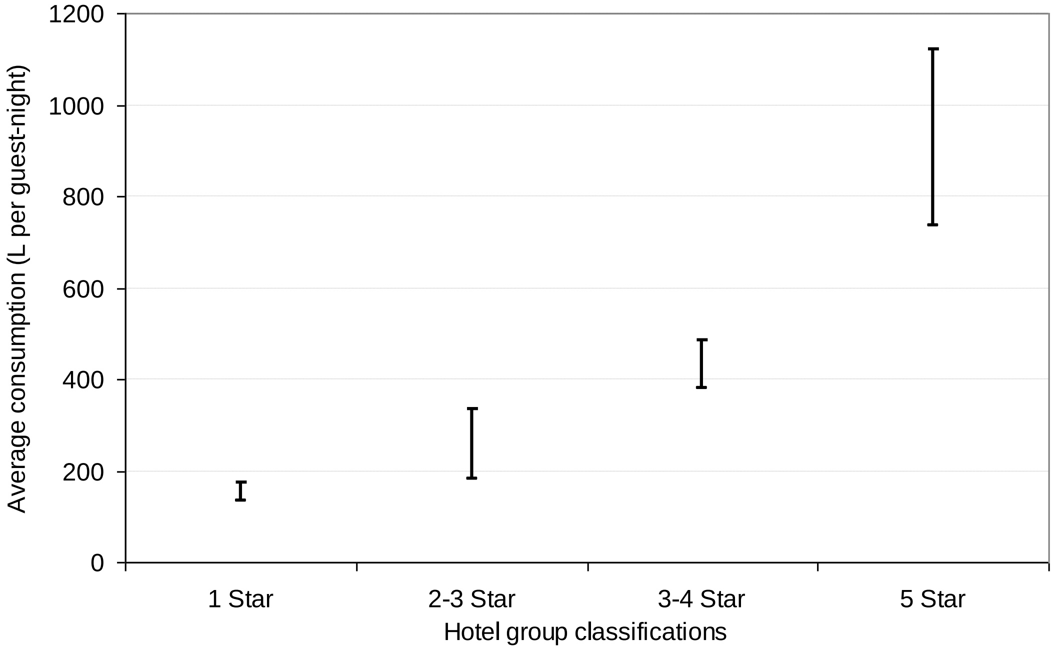
Water consumption across accommodation types

Water typically accounts for approximately 10 % of utility bills in hotels, but can vary considerably across different types of accommodation (Table 5.1).

Table 5.1: Water use across different accommodation types, based on a sample of 375 enterprises in Austria and Germany

Accommodation type	Specific water consumption
	(L/guest-night)
Hotel	312
Holiday house	273
Bed & breakfast	226
Campsite	148
Group accommodation	115
Source: Ecotrans (2006).	

Specific water consumption per guest-night, and the distribution of that consumption across water using processes, also varies within accommodation types according to a range of factors. One factor is the number of services and degree of perceived luxury (Figure 5.1). Data presented in CIRIA (2006) indicate 60 % less water consumption per bed space in 1-star compared with 3-star accommodation, and 111 % more water consumption per bed space in 5-star compared with 3-star accommodation. The provision of en-suite bathrooms is an important factor affecting water consumption. Ecotrans (2006) estimated that swimming pools increase water consumption for hotels and campsites by the equivalent of 60 L per guest-night.



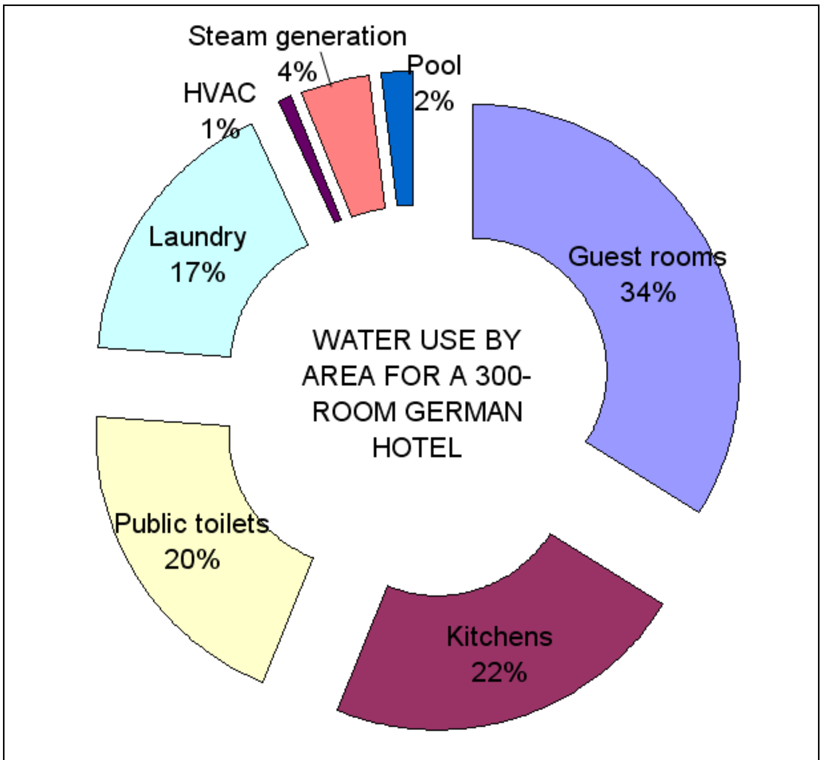
NB: Assumes 1.4 guests per occupied room.

Source: Accor (2010).

Figure 5.1: Average water consumption for hotel brands within a large European hotel chain according to star rating (highest and lowest brand averages displayed for each rating)

Processes responsible for accommodation water consumption

The major areas of water consumption in accommodation are guest bathrooms, kitchens and laundry facilities, and communal toilet facilities, as indicated for a German hotel in Figure 5.2. Swimming pools and the irrigation of green areas can contribute an additional 10 – 15 % and 20 – 25 %, respectively (Eurostat, 2009), and room cleaning approximately 12 – 47 L/guest-night according to Gössling et al. (2011). Employees can also contribute significantly to water use, with average water use for an office employee reported at 16 L/day (CIRIA, 2006) – primarily in toilet facilities used by staff. Depending on the cooling system installed, cooling towers may be responsible for a further 10 – 25 % of water consumption in a hotel (Smith et al., 2009).



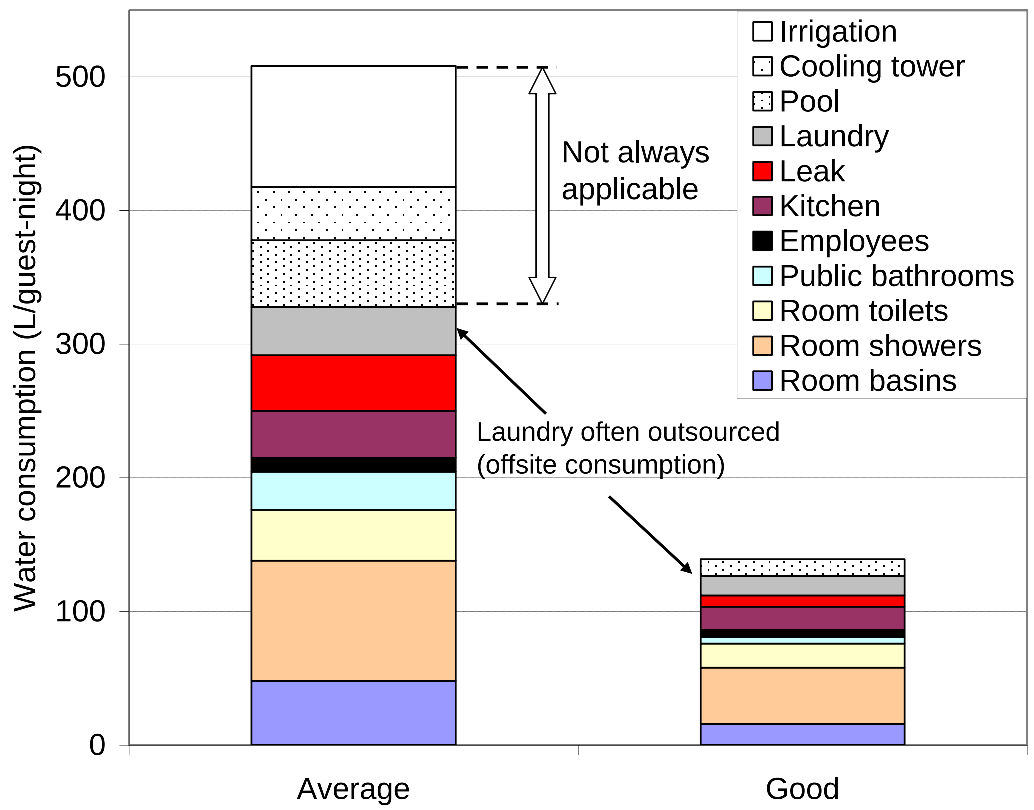
Source: ITP (2008).

Figure 5.2: Water use from sub-meter data in a 300-room hotel in Germany using 620 litres of water per guest-night

Opportunities to reduce water consumption

There is great potential for water reductions across accommodation enterprises. Water-inefficient hotels can typically reduce water consumption by over 50 % (Figure 5.3). A large portion of potential savings can be achieved through relatively simple and inexpensive installation of efficient water fittings which have a relatively high frequency of replacement (EC, 2009).

This chapter describes best environmental management practices to minimise water consumption in guest areas, laundries and pool areas. Best practice for other important water using processes, such as dish washing in kitchens and irrigation of green areas, are addressed in Chapter 8 and Chapter 9, respectively (Table 5.2). Optimisation of HVAC systems can also be important to reduce water consumption in cooling towers (section 7.2).



NB: Assumes 80 % room occupancy (20 % double occupancy). Average and good performance based on average and benchmark data presented for best management practices described in this chapter.

Figure 5.3: Modelled specific water consumption per guest-night in a 120 bed hotel implementing average and good management across water using processes

Table 5.2: Portfolio of techniques important for the minimisation of water consumption

Technique	Measures	Section
System maintenance	– Optimisation of system design to avoid excessive water pressure and heat loss – Regular inspection and maintenance of water fittings and leak 'hotspots' (e.g. heat exchangers) – Monitoring of water consumption, including sub-metering of important water-using areas and benchmarking	Section 5.1
Installation of efficient water fittings in guest areas	– Installation of low-flush and dual-flush toilets – Installation or retrofitting low-flow showerheads or retrofitting pressure regulators and/or aerators – Installation of low-flow faucets and retrofitting with pressure regulators and/or aerators – Installation of low-volume baths and basins – Installation of thermostatic shower controls – Provision of guest information to encourage lower water consumption – Installation or retrofitting of controlled flush or waterless urinals – Installation of sensors or timers to control faucets and showers in public areas (toilets and changing rooms)	Section 5.2

Efficient housekeeping operations	– Green procurement of room textiles, especially bedclothes and towels, to minimise lifecycle impacts – Implementation of bedclothes and towel reuse schemes to reduce laundry volumes – Staff training in efficient cleaning techniques that minimise water and chemical consumption – Inspection and reporting of leaking water fittings – Green procurement of room consumables – Housekeeping measures to reduce energy consumption	Section 5.3
Optimised small-scale laundry processes	– Green procurement of efficient washing machines – Installation of holding tanks and programme modification to reuse rinse water – Optimised laundry sorting and loading – Optimum washing machine programming to minimise water, chemical and energy consumption – Measures to reduce energy consumption during washing, drying and ironing (efficient equipment, heat recovery, etc.)	Section 5.4
Optimised large-scale laundry processes	– Optimisation of continuous batch washer programming to minimise water, chemical and energy consumption – Optimised laundry sorting and loading – Press and rinse water reuse and wash water recovery where economically viable – Measures to reduce energy consumption during washing, drying and ironing (efficient equipment, heat recovery, etc.)	Section 5.5
Optimised pool and spa area operations	– Appropriate pool sizing – Optimisation of backwashing operations – Use of pool covers – Optimisations of pool management to maintain an appropriate temperature and reduce chemical consumption	Section 5.6
Rainwater and greywater recycling	– Installation of rainwater collection and internal distribution system – Installation of separate grey water collection and internal or external distribution system	Section 5.7
Water management in kitchens	– Installation or retrofitting of low-flow high pressure spray valves for prewashing – Green procurement of efficient dishwashers with water reuse and heat recovery – Implementation of efficient washing and cooking techniques	Section 8.3
Environmental management of green areas	– Planting of green areas with indigenous species to minimise irrigation requirements – Installation and maintenance of efficient irrigation system – Use of waste water for irrigation	Section 9.2
Water management on campsites	– Reuse of grey water for irrigation and toilet flushing	Section 9.5

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5.1 Water system monitoring, maintenance and optimisation

Description

Leaking water pipes and appliances can increase water consumption considerably, and in the process incur significant costs. A leaking toilet can waste up to 750 litres of water per day (ITP, 2008), compared with 30 litres per day required for five full flushes of a low-flush toilet in a guest bathroom. A dripping tap can waste up to 70 litres of water per day, and it has been estimated that in a typical large hotel, leaking taps alone can increase total water consumption by 5 % – equivalent to 15 litres per room-night (Smith et al., 2009). A survey of eight hotels in Bulgaria found that leakage accounted for between 32 % and 68 % of water consumption (EC, 2009). Kitchens are also a significant source of water consumption and leakage, addressed specifically in section 8.3.

Water wasted through leakage can be detected by an effective monitoring and maintenance programme that involves the following.

- Daily checks and reporting procedure by housekeeping staff to detect obvious leaks, such as leaking taps or toilets.
- Detailed periodic inspections to detect hidden leaks, including inspection of pipe joints, appliances, and heat-exchanger units. On large premises, technicians may perform detailed testing that may include use of leak-detection cables and portable clamp-on flow-meters.

Monitoring and benchmarking of water consumption is the first step to improving water use efficiency. Monitoring of water use can be performed at varying levels of detail depending on resources available and the size of premises. At the most basic level for small premises, annual water consumption may be recorded and compared with the number of guest-nights in order to benchmark performance against comparable accommodation premises and identify performance improvement potential. An audit of water-using equipment in all areas can be used to identify possible measures to reduce consumption – for example through targeted implementation of the BEMP techniques described subsequently in this chapter. For larger premises, sub-metering of different areas, such as the kitchen, pool and spa area, and accommodation zones, can help to identify leaks and improvement options, and may enable the benchmarking of water consumption per functional unit for specific water-using processes (described in sections 5.2 – 5.6 and section 8.3). Sub-meters may be connected to a central automatic recording system, or Building Management System (BMS), that continuously records consumption and provides detailed data on water use patterns throughout the premises.

Domestic hot water (DHW) heating accounts for a significant portion of energy used on accommodation premises (section 7.1). Effective system monitoring and implementation of identified water reduction measures can significantly reduce energy use for water heating. Further, monitoring can be used to accurately control water heating so that hot water production matches demand, in terms of quantity, timing and temperature. DHW is often heated to more than 80 ºC on accommodation premises, compared with a requirement of only around 45 ºC to supply most needs (Lamei, 2009) – although at least periodic heating to 60 ºC may be required to minimise the risk of legionnella bacteria colonising the system. Effective pipe insulation reduces water consumption by: (i) reducing the time required for hot water to arrive at opened faucets; (ii) by reducing heat loss from hot water moving through the pipes. These two factors enable less water to be heated to a lower temperature, thus significantly reducing water consumption and considerably reducing energy consumption.

Table 5.3: Measures to monitor and maintain water systems in accommodation

Measure	Description	Applicability
Water audit and benchmarking	Assess water use on a seasonal basis and draw up inventory of main water using equipment. Calculate water consumption per guest-night in different seasons. Identify priority measures to reduce water consumption.	All accommodations
Periodic monitoring	Record water consumption periodically (daily, weekly, monthly), and check consumption during quiet times (e.g. early hours of the morning) to detect leaks.	All accommodations
Sub-metering	Divide premises into zones, install sub-meters and periodically monitor water consumption.	All accommodations
Continuous monitoring	Install complete continuous monitoring system, with automatic recording of flow at all sub-meter locations.	Large hotels
System inspection and maintenance	Regularly inspect equipment. Housekeeping inspection of taps, toilets and drain plugs. Technician inspection of valves, pipes, pipe-insulation, aerators, and equipment such as heat-exchangers. Repair or replace damaged equipment.	All accommodations
Avoid excessive pressure	Install pressure reducers at relevant points and adjust to the minimum pressure sufficient to supply the maximum flow rate required at those points.	All accommodations
Water conditioning	Install an electronic water conditioning system to 'soften' hard water by removing excess calcium and magnesium ions.	All accommodations
Adequate insulation	Make sure that all water pipes are adequately insulated to minimise heat transfer heating and cooling energy requirements.	All accommodations

Achieved environmental benefit

<u>Leak avoidance</u>

Even small individual leaks with barely perceptible flow rates can result in significant water wastage over a year, whilst modest leaks that may still be undetectable in accommodation premises can result in large wastage of hundreds of m^3 per year (Table 5.4). A number of small leaks throughout accommodation premises can contribute substantially to total water consumption, and easily result in cumulative wastage of thousands of m^3 per year in larger premises. Leaking toilet cisterns are common in accommodations. Analysis of data from a water monitoring study of eight rooms in one hotel led to the discovery of a leaking cistern in one room losing 380 litres per day that had gone undetected for at least the 90 days of the study.

Table 5.4: Water flow rates and daily/annual wastage from different types of leak

Leak description	Flow rate		Daily water loss	Annual water loss	Annual cost
	L/min	L/hour	L	m^3	EUR
One drip per second	0.003	0.17	4	1.5	2.92
Drips break to stream	0.063	3.8	90	33	65.70
1.5 mm diam. stream	0.22	13.3	320	117	232.36
3 mm diam. Stream	0.68	41	985	360	719.06
6 mm diam. Stream	2.43	146	3500	1 278	2 555.00
Source: Derived from data in Cridge (2000).					

Consequently, the avoidance of leaks through monitoring, inspection and maintenance can reduce water consumption dramatically. Figure 5.4 presents the monthly water consumption for a large hotel in central Paris over a period of four years, and indicates the quantity of water wasted by one single major leak detected in October 2010. In this case, a large diameter valve in a void space behind a wall was left open, letting 100 m^3 of water from a supply pipe flow directly into a waste water pipe undetected. The leak represented 30 % of total water consumption in 2009, and was discovered during renovation work. More detailed monitoring and benchmarking of water consumption (e.g. tracking consumption per guest-night) may have resulted in more rapid detection of the leak. An increase in specific consumption of 9 % per guest-night between 2007 and 2008 (Figure 5.4), despite a 10 % increase in guest-nights (the relationship between guest-nights and specific consumption is usually negative), reflects the impact of the leak on specific water consumption.

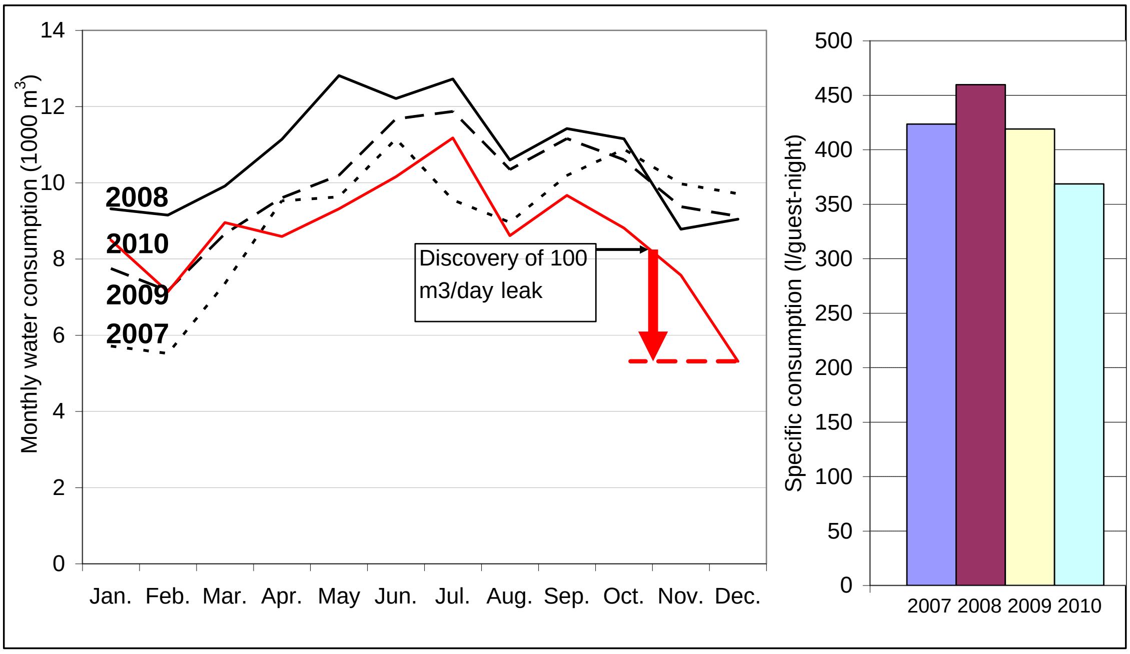


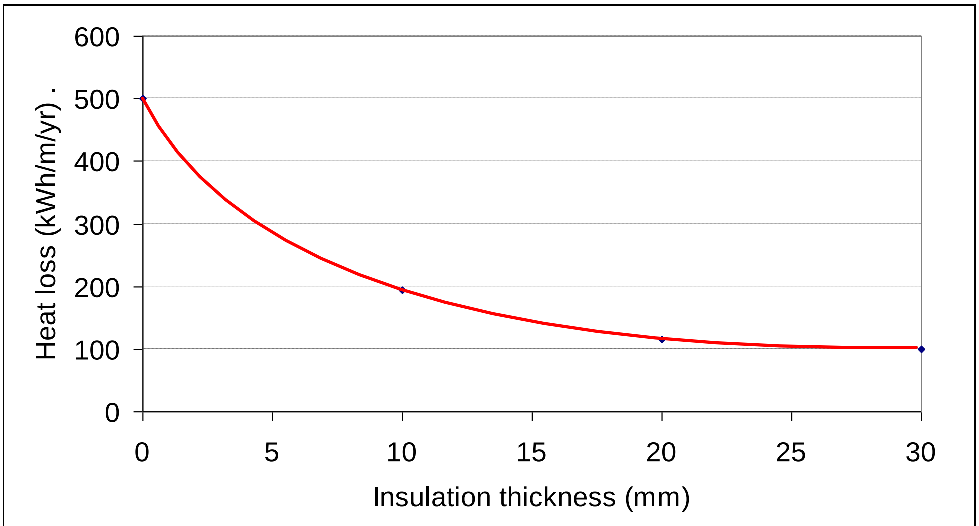
Figure 5.4: Monthly water consumption over four years for a large conference hotel (left), annual specific consumption (right), and the reduction in water consumption after repair of a major leak

Water management plans

Monitoring and reporting of water consumption is an integral component of water management plans with defined targets that can achieve substantial reductions in water consumption over time. For example, Accor have set a target to reduce water consumption by 10 % per occupied room between 2006 and 2010 in owned and leased hotels (Accor, 2011). Meanwhile, Scandic have been monitoring specific water consumption across hotels since 1996, and can consequently report that average water consumption per guest-night decreased by 25 % between 1996 and 2010 (see Figure 2.3 in section 2.1). The difference between the top tenth percentile of performers and median performance across mid-range hotels displayed in Figure 5.7 is 50 litres per guest-night, equivalent to 1 825 m^3 per year for a 100-room hotel.

Energy savings

For every m^3 reduction in hot water consumption, approximately 52 kWh of energy is saved, assuming water is heated by 45 ºC. Meanwhile, 20 mm of insulation can reduce heat loss by almost 400 kWh per year for every metre of large diameter (5 cm) piping (Figure 5.5).



Source: Derived from data in TUI Travel Plc (2011).

Figure 5.5: Effect of insulation thickness on heat loss from a 5 cm plastic pipe carrying water at 60 °C in an ambient air temperature of 25 °C

Appropriate environmental indicator

Performance indicators

The most appropriate environmental indicator for water use efficiency is water consumption per guest-night. The number of overnight guests is the primary determinant of water consumption for showers, toilets and basins, laundry processes and kitchen processes (Bohdanowicz and Martinac, 2007). 'Fixed' water use for some processes – e.g. pool maintenance and irrigation of green areas – can lead to an inverse relationship between water use per guest-night and occupancy rate (Gössling et al., 2011).

The EU Ecolabel for tourism stipulates that *'the tourist accommodation shall have procedures for collecting and monitoring data on overall water consumption (litres)…Data shall be collected where possible, monthly or at least yearly, for the period when the tourist accommodation is open, and shall also be expressed as consumption per overnight stay and per m^2 of indoor area'*.

Calculating water use per guest-night is a simple task:

$C_{GN} = (C_T \text{ x}1000)/N_{GN}$	
C_{GN}	Consumption (L) per guest-night
C_T	Total consumption in m^3 for the period of calculation (from utility bill or water meter readings)
N_{GN}	Number of guest-nights over the same period of calculation

To provide a robust average of water use efficiency that smooths out any seasonal variability, it is recommended to calculate water consumption per guest-night over an entire year. Note that water use is usually expressed in m^3 on water meters and bills and is multiplied by 1000 to be converted into litres. Where guest-night data are not available, occupied rooms or simply number of beds may be used as denominators (though the added value of the latter denominator is small).

Trends in specific water consumption over time provide a useful indication of progress in improving water efficiency. Figure 5.6 shows the distribution of trends for 97 hotels in a hotel group, and the trend in aggregate specific water consumption for the group, over a 10 year period. A wide range of performance can be observed, including deteriorating water efficiency for a significant portion of hotels, perhaps reflecting the installation of additional water-using facilities or more luxurious water fittings.

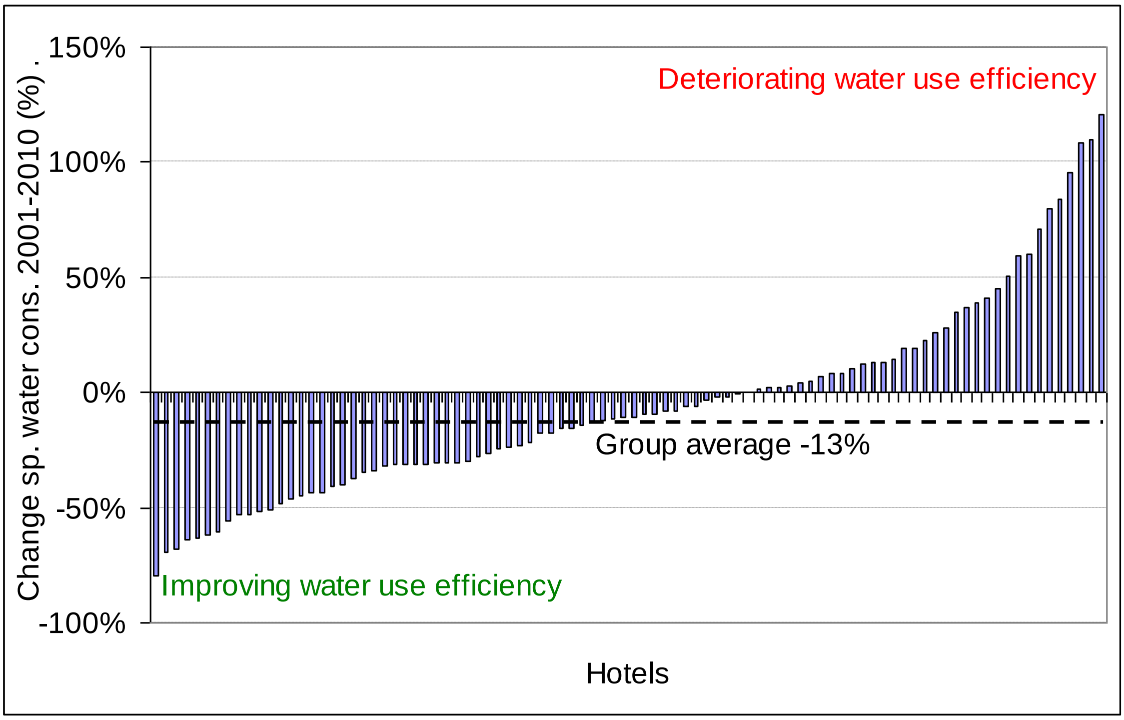


Figure 5.6: Change in specific water use for 92 hotels in a hotel group, and the change in total group specific water consumption, between 2001 and 2010

Management indicators

In addition to the above performance indicators, management indicators of best practice include:

- regular monitoring and recording of consumption;
- installation of water sub-metering for major water-using areas and processes (i.e. laundry, kitchen, pool and spa areas, cooling tower);
- establishment of an action plan to reduce water use, with measurable and scheduled; targets;
- all pipes carrying heated or chilled water are insulated;
- regular inspections are carried out to check for leaks;
- staff training to reduce water use (see sections 5.3 and 8.3, on housekeeping and kitchen water use, respectively).

Benchmarks of excellence

Two benchmarks of excellence are proposed for this BEMP, the first of which is a management indicator and the second of which is a performance indicator. The first benchmark is:

BM: implementation of a site-specific water management plan that includes: (i) sub-metering and benchmarking all major water-consuming processes and areas; (ii) regular inspection and maintenance of water system "leak points" and appliances

Various benchmarks have been proposed for overall specific water consumption in tourist accommodation, for example within *'Environmental, Health and Safety Guidelines for Tourism and Hospitality'* published by the World Bank's International Finance Corporation within (IFC, 2007) (Table 5.5). Other benchmarks for accommodation water use efficiency include those contained within the Nordic Swan ecolabel, ranging from 200 L/gn for basic ('Class C') accommodation to 300 L/gn for fully serviced ('Class A') accommodation. Ecotrans (2006) also propose benchmarks for different types of establishment.

Table 5.5: A selection of benchmarks proposed for water use in different types of accommodation

Accommodation type	Source	Benchmark (temperate)	Benchmark (Mediterranean)
		Litres per guest-night	
Camp sites	Ecotrans (2006)	96	
Bed and breakfast	Ecotrans (2006)	133	
Small serviced hotels	Ecotrans (2006)	213	
	IFC (2007)	200	220
	Nordic Swan (2007)	200	
Mid-range serviced hotels	IFC (2007)	350	450
	Nordic Swan (2007)	250	
Luxury serviced hotels	IFC (2007)	500	600
	Nordic Swan (2007)	300	

Figure 5.7 summarises the performance of individual hotels within a mid-range European hotel chain, and Hostelling International hostels in Switzerland. Based on tenth percentile best performers, and other values for mid-range hotels (Accor, 2010; NH Hoteles, 2011), the following benchmarks of excellence are proposed for total water consumption in fully serviced hotels with restaurants predominantly serving residents, and mid-range hostels.

BM: total water consumption ≤140 L per guest-night in fully serviced hotels, and ≤100 L per guest-night in accommodation where the majority of the bathrooms are shared across rooms (e.g. hostels).

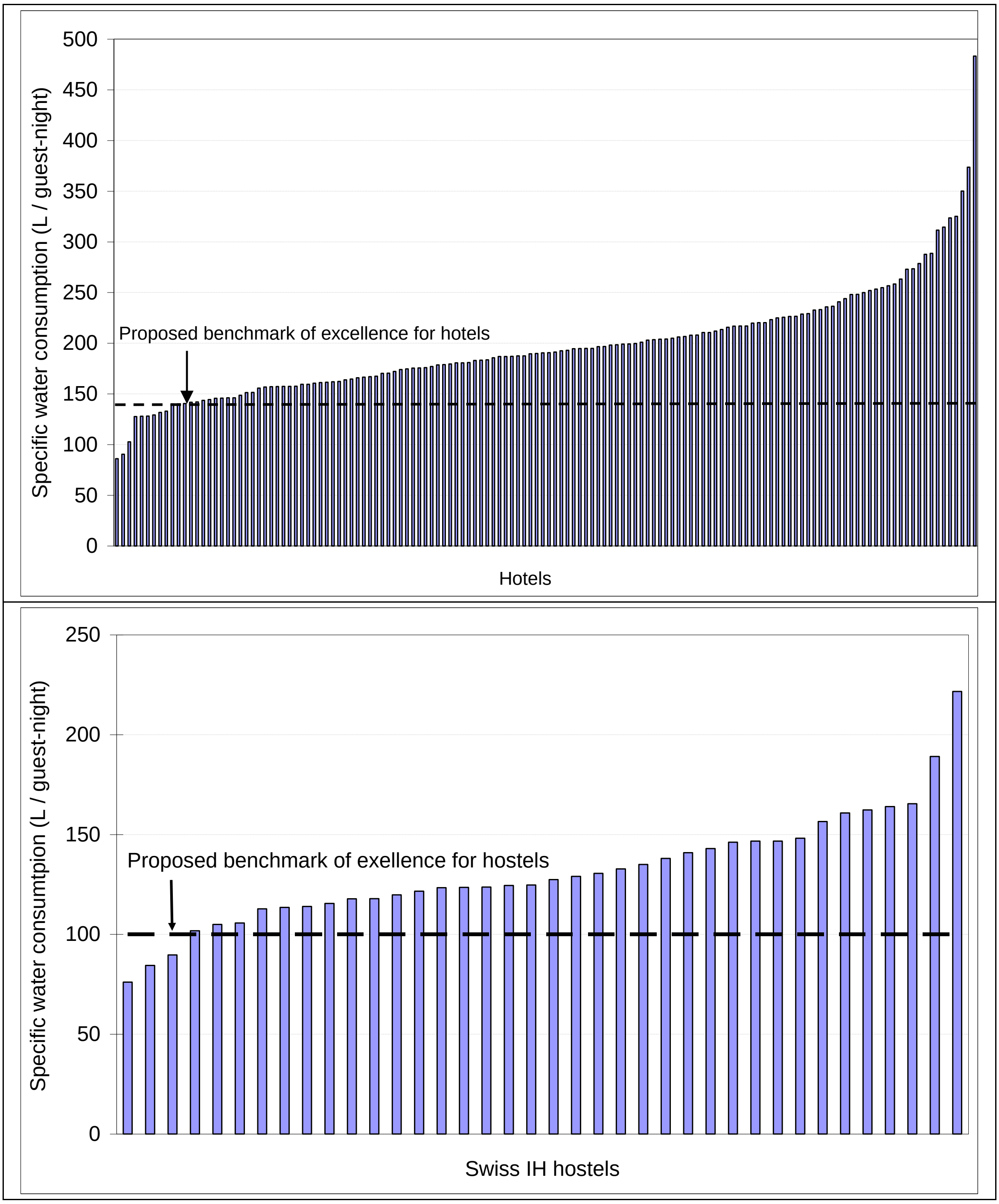


Figure 5.7: Distribution of water consumption, expressed per guest-night, for individual hotels within a large European hotel chain (above) and for Swiss hostels (below) used to derive benchmarks of excellence

The above benchmark for hotels may not be achievable where hotels have large swimming pools or restaurants serving a high proportion of non-residents. For one German hotel, water consumption is 146 L/gn within the dedicated accommodation area, but this increases to 204 L/gn including consumption in the kitchen that serves 216 400 non-resident diners per year (46 % of diners), and further increases to 256 L/guest-night including consumption in the swimming pool and spa area (Figure 5.8).

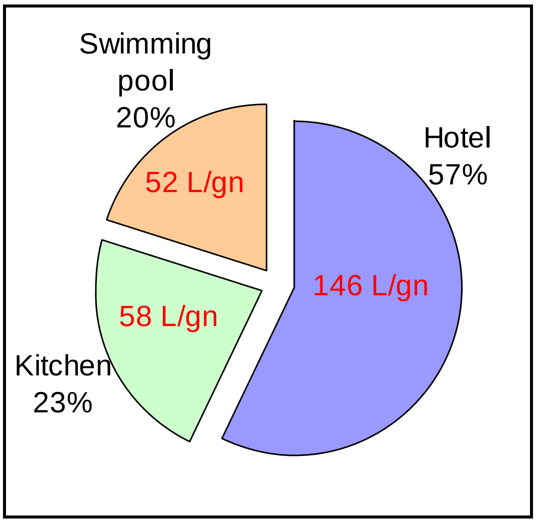


Figure 5.8: Water consumption in three areas of a German hotel

Cross-media effects

There are no significant cross-media effects associated with this technique. Reducing water consumption leads to a reduction in the quantities of chemicals and energy required to treat and pump water. Reducing hot water consumption leads to a considerable reduction in energy use for water heating.

Operational data

Monitoring and leak detection

Managers in all types of accommodation may perform a basic audit of water using equipment to compare with water consumption data in order to draft a water balance. For the water inflow, annual water consumption can be taken from water bills (actual rather than estimated readings should be used). Flow rates from taps and showers can be easily measured according to the following procedure: (i) turn on the tap or shower to full flow; (ii) place a container of known volume (e.g. 5 litres) under the flow; (iii) time how many seconds it takes to fill the container to the indicated volume mark; (iv) calculate the flow rate using the following equation:

F = (V/t) x 60		
F	flow rate	L/minute
V	volume of water in container	L
t	time taken to fill container	seconds

This process can be performed for the different types of fittings throughout the premises and can be multiplied up by the number of such fittings and estimated use rates (average frequencies and durations of use). Water consumption for processes occurring in large equipment such as washing machines and dishwashers can be estimated from technical information and estimates of usage rates. The information obtained from this procedure can be tabulated or inserted into a flow-chart, and compared with best practice water consumption for different fittings and processes (e.g. contained in this document) in order to identify priority measures to reduce consumption. Water consumption data can be divided by the number of guest-nights in order to benchmark performance, as described under 'appropriate environmental indicator'. These benchmarks should be used as a basis for continuous improvement targets.

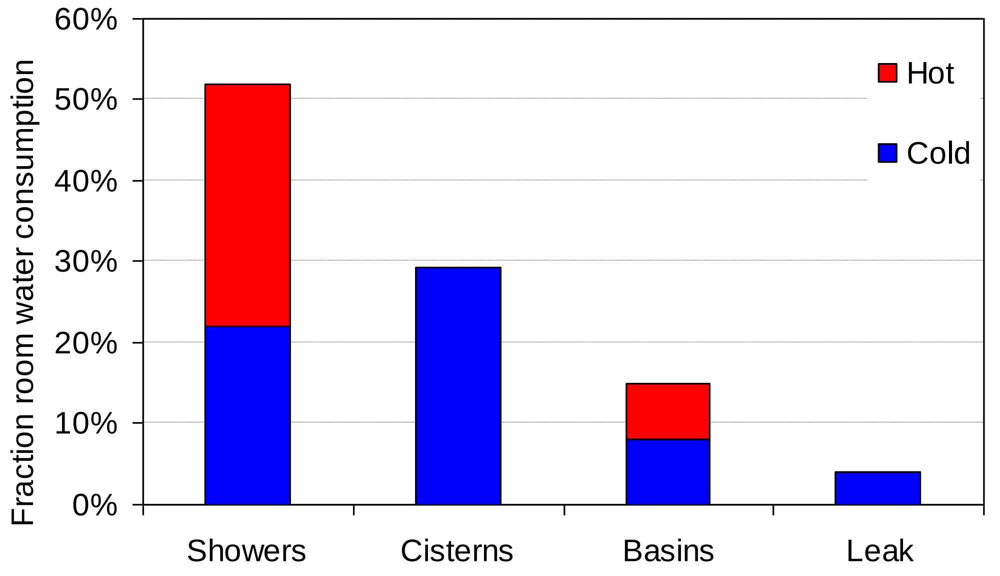
For more detailed auditing of water consumption and leak detection in larger premises sub-metering is required. Inexpensive mechanical water meters can be fitted at fixed positions within the distribution system and require periodic replacement.

Ultrasonic meters are relatively expensive, but may be clamped on to the outside of pipes and moved to different positions in order to audit consumption in different zones or to check for leaks. Flow meters should be installed or clamped at the inflow points to different zones within the hotel, and preferably attached to electronic recorders in order to provide information on daily patterns of water consumption that help to isolate the effect of different processes or leaks.

Records of water consumption should be analysed monthly to identify any irregular patterns. In addition to the main accommodation zone(s), priority zones for water sub-metering include:

- kitchens
- laundry areas
- public toilets
- pool areas
- feed lines to steam heat-exchangers.

Figure 5.9 presents results of an intensive sub-metering study of eight guest rooms in one hotel performed by engineers from the Polytechnic University of Valencia. Ultrasonic meters were clamped to all feeder pipes in the eight bathrooms in order to monitor hot and cold water consumption across all fittings. Data were logged automatically, providing insight into the frequency, duration and intensity of water consumption across different fittings, and demonstrating water savings achievable from the installation of low-flow fittings (see section 5.2).



NB: Aerators fitted to showers and basin taps.

Figure 5.9: Breakdown of water consumption across eight rooms in a hotel obtained from a study employing sub-metering of flow rates through pipes to individual fittings

Water systems and equipment should be inspected at least every six months, including all fittings (Business Link, 2011). Points for particular attention include:

– toilet cisterns

- all taps
- basin drain plugs
- urinal flush-control systems
- HVAC circuits (especially heat exchangers)
- dishwashers.

On small premises, inspections may be performed by managerial or cleaning staff. Cleaning staff should be trained to identify and report leaks during the cleaning routine. Leaking toilets (e.g. flapper valves) are common but difficult to detect. Food colouring may be added to the cistern water to identify slow leaks into the toilet bowl. Water meters can also be checked late at night (~00:00) and early in the morning (~05:00) to identify unexpected water consumption during low water use periods that may indicate leakage.

On larger premises, visual inspection of accessible fittings may need to be supplemented with more sophisticated inspection to detect leaks within extensive piping networks. Methods for such inspection include the use of leak detector cables and highly absorbent sensing tape to detect small leakages (EC, 2012).

Automatic leak detection systems based on detector cables, or 'water fuses' that cut-off water when unexpected flows occur, may also be installed alongside water piping during construction or extensive renovation of large premises. Water fuses can detect low continuous flows down to two litres per hour (Environment Agency, 2007).

Accor in France pool resources across the hotel group to target priority hotels. A national team composed of specialised regional technicians periodically congregate at specific hotels within the group identified by group-wide benchmarking as having high specific water consumption. The team conducts an intensive inspection of the hotel's systems and water-using equipment.

System optimisation and maintenance

The water flow rate from fittings is exponentially related to pressure (pressure is related to the square of velocity according to Bernoulli's equation). Even where flow restrictors are fitted, system pressure can significantly influence flow rate (see Table 5.10 in section 5.2). Higher system pressure can increases the risk and magnitude of leaks. Most fittings, such as bathroom fittings in guest rooms (including high-performance low-flow fittings), operate well with a system pressure of one bar. Even fittings and appliances that may require higher pressure to operate effectively, such as pre-rinse spray valves in the kitchen or pressure-assisted flush toilets in public areas, do not require more than two bar pressure (see section 5.2). The main reasons to maintain high pressure, above two bar, in the distribution system are to:

- ensure an adequate flow rate at times of peak demand – which can be high on accommodation premises owing to the potential for simultaneous demand across a large number of rooms (e.g. morning or evening showers);
- enable the use of smaller diameter pipes, resulting in lower heat loss through reduced lag run time.

Extensive specification of low-flow fittings can considerably reduce peak water demand and thus enable lower-bore pipes and/or lower system operating pressure. Larger diameter pipes lose more heat than smaller diameter pipes (Figure 5.10), and result in longer lag times, but potentially lose less heat per L flow. Careful specification of pipe sizes and layout (e.g. number of fittings served by individual pipes) during plumbing installation is a critical factor to ensure efficient operation in terms of: (i) meeting the pressure needs of all appliances, even at peak demand; (ii) minimising lag times by avoiding over-sized pipes; (iii) reducing the risk of leaks and excessive flow rates by reducing operational pressure. Pressure reducers may be installed at strategic points within the distribution system in order to avoid excessive pressure at fittings.

Heat losses from pipes are proportionate to the temperature difference between the water inside and the surrounding temperature (Figure 5.5), so that in an ambient temperature of 20 ºC water at 60 ºC loses twice as much heat energy per metre of piping as water at 40 ºC. Reducing excessive water temperature is an effective measure to reduce heating energy demand. A water temperature of 40 ºC at the point of use is sufficient for guest bathrooms, and regulations in some countries restrict the maximum temperature of hot water in commercial and public buildings. Separate boiler systems should be installed for hot water and central heating systems to avoid overheating of hot water based on heating system temperature requirements. One universally applicable best practice measure is to ensure adequate thermal insulation of all hot water pipes (see Figure 5.5).

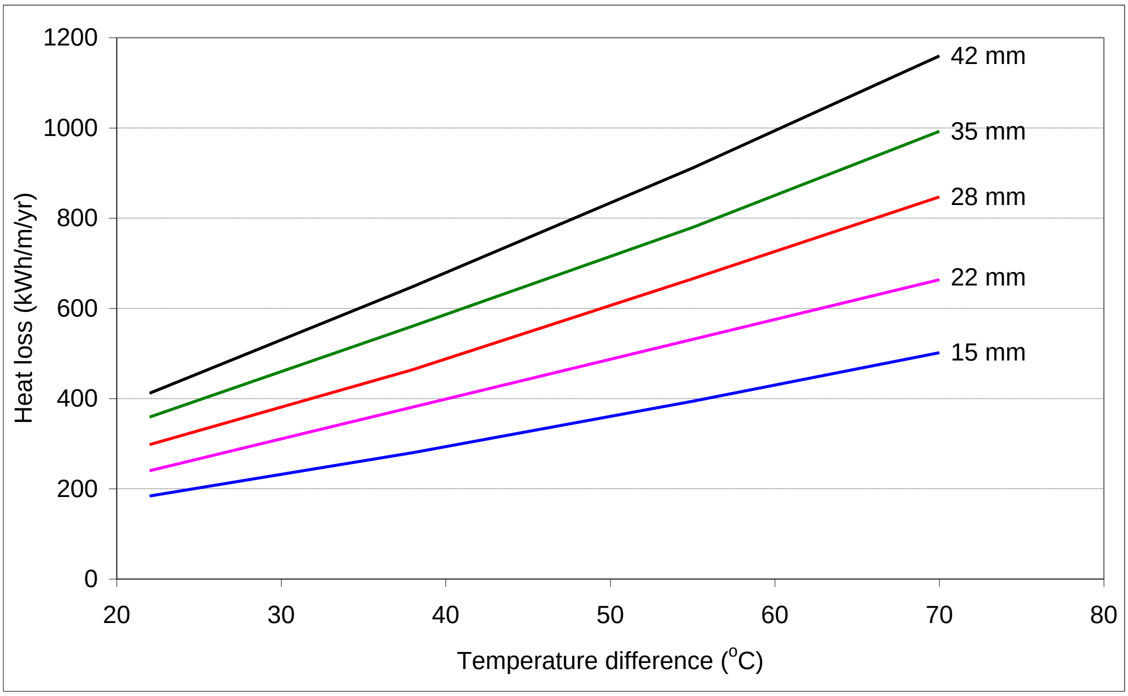


Figure 5.10: Heat loss from un-insulated copper piping of various diameters according to the temperature differential between the water flowing through them and surrounding air

It is imperative to refer to relevant national legislation on water system hygiene, particularly with respect to the minimisation of risk from Legionella bacteria. Usually, water systems above a specified capacity must be heated to at least 60 ºC, though this may be implemented periodically.

Another important best practice measure is to install a water conditioning system, especially where water contains significant levels of carbonates. This is recommendable on all premises, and can significantly increase the lifetime and efficiency of water appliances. In the absence of a centralised system, individual water conditioning systems are required for appliances such as dishwashers (section 8.3).

Other measures that can improve overall system efficiency and reduce leaks include:

- installation of taps with ceramic disc valves instead of screw-down valves with rubber washers that are more susceptible to wear and eventual leakage;
- fitting of long-life rubber O-rings when replacing worn seals or (retro-)fitting plumbing fittings;
- routine replacement of aerators, at least every six years;
- ensuring that basin drain plugs have a good seal, so that guests can use the basin for tasks such as shaving instead of leaving a tap running.

Applicability

Monitoring and maintenance is applicable as a best practice technique for all types and sizes of accommodation. In small organisations (SMEs), monitoring may simply involve recording total water consumption at (at least) monthly intervals based on meter readings.

The Henllys (Old Couthouse) Hotel in Wales provides an example of an SME benefitting from monitoring. The management of this small 10 room hotel noticed an unusual consumption pattern and inspected their water system. A 900 L/day leak was tracked down to a leaking pipe that supplied an out building. Fixing the leak saved 330 m3 of water per year and GBP 270 per year in water supply costs (the hotel is not connected to the mains sewer network).

Economics

A mechanical flow meter costs in the region of EUR 300[7] whilst a portable ultrasonic flow meter can cost approximately EUR 2000[8], whilst flow monitors cost approximately EUR 400[7]. These investments may be recouped within a few years where monitoring helps to reduce excessive water consumption and avoid leaks.

At a water supply and disposal price of EUR 2.50 per m3, a single leaking toilet wasting 750 litres per day could cost over EUR 684 per year, whilst reducing consumption by 5 % in a typical 100 room hotel with an average consumption of 200 L per room per night could save EUR 913 per year. In the example presented in Figure 5.4, the cost of the 100 m3 per day leak was almost EUR 100 000 per year, at a water price of EUR 2.73/m3.

Cost savings from reductions in hot water consumption are considerably higher. For an average food and hospitality business, the full cost of water use and disposal was found to be almost ten times higher than the supply cost alone, with 80 % attributable to heating (assuming electric heating to 60 ºC) (Smith et al., 2009). The cost of water use, and value of water savings, can be calculated from the following equation (elaborated in Table 5.6) :

$$C_T = V_T \times (C_S + C_D) + V_H \times (\Delta T \times SC_W \times (1/E_{EN}) \times C_{EN})$$

Table 5.6: Elaboration of terms in the water cost equation

Term	Abbrev	Unit	Typical values
Total cost	C_T	EUR	
Total volume consumed	V_T	m^3	
Supply cost	C_S	EUR/m^3	EUR 2 – 4 (EU average EUR 2) combined supply and disposal cost (EC, 2009)
Disposal cost	C_D	EUR/m^3	
Volume heated	V_H	m^3	
Heating temperature increase	ΔT	ºC	30-80 ºC
Specific heat capacity water	SC_W	kWh/m^3/ºC	1.16
Heating efficiency	E_{EN}	Fraction	0.85 (oil boiler) to 0.99 (electric heater)
Cost of energy	C_{EN}	EUR/kWh	EUR 0.06/kWh for gas up to EUR 0.22/kWh for electricity (Energy.EU, 2011)

[7] http://www.kimray.com/LinkClick.aspx?fileticket=qOCSQItnW7U%3D&tabid=192&mid=749

[8] http://www.globalw.com/catalog.html

Driving force for implementation

The main driving force for implementation of monitoring and maintenance is to identify water use efficiency options and to detect and prevent leaks, thereby reducing costs associated with excessive water consumption and wastage, and reducing costs associated with water heating (see 'economics' section). In addition, it is becoming common for hotels to report their specific consumption in annual sustainability reports, which requires monitoring.

National, regional or local governments may provide incentives in the form of subsidies or tax breaks to encourage installation of water efficient fittings. For example, in the UK, the Enhanced Capital Allowance scheme allows business to deduct the capital cost of water-saving equipment from taxable profit in the year of purchase (http://etl.decc.gov.uk/). Equipment covered by the scheme relevant to this technique includes:

- flow controllers
- meters
- leakage detection
- pipe work insulation.

Reference organisations

Accor Hotel Group, Scandic Hotel Group.

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5.2 Efficient water fittings in guest areas

Description

Guest areas are defined as guest rooms, public toilet and gym/spa changing areas within accommodation enterprises. The installation of efficient water fittings also applies to public areas in other tourism establishments, such as bars and restaurants, and is cross-referenced by section 9.4 dealing with water efficiency in campsites. In a non-optimised hotel, water consumption in guest rooms can be over 200 litres per guest-night, and represents almost half of the total water consumption (Figure 5.2), assuming flow rates of 12 L/min for taps, 15 L/min for showers and 12 L/flush for toilets. These flow rates can be up to twice as high, depending on the equipment installed. High end luxury hotels may provide multi-head or large-head showers using in excess of 20 L/min and large bath tubs (>300 L) as part of their premium offer. Eurostat (2009) attribute comparatively high water use in hotels to 'a pleasure approach' taken by tourists to showering and bathing. Showers can account for over 50 % of direct water use by guests in hotels (Smith et al., 2009).

Water consumption in public spaces is highly variable, and depends on the services offered in the hotel and the number of day visitors, but can make a considerable contribution to total water consumption. For example, one urinal flushing continuously four times per hour can consume over 400 L/day, and a leaking toilet in a public area can waste up to 750 L/day (ITP, 2008). Meanwhile, showering facilities provided in pool, spa and gym areas can be associated with intensive water consumption. Taps in public areas may be left open or not fully closed.

In addition to maintenance and optimisation of the water system (section 5.1), there are four approaches for accommodation managers to reduce water use in guest areas, for a given level of service:

- install efficient water fittings;
- retrofit flow restrictors (aerators and/or pressure regulators);
- encourage guests to save water through information notices;
- train staff to save water during cleaning operations.

The installation of efficient water fittings selected through green procurement is the most effective approach, owing to the high saving potential of more efficient fitting types and the relatively high frequency of replacement (EC, 2009). The latter two approaches are described in more detail in section 5.3 that addresses housekeeping. Table 5.7 provides an overview of the main fittings that may be installed to reduce water consumption, and their applicability. Selection of the most efficient fittings during construction or renovation offers high saving potential. For example, new low-flush toilets are available with flush volumes of four litres for a full flush (Plumbing Supply Services, 2011), urinals are available that do not require any water for flushing (Green building store, 2009), taps are available with flow rates as low as two litres per minute and showerheads are available with flow rates as low as five litres per minute. However, there are also many retrofit options that enable considerable savings to be realised at relatively low cost, most notably aerators, flow-restrictors and efficient showerheads (Table 5.7). Figure 5.11 presents measured flow rates before and after the installation of aerators in the fittings within a hotel. Some of these options may not be applicable where water pressure is low or electric showers are used, as is common in the UK and Ireland for example.

Where low flow fittings are installed, guests may be notified of the benefits of these devices. Guest behaviour is an important driver of water consumption. One reason for higher water consumption in hotels and other accommodation establishments is a 'pleasure effect' – i.e. guests like to relax under a hot shower or in a bath during their stay (Eurostat, 2009). Reusing towels and bed linen is an important way to reduce water, energy and chemical consumption that is described in section 5.3. Other ways that guests can reduce water consumption include:

- taking a shower instead of a bath (where there is a choice)

- taking shorter showers
- turning off taps when brushing teeth and shaving
- selecting the low flush option on dual-flush toilets.

These messages can be conveyed to guests by putting up prominent notices in bathrooms.

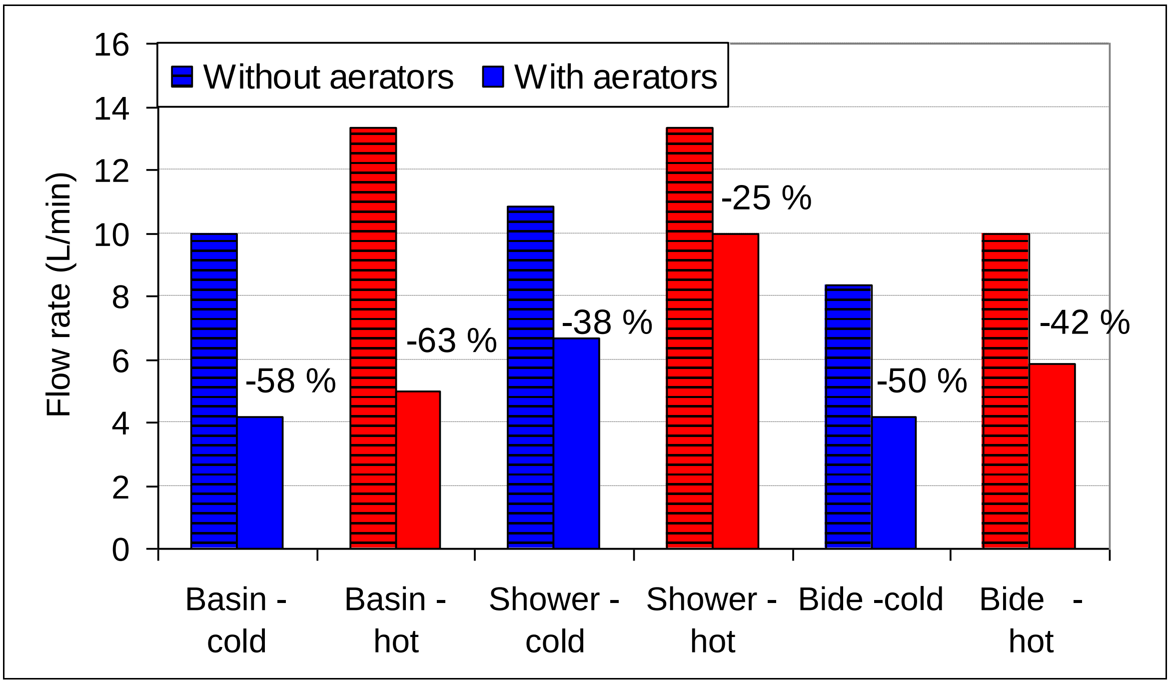


Figure 5.11: Measured cold and hot water flow rates from hotel fittings before and after installation of aerators

An innovative solution to reduce shower water consumption that recognises the 'pleasure effect' sought by guests is to install a water recirculation system into the shower. After washing using a standard low-flow showerhead, the guest may choose to close the drainage valve in the deep shower tray, activating a pump that recirculates the water through a large overhead 'rainshower' head via an electric heater, thus enabling water use to be curtailed for the non-washing fraction of the shower, and for showers to be prolonged without increasing water consumption.

Rainwater may be used for toilet flushing and even showers, and grey water for toilet flushing. Water recycling is described in section 5.7.

Table 5.7: Summary of the main fittings that can be installed as either simple retrofits to existing fittings, or as complete new fittings during construction/renovation to reduce water consumption in guest areas

Feature	Fitting	Description	Saving	Applicability
Showers	Aerator/flow regulator	(Retrofit) Aerators are simple vacuum valves with an air intake that can be easily retrofitted between the tap and hose, or between the hose and showerhead. They introduce air into a pressurised water flow that expands when exiting the valve to create the feeling of higher flow rate, whilst generating less splashing to achieve a greater wetting efficiency. They may be combined with flow regulator valves that adjust flow space in response to pressure, ensuring a set maximum flow rate.	Up to 50 % reduction (6 L/min) in flow rate	Universal where pressure at least one bar
	Low-flow showerheads	(Retrofit) Low flow showerheads may incorporate aerators, or nozzle designs that generate fine droplets in an efficient spray pattern.	Up to 50 % reduction (6 L/min) in flow rate	Universal, when fitting new showers
	Thermostatic mix valves	(Renovation) Thermostatic mixer valves are fitted during shower installation, and adjust the ratio of hot to cold water to ensure a constant temperature, potentially reducing water wastage during temperature adjustment.	Up to 3 L per shower(*)	
	Push-button timers	(Renovation) Push-button timers are mechanically operated by a pinhole within a diaphragm, and close after up to 30 seconds.	27 L per shower(**)	Spa and pool areas, hostels, campsites
	Water recirculation	A pump recirculates water collected in a deep shower basin to an overhead rainshowerhead via an electric heater, activated by the user closing the drainage valve in the shower basin.	27 L per shower**	
Toilets	Low-flush	(Renovation) New low-flush gravity toilets with optimised cistern and bowl designs use between four and six litres per full flush.	6 L per full flush	Universal, when fitting new toilets
	Dual flush mechanism	(Retrofit) Dual flush mechanisms are usually incorporated in new low-flush toilets, but may also be retrofitted to existing cisterns. These mechanisms consist of two buttons that allow the selection of a full flush (e.g. 6 L) for solid materials or a half flush (e.g. 3 L) to flush urine. Average water use is calculated assuming one third of flushes are full flushes and two-thirds are half-flushes.	33 %	Universal, new or retrofit
	Cistern displacement device	Bags of water, granules or pebbles may be inserted into the cistern to reduce the water volume, or the float-arm may be adjusted to reduce the fill level.	0.5 – 2 L per flush	When fitting new frequent use public toilets
	Delayed action inlet valve	Delayed action inlet valves delay inflow into the cistern until the outflow valve is closed, reducing flush volumes by up to one litre	Up to one L per flush	Older high-volume cisterns

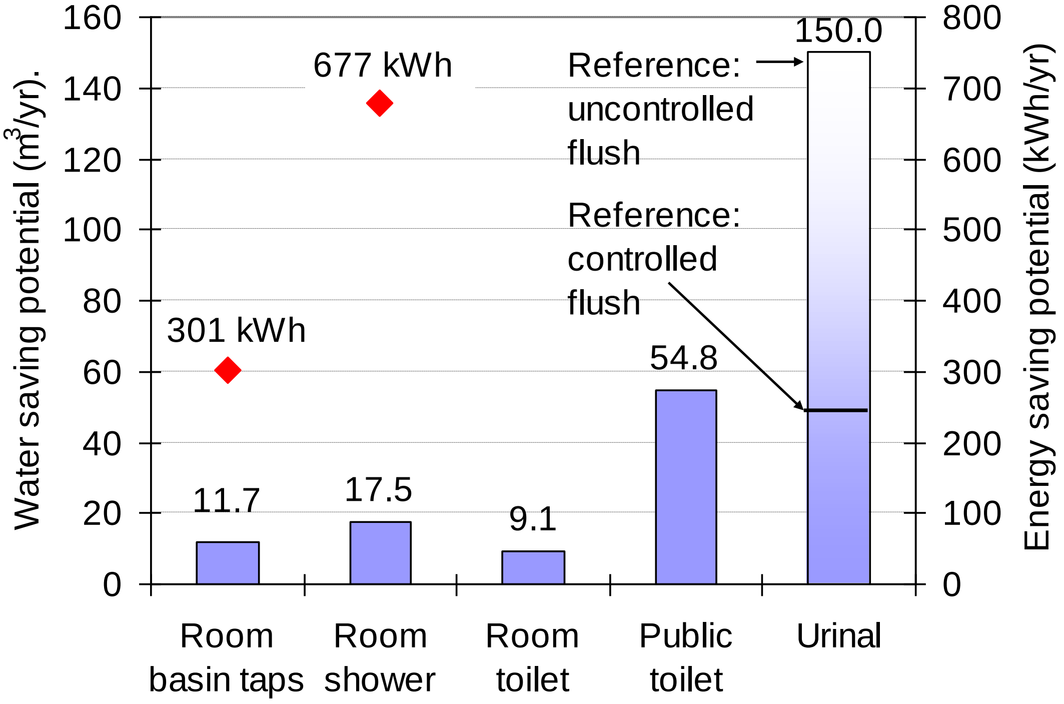
Feature	Fitting	Description	Saving	Applicability
	Siphon-valve	(Renovation) Cisterns with siphon valves instead of simple push ('flap') valves controlling water flow into the bowl are more expensive but less prone to leakage.	Up to 150 L/day(***)	
	Pressure-assisted	(Renovation) Pressure-assisted toilets can either use a sealed plastic tank containing pressurised air separated by a rubber diaphragm to maintain supply pressure, or an adjustable volume-control valve that directly feeds off the pressurised water supply to flush the bowl (at least 3/4 inch pipe and 2 bar pressure required). These are particularly suitable in heavily used public toilets.	Up to 8 L per flush	
Taps	Aerator/flow regulator	(Retrofit) As for showers, aerators with or without flow regulators can be easily retrofitted by screwing on to the ends of taps to reduce the flow rate whilst maintaining wetting effectiveness and perceived flow.	Up to 50 % reduction in flow rate	Universal where pressure at least one bar
	Spray taps	(Renovation) Spray taps integrate flow regulators and aerators with a spray pattern that maximises wetting effectiveness and flow perception, enabling flow rates as low as 2 L/min.	Up to 80 % reduction in flow rate	
	Self-closing taps	(Renovation) Self-closing valves are activated by a simple push-button or passive infra-red sensor, and are mechanically controlled to close after one to 30 seconds. They can be installed on taps in public areas and in showers in lower grades of accommodation to reduce flow times.	Variable(****)	Spa and pool areas, public toilets, staff toilets, hostels and campsites
Baths and basins	Low volume designs	Select low volume basins with optimised design basins, and bath tubs (e.g. body shaped) where necessary, for installation. Accounting for an average body volume of 70 L, low-volume baths require 60 L to fill compared with up to 230 L for some baths.	Up to 170 L per bath	
Urinals	Low-flush urinals	Low-flush urinals require a maximum of 1.5 L per flush, and may be bought new or installed through retrofitting of existing urinal cisterns to reduce flush volume as described for toilets (above).	Up to 3 L per flush	Public toilets (and staff facilities) in hotels and restaurants, toilets in hostels and campsites
	Flush timing control	Various mechanisms can be installed to control the timing of flushes, including detection devices based on infrared sensors or hydraulic valves, user-operated valves, or timers set at regular intervals during operating hours (as few as four flushes per day may be acceptable).	Up to 300 m^3 per urinal per year	
	Waterless urinals	Waterless urinals may be bought new or installed through the retrofitting of existing urinal systems. Waterless urinals are designed to drain urine with no flushing while maintaining hygienic conditions and containing odours, using either: (i) a spring-loaded flap; (ii) a layer of oil floating on the surface of the trap liquid; (iii) plastic pads impregnated with chemicals to destroy bacteria and odours, inserted into the S-bend; (iv) weak negative pressure in the waste pipe induced by a small fan.		

(*)Assuming reduction of 20 seconds in temperature adjustment, at 9 L/min.
(**)Assuming reduction of three minutes in (non-recirculated) shower duration at flow rate of 9 L/min.
(***)Up to 750 L/day from leaking toilet (ITP, 2008), approximately 20 % of toilets leaking.
(****)Depends on use pattern, user behaviour assumptions for user-controlled taps, and settings (in some circumstances, use can be higher than for user-controlled taps: EC, 2009).
Source: EC (2009); Environment Agency (2007); ITP (2008).

Achieved environmental benefit

In terms of total water savings in guest areas, installing low-flow showers throughout all guest rooms can achieve the greatest total savings, reducing typical guest water consumption by almost 10 % (Figure 5.3). This is followed by replacing bathroom taps (reduces total water consumption by approximately 5 %) and toilets (reduces total water consumption by approximately 3.5 %).

However, expressed **per fitting**, the greatest savings are associated with the installation of waterless urinals (up to 150 m3 per urinal per year) and low-flush (including dual flush) public toilets (up to 55 m3 per toilet per year) (Figure 5.12). Savings for individual low-flow showers, low-flow basin taps and low-flush toilets equate to annual savings of 17.5, 11.7 and 9.1 m3/yr, respectively. Reduced use of hot water in low-flow taps and showers can save 301 and 677 kWh per fitting, respectively (Figure 5.12), conservatively assuming that on average the temperature of water used in showers and taps and showers has been elevated by 30 ºC and 20 ºC, respectively, using a 90 % efficient boiler.



NB: Assumes five toilet flushes (includes cleaning flush), six minute shower and six minutes use of basin taps per guest-night (includes two minutes cleaning use), 80% occupancy (of which 25 % double occupancy), 30 flushes per day for public toilets.

Figure 5.12: Annual water savings (m^3) and energy savings (kWh) per fitting achievable by implementation of best practice compared with average practice

Appropriate environmental indicator

The most appropriate environmental indicator for water efficiency of taps and showers is flow rate expressed in L/min, as provided in technical specifications or measured. For example, Accor (2007) recommend maximum flow rates of 6 L /min for taps and 12 L / min for showers. The effective flush volume of toilets is the most useful indicator of the design efficiency of installed toilets that accounts for flushing reductions achieved by dual flush mechanisms. The BREEAM sustainable building standard for offices specifies a maximum effective flush volume of 4.5 L per flush, whilst Accor (2007) recommend a maximum flush volume of 7 L for toilets. Meanwhile, compulsory criteria for the award of the EU Ecolabel to tourist accommodation (2009/578/EC) and camp sites (2009/564/EC) require that: (i) flow rates do not exceed 9 L/min for taps (excluding kitchen and bathtub taps) and showerheads; (ii) All urinals shall be fitted with either automatic (timed) or manual flushing systems so that there is no continuous flushing.

Energy consumed to heat hot water is also an appropriate environmental indicator, although it may be difficult to isolate energy consumption for heating of hot water used in guest areas from other demands for hot water, including kitchen, laundry and space heating (depending on system design). ITP (2008) propose benchmarks for water heating of 4.5 and 4.0 kWh/guest-night for luxury hotels located in temperate and Mediterranean areas, respectively.

Table 5.8: Proposed benchmarks of excellence for water use in guest areas

Aspect	Best practice	Quantitative benchmark
Shower fittings	Low-flow showerheads, aerators and flow-restrictors	Average shower flow rate ≤7 L/min
Retrofitted tap (except bath)	Aerators and flow-restrictors	Average tap flow rate ≤6 L/min
New tap fittings(*) (except bath)	Spray taps	Average flow rate ≤4 L/min
Toilet	Low-flush, dual-flush	Average effective flush ≤4.5 L
Urinal	Waterless urinals	Average urinal water use ≤2.5 L/person(**)/day
Guest information	Prominent notices in all bathrooms on water-saving measures	NA
Total water use in guest areas	Implementation of all above measures	Average water use in guest areas ≤100 L/guest-night(***)
Energy for heating water in guest areas	Implementation of above measures and system optimisation (section 5.1)	3.0 kWh/guest-night(****)
(*)Recent retrofit. (**)Based on average use rate. (***) See Figure 5.3. (****) based on heating 60 L water by 40 ºC.		

The information above is distilled into the following benchmarks.

BM: water consumption, and associated energy consumption for water heating, of ≤100 L and 3.0 kWh per guest-night, respectively, for ensuite guest bathrooms.

BM: shower flow rate ≤ 7 L/min, bathroom tap flow rate ≤6 L/min (≤ 4 L/min new taps), average effective toilet flush ≤ 4.5 L, installation of waterless urinals.

The former benchmark does not apply to accommodation where the majority of bathrooms are shared across rooms (see separate benchmark for such accommodation in section 5.1). Energy consumption in the former benchmark may be estimated based on hot water consumption in guest areas (see Table 5.6 and associated equation in section 5.1). In practice, it may not be possible to measure performance in relation to the former benchmark (depending on the level of sub-metering in place), in which case the latter benchmark indicates best practice.

Cross-media effects

Reducing water consumption in guest areas through installation of efficient fittings can also significantly reduce energy consumption for water heating, and is not associated with any significant cross-media effects. Correctly installed and operated waterless urinals do not require significant additional quantities of cleaning chemicals.

Operational data

Green procurement

Green procurement of water fittings and building specifications decided during design, construction and renovation are critical to reducing water consumption. Accor's International Sustainability Guidelines document (Accor, 2008) contains a section with recommended efficient fittings and fixtures, including the installation of flow regulators to all basin taps and showers to achieve maximum flows of 6 L/min, and the installation of infra-red sensors on public toilet urinals and taps.

Showers

A range of installation features related to the water system, mixer controls and showerhead control water use in showers (Table 5.9). Shower mixer valves may be controlled by manual operation of taps, or via a thermostat. Control of both shower flow and temperature via hot and cold taps is imprecise and can be time consuming, thus wasting water. The risk of scalding is also higher. Thermostatic mixers maintain a specific water temperature, adjusting for flow and pressure variations, according to calibrated settings. They enable precise and rapid temperature control at different flow rates, allowing water flows to be stopped and restarted quickly – e.g. to apply shampoo (Environment Agency, 2007). Thus, the relatively high investment cost for thermostatic mixers (compared with other bathroom fittings) is justified in terms of guest comfort and reduced water consumption.

Table 5.9: The main fixed features that affect water use in showers

Supply system	Controls	Head design
– Boiler warm up time – Pipe dead-leg – System pressure (and stability)	– Precision and speed of temperature adjustment – Compensation for pressure and flow	– Flow restrictor – Aeration – Droplet size – Spray pattern – Size

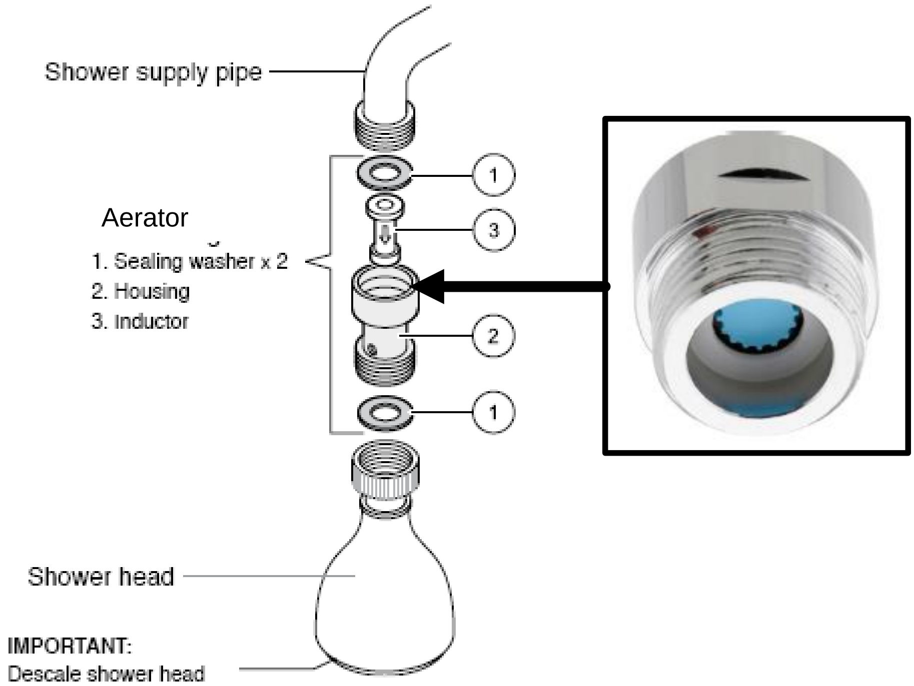
Ceiling fitted rain showers consume large quantities of water, and should be avoided. For example, Accor (2008) recommend maximum flow rates of 9 – 12 L/min for normal showers and 20 L/min for ceiling rain showers. Low-flow showerheads can be purchased and retrofitted onto existing showers, and typically achieve flow rates of 5 – 9 L/min. Design features include in-built aeration and sometimes flow restrictors, nozzles to minimise water droplet size, and spray patterns that match the body cross-section. Designs that produce small droplets are sometimes associated with 'cold feet' owing to rapid droplet cooling. The performance of low flow showerheads varies, partly in response to pressure, and it is important to test a type of showerhead on the premises before deciding to install it widely. A pressure of at least one bar is required for effective operation, and low-flow showerheads may not work on electric-showers or gravity-fed systems that are extensive in the UK and Ireland. Flow rate is exponentially related to pressure (pressure is related to the square of velocity: Bernoulli's equation), and system pressure therefore has a dramatic effect on flow rate in most showerheads that do not contain pressure restrictors. Even low-flow showerheads with inbuilt flow-restrictors can still use two-thirds more water than necessary when system water pressure is high (Table 5.10). These points emphasise the need to:

- regulate system pressure (section 5.1)
- trial low-flow fittings, especially showerheads, before committing to a specific type/model for the entire premises.

Table 5.10: Flow rate in response to pressure from a low-flow showerhead with flow restrictor

Pressure (bar)	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
Flow rate (L/min)	3.6	5.1	6.3	7.0	7.9	8.6
Source: Grohe (2011).						

A lower cost option to reduce shower flow rates is to install aerators with built-in flow restrictors. These are small devices that can be screwed into standard fittings, between the fixed pipe and hose, or between the hose and showerhead (Figure 5.13). These devices are inexpensive but require periodic cleaning and replacement as they can become blocked (especially where water is hard).



Source: Challis (2011) and Bristan (2011).

Figure 5.13: Installation of an aerator in a shower feed

Push valves are a useful mechanism to control shower duration in public areas such as pool and spa changing areas, or hostel and campsite showering facilities. They may comprise a pinhole or cartridge control mechanism. Cartridge mechanisms are self-cleaning, but pinhole mechanisms are susceptible to blockage, especially in hard water areas, so periodic inspection and cleaning is required (Envirowise, 2007). Water conditioning is important in hard water areas (section 5.1).

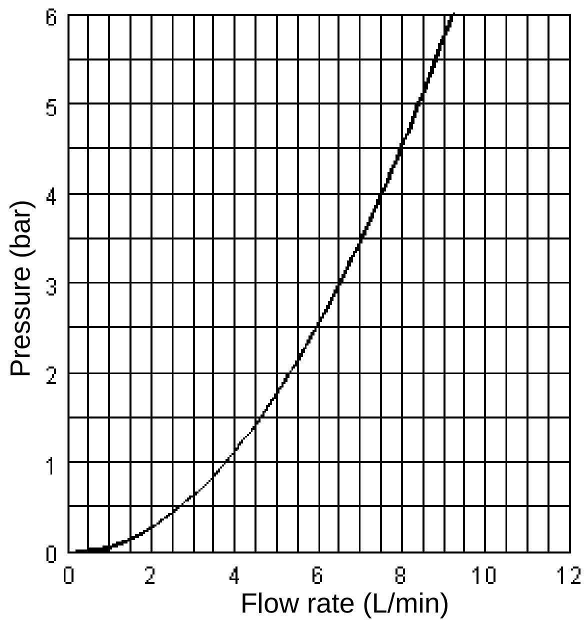
Recirculating showers are bought and installed as a unit (e.g. Hotel Gavarni in Paris), but are expensive and do not pay back in terms of water and energy savings at current prices.

Taps

Low-flow taps achieve flow rates of 2.5 – 6 L/min through design features including flow restrictors, aeration and spray design. Even low flow taps are sensitive to system pressure (Figure 5.14), again highlighting the importance of water system optimisation (section 5.1). As for showers, although careful selection of the best products during installation can achieve the lowest flow rates, a number of retrofit options are available – primarily flow restrictors and aerators that screw onto the end of most standard ½ inch taps. Alternatively, or in addition, isolating ball valves may be installed in bathroom feed pipes to restrict the flow rate in high pressure systems (Envirowise, 2007).

Taps in public areas may be fitted with self-closing push valves or infrared sensors. The savings associated with such devices depend heavily on the users and timing. In some cases, push taps have been found to increase water use compared with screw down taps (EC, 2009). Infrared sensors are the preferred option as they have hygiene and precision advantages.

Aerators may become blocked over time, and require periodic inspection, cleaning and replacement. In all cases when installing taps or shower fittings, long-life O-rings resistant to over-tightening should be fitted (and over-tightening avoided) in order to minimise the risk of leaks and future maintenance requirements.



Source: Grohe (2011).

Figure 5.14: The effect of pressure on flow rate for a ½ inch (127 mm) bathroom mixer tap

Toilets

Standard gravity tank toilets are the most common type of toilet installed on accommodation premises, and do not require high water system pressure. Of these, button-operated flap valve cisterns offer the lowest installation costs, but are vulnerable to leakage from small particles preventing a seal and worn rubber seals (Environment Agency, 2007). Leaks occur in up to 20 % of installations, and can waste considerably more water than is used in actual flushing, but are difficult to detect. Regular inspection of toilets, including new low-flush toilets, is therefore important (section 5.1). In addition, flap valve cisterns allow refill water to flow through the cistern during the flushing, increasing flush volumes by up to 17 % (Environmental Agency, 2007). Cisterns containing siphon-controlled outflows are more expensive to buy and result in slower cistern refilling that can in some cases restrict their practicality in commercial settings, but result in a considerably reduced leakage rate. Low and dual flush toilets with siphons are available (Green Building Store, 2009), and may prove cost-effective when lower leakage rates are considered over the installed lifetime.

Cistern displacement devices can be inserted into cisterns to reduce water volume, or the float-arm may be adjusted to lower the fill level. Cistern displacement devices may be purchased, or improvised from e.g. bags of pebbles. When inserting cistern displacement devices it is important:

- to take care not to damage the cistern inlet or outlet valves
- not to restrict outflow
- to avoid objects that introduce debris or small particles into the cistern (that could prevent flap valve from sealing shut)
- not to reduce flush volume below hygienic (i.e. effective full flush) volume.

Dual flush toilets should be clearly labelled so that guests know how to operate the low flush (e.g. which button to press). Reassurance should be sought from the relevant authorities that the local sewer system is compatible with low-flush toilets: i.e. that installing such toilets will not significantly increase the risk of blockages (EC, 2009).

Valve-operated flush toilets are more expensive to install than gravity-tank toilets, but do not require any refill time and are therefore appropriate where the frequency of use is high (for example common toilet areas). They cannot be easily retrofitted and should therefore be specified during construction or renovation. Valve-operated toilets require a system pressure of at least 1.8 bar, and should be fitted to bowls designed for shorter, higher pressure flushes (EC, 2009). Valves are fitted directly to the water supply system and are manually adjusted to produce the correct flush volume at the location-specific pressure, resulting in a low volume when correctly adjusted (periodic checking required).

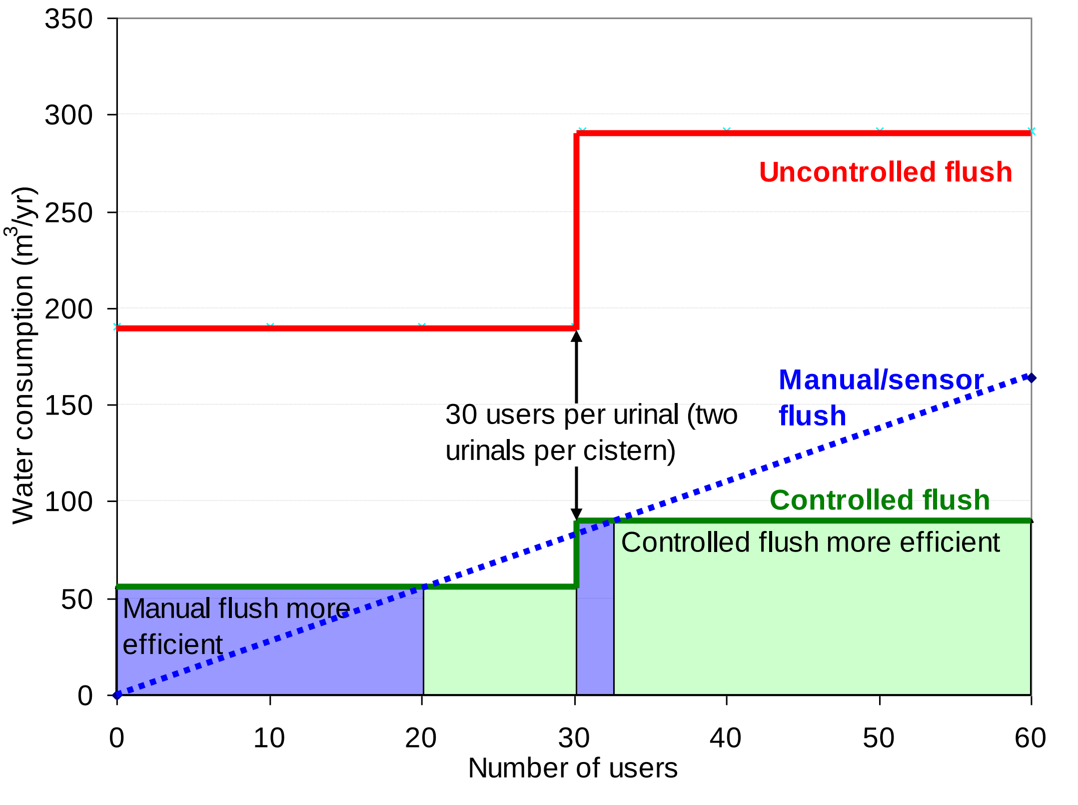
Pressurised tank toilets are also more expensive than gravity-tank systems, and have comparable refill times, produce a more effective flush and enable lower flush volumes. They comprise a sealed plastic tank containing pressurised air behind a diaphragm that is compressed by water from the pressurised supply system (at least 1.8 bar required). Pressurised tanks can be retrofitted, but are easier to install during construction or renovation.

In all cases, it is important that flush effectiveness be maintained otherwise water savings can be negated or even reversed by repeated flushing. For pressurised flushes, it may be necessary to change the toilet bowl to achieve best results.

Urinals

Urinals may be in the form of individual bowls or multi-user troughs, with a cistern or direct feed flush, with manual flush control, timed flush control, usage flush control, or they may be uncontrolled (i.e. flush when cistern is refilled). A controlled urinal flushing four litres of water six times per hour can use 105 m^3 per year if operating 12 hours per day, whilst an uncontrolled urinal with a flush operational 24 hours per day could use up to 500 m^3 per year. A single urinal can serve up to 30 users per day (Environment Agency, 2007), and at up to 20 users per day it is more efficient to have a manual or sensor-controlled flush than a timer-controlled flush (Figure 5.15). However, at higher user rates, a timer-controlled flush is more efficient. With a use demand of 60 users, water use per person ranges from 4 L/day for a controlled flush urinal to 13 L/day for an uncontrolled flush urinal. Therefore, unless installing waterless urinals, it is important to base the method of flush control on the expected use rate. For both uncontrolled and timer-controlled flushing, the flushing system should be deactivated outside hours of use (e.g. overnight).

A number of types of sensor are available to activate flushes after use. The most common is a passive infrared sensor that detects the user at the urinal and activates the flush valve when the user leaves. Other types of sensors include door switches or hydraulic valves that activate the cistern valve in response to water flow or a pressure drop from water used elsewhere (e.g. taps opened to wash hands).



NB: In all cases, assumes 16 hours of operation per day, 365 days per year. For manual flush urinals, an average of 5 flushes of 1.5 L per user is assumed.
Source: Derived from Environment Agency (2007).

Figure 5.15: Annual water consumption for uncontrolled, controlled and manual/sensor flush urinals serving different numbers of daily users

The best solution to reduce water consumption for urinal flushing is to install waterless urinals. These operate using a spring-loaded trap, a layer of barrier oil floating in the trap, or chemical-impregnated plastic pads inserted in the trap. Best environmental practice is to use 'chemical-free' waterless urinals (e.g. Culu, 2011). One new design uses a low power fan to generate negative pressure in the waste pipe (Green Building Store, 2009). Prior to installation, waste pipes should be assessed and modified to remove any flow restrictions, and thoroughly cleaned where retrofitting. Where urinals are being converted to waterless operation, best practice to avoid legionella risk in 'dead-leg' pipe work is to isolate the redundant water supply pipes, using either an existing valve or by cutting the supply spur as close to the T-joint as possible and installing an isolation valve and stopper (so that supply may be restore if required) (Waterless Urinals, 2011).

Waterless urinals require specialist cleaning with compatible chemicals, and in some cases replacement of the barrier liquid or pad once every one to two weeks (Business Link, 2011; Culu, 2011). Correct maintenance is critical to satisfactory operation of waterless urinals. Where microbiological systems are installed, it is important to avoid use of drain clearing acids that kill useful microbes that degrade organic matter and prevent, and that degrade gels or liquids used in barrier systems (Waterless Urinals, 2011).

An intermediate solution is the use of plastic sleeves impregnated with enzymes that break down odours, enabling flush controllers to be set to just four flushes per day, saving up to 90 % of water used in controlled flushing systems (ITP, 2008).

<u>Basins and baths</u>
It is important to ensure that basins are installed with an effective drain plug (that is periodically inspected and replaced where necessary: section 5.1) so that guests can use them for washing and shaving without leaving water running. When selecting basins for installation during construction or renovation, functionality should be a priority. Basins should be sized and shaped so that guests can comfortably wash their hands and shave. Very large and deep basins should be avoided.

Baths are not a standard feature in hotels and other accommodation premises, and often space and water can be saved by avoiding the installation of bath tubs in guest bathrooms. In high end establishments or suites where baths are provided, bath tubs of an efficient size and shape should be selected. Bath tub volumes range from 130 to 300 L. Care should be taken to compare volumes on a like-for-like basis; i.e. the volume required to fill the tub to the mid-point of the overflow outlet (Environment Agency, 2007) – some manufacturers subtract a typical body volume (70 L) from quoted fill volumes. Well-designed bath tubs are shaped to follow body contours, and therefore reduce water volume.

<u>Guest information</u>
The most effective manner to convey information on water use to guests is with notices prominently placed at the point of use – e.g. on bathroom walls or mirrors in front of basins. Information that can be included is:

- how guests can indicate they would like to reuse towels, for example by hanging them after use (see section 5.3);
- how guests can save water by turning off taps when washing teeth and shaving;
- how guests can save water by taking a shower instead of a bath;
- water savings associated with the above actions;
- any low-flow fittings installed and the amount of water they save.

The operation of dual flush toilets should be clearly indicated on or above the cistern (see above).

Emerging techniques
Toilets with 1.5 L flush are being developed (Environment Agency, 2007).

Applicability
Table 5.7 refers to the applicability of various techniques. The following are key points relating to applicability.

- Aerators and flow restrictors are inexpensive and suitable for retrofitting where water system pressure is at least one bar and low-flow fittings are not installed. They are not applicable to gravity-fed water systems common in some member states (e.g. UK and Ireland).
- Low-flow showerheads can be fitted or retrofitted where water system pressure is at least one bar, but should be tested on the premises before widespread installation. They are not applicable to gravity-fed systems or some electric showers.
- Thermostatic mixers for showers can be fitted in place of basic mixer taps during construction or renovation.
- Low-flow taps can be fitted or retrofitted in almost all situations, but work more effectively under water pressure of at least one bar. They should be tested on premises before widespread installation.
- Toilet retrofits such as cistern displacement devices and dual-flush mechanisms are universally applicable where existing flush volumes are greater than 6 L.
- Low-flush gravity-tank toilets can be fitted or retrofitted in all situations. Flush-valve and pressure tank systems can be fitted during construction or renovation.
- Waterless urinals are universally applicable, and can be realised through retrofitting existing urinal pods or troughs with modified traps or waste-pipe fans.

Economics
Installation of efficient fittings reduces water supply and disposal costs, and also energy costs where consumption of heated water is reduced (showers and basin taps) – see Table 5.6 and associated equation in section 5.1.

Table 5.11 provides an overview of fitting costs and annual savings where average fittings are replaced by efficient fittings conforming to the benchmarks specified above. Labour costs associated with installation will vary depending on whether in-house maintenance staff or external plumbers carry out the tasks, and have been excluded from the calculations. Retrofitting options are simple and would typically require ten to 30 minutes labour per fitting.

It is important to note that attributing the entire cost of new fittings to water efficiency provides a **worst case indication of payback period** as efficient fittings will usually be specified when undertaking construction or renovation work, and the additional costs compared with less efficient fittings will be a fraction of the fitting prices quoted in Table 5.11. Accounting for these caveats, information in Table 5.11 supports the following conclusions.

- All retrofit options offer short payback periods, ranging from two to 10 months.
- Fitting combined flow-restrictors and aerators can realise almost immediate payback.
- Selecting (or retrofitting) efficient bathroom taps and showers can save a considerable amount of money through reduced water and energy consumption.
- For guest bathrooms, selecting low-flush toilets during construction or renovation can save a significant amount of money: enough to justify bringing forward replacement by a few years, or spending 30 – 50 % more on an efficient model.
- For public areas, selecting (or retrofitting) low-flush toilets and waterless urinals can save a considerable amount of money through reduced water consumption.

- For public areas, considerable water and energy reductions associated with shower timers result in a short payback period of 6 – 8 months, justifying retrofitting.

In addition to information presented in Table 5.11, passive infrared sensors for urinals can be installed for a total cost of approximately EUR 280 per urinal (Ecosys, 2007), resulting in payback time of nine months.

Recirculating showers are not included in Table 5.11. They represent an innovative but so far expensive option for reducing water consumption. The full cost of installing a recirculating shower unit is EUR 7 000 (Hotel Gavarni, 2011). This should be compared with the full costs of installing a conventional shower, including basin, tiles and all fittings, but still represents a considerable premium. Recirculating showers are therefore appropriate for hotels particularly committed to environmental protection, but not yet widely applicable across the sector.

Table 5.11: Annual financial savings and worst-case payback estimated for replacement of average water fittings with efficient water fittings

Fitting	Cost	Saving			Payback
		Water	Heating (oil)(*)	Total	
	EUR	EUR/yr			Months
Low-flow basin taps(**)	100 – 200	29	24	**53**	**23 – 45**
Combined flow-restrictor and aerator	10	22	18	**40**	**3**
Low-flow showerhead	20 – 50	44	54	**98**	**2 – 6**
Combined flow restrictor and aerator	10	44	54	**98**	**1**
Shower push-button timer	150 – 200	164	203	**367**	**5 – 7**
Low-flush toilet(**) (bathroom)	70 – 150	23		**14**	**36 – 78**
Cistern displacement/dual-flush retrofit (bathroom)	20	23		**14**	**10**
Low-flush toilet (public)(**)	150	137		**137**	**13**
Bathroom cistern displacement/dual-flush retrofit (public)	20	137		**137**	**2**
Urinal flush control (from uncontrolled)	200	375		**375**	**7**
Waterless urinal (from controlled flush)	150	375		**375**	**5**

(*)For energy savings, it was assumed that water used in showers and taps has temperature elevated by, on average, 30 ºC and 20 ºC, respectively, fed by a 90 % efficient oil-fired boiler.
(**)Cost of new fittings provides a worst case cost estimate where recently installed existing fittings are replaced by efficient new fittings.

Source: Alaris Avenue (2011); Bathroom Supplies (2011); Not Just Taps (2011); Plumbing Supply Services (2011); Plumb World (2011); Discounted Heating (2011); Waterless Urinals (2011).

Driving force for implementation

Measures to reduce water use in guest areas are associated with significant cost savings, attributable to reductions in both water and energy consumption. Measures to reduce water consumption can also be readily conveyed to guests to promote an environmentally conscious image.

In some Member States regulations specify minimum efficiency standards for new water-using devices installed in buildings. For example, the UK Water Fitting Regulations (1999) stipulate that:

- no flushing device shall be installed for a toilet pan that produces a volume greater than 6 L per flush;
- non-automated urinal flushing systems should be switched off overnight or when building not in use;
- automatically operated urinals should use no more than 10 L per hour per single bowl or 7.5 litres per hour per bowl or per 700 mm of trough fed by a cistern serving more than one urinal;
- manually or automatically operated pressure flush valves should use no more than 1.5 L per flush.

A list of relevant regulations is presented in EC (2009). National, regional or local governments may provide incentives in the form of subsidies or tax breaks to encourage installation of water efficient fittings. For example, in the UK, the Enhanced Capital Allowance scheme allows business to deduct the capital cost of water-saving equipment from taxable profit in the year of purchase (http://etl.decc.gov.uk/). Equipment covered by the scheme relevant to this technique includes:

- efficient toilets
- efficient taps
- rainwater harvesting equipment.

Reference organisations

Examples of extensive low-flow fittings include: Hotel Gavarni (Paris), Ibis hotels, Scandic hotels.

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5.3 Efficient housekeeping

Description

Housekeeping is a critical component of accommodation services, a key control point for service quality, and provides a link between accommodation management and guests. The major functions of housekeeping are to:

- make up beds and replace used bedclothes;
- replace used towels and floor mats in bathrooms;
- clean bathrooms and bedrooms;
- replace all consumables (food, drinks, soaps, shampoos, etc.);
- remove rubbish.

Section 6.1 deals with green procurement to minimise waste, such as the use of soap dispensers instead of single-use soaps, and section 6.2 addresses best practice for waste sorting to minimise waste sent for disposal. This section deals with the first four points in the above list, and is located within the water management chapter of the document because of the importance of these points, in particular laundry reduction, to water consumption.

The provision of clean, crease-free bedclothes is a particularly important quality control point for accommodation establishments: unclean or creased bedclothes can give guests an instant bad impression. Hotels launder 2 kg to 6 kg of bed linen and towels per room per day[9], in the process consuming up to 100 litres per occupied room – almost as much water as all other service activities combined in a best practice hotel (see Figure 5.3 in section 5). Bedroom laundry comprises sheets, pillow cases, duvet covers, towels and bath mats. Laundry represents a major potential source of saving for water, energy and chemical consumption within accommodation enterprises. Before laundry operations are optimised (sections 5.4 and 5.5), considerable savings can be achieved through the minimisation of laundry volumes. Bed linen and towel reuse programmes can reduce laundry volume by half (Smith et al., 2009). Management and housekeeping staff play a key role in the effective design and implementation of such programmes. Green procurement of textiles to reduce their lifecycle impact is also an important control point.

Guest room and bathroom cleaning is a major source of chemical consumption within accommodation establishments, and a significant source of water consumption. Chemical use can be minimised through; (i) appropriate dilution of cleaning agents usually purchased in concentrated form; (ii) efficient cleaning technique; (iii) use of microfiber clothes. Regular staff training on chemical handling is very important, from a health and safety and environmental perspective. Selection and green procurement of less environmentally harmful cleaning agents, such as those that have been awarded an ISO Type-I ecolabel (e.g. EU Ecolabel, Nordic Swan: section 2.2), can significantly reduce the impact of cleaning. Meanwhile, Gössling et al. (2011) estimate that room cleaning consumes 12 – 47 L/guest-night of water. Water can be saved by:

- turning off taps during cleaning
- flushing toilet not more than once.

The water saving associated with actions depends on the water efficiency of the fittings (section 5.2), but is in the region of 6 – 15 L/min and 2.5 – 12 L per flush, respectively.

Finally, housekeeping staff are positioned to influence guest behaviour, and to ensure efficient operation of equipment within rooms. For example, where solar gain is high (e.g. windows

[9] Accor (2010) refer to 4 kg per room per night; O'Neill et al. (2002) refer to median laundry of 5.4 kg per room per night from a US study, ranging from 2.4 to 15.8 kg per room per night; Alliance for Water Efficiency (2009) refer to example of 5 lb (2.3 kg) per room per night; Bohdanowicz and Martinac (2007) refer to an average of 2 kg per guest-night for Scandic hotels and 3.7 kg per guest-night for Hilton hotels.

exposed to direct sunlight during summer months), housekeeping staff may close shutters or curtains in order to prevent excessive heating of the rooms. Similarly, where unoccupied room temperature is not controlled by a centralised building management system (section 6.1), housekeeping staff may reset temperature controls to values that maintain guest comfort whilst minimising energy consumption. Housekeeping staff can check for leaking water fittings (section 5.1) and other damaged equipment that can increase water or energy consumption (e.g. damaged seals on fridge doors). Table 5.12 summarises best practice for housekeeping operations.

Table 5.12: Portfolio of housekeeping measures to reduce environmental impact of accommodation

Aspect	Measure	Description
Efficient housekeeping all	Staff training	Staff are provided training in relevant operational tasks to maximise (environmental) efficiency, and tasks are explicitly linked with the organisation's environmental objectives (see section 2.1).
Reduce laundry water, energy and chemical consumption	Bedclothes reuse	Implement a schedule to change bed linen once per specified number of days for the same guest, unless a more frequent change is requested. Implement a top-to-bottom sheet change.
	Towel reuse	Implement an on-request towel change, with the procedure to indicate towel washing clearly conveyed to guests.
	Textile green procurement	Purchase bedclothes and towels that combine low supply chain environmental impact with good use-phase (laundry) environmental performance.
Reduce cleaning water and chemical consumption	Green procurement	Avoidance of environmentally damaging chemicals, selection of ecolabelled cleaning agents and microfiber clothes.
	Efficient cleaning	Train staff on safe and efficient use of cleaning agents and chemical-free methods (e.g. one-flush toilet cleaning and microfiber cloths).
Reduce energy consumption	Energy check	Switch off appliances, close windows, reset temperature controls
Reduce waste	Avoidance of single use soaps	See section 6.1 on waste avoidance
	Waste sorting	See section 6.2 on waste sorting and recycling.
Other	Green procurement consumables	Purchase lower environmental impact consumables such as toilet paper, tissue paper, writing paper and magazines for rooms (e.g. ecolabelled or FSC certified paper)

Achieved environmental benefit

Green procurement

Increasing the useful life of textiles by specifying appropriate durable textiles with lower laundry (in particular drying) requirements significantly reduces resource depletion and energy consumption, and a range of other impacts associated with textile production such as water pollution, climate change, ecotoxicity. Kalliala and Nousiainen (1999) concluded that the potential lifetime of 50/50 cotton-polyester fabrics is twice as long as similar fabrics made of pure cotton in hotel textile services, resulting in 42 % less production energy. Mixed fabrics also require 20 % less laundering energy than pure cotton.

Green procurement of textiles, paper, cleaning agents and food based on ISO Type-1 ecolabels and organic certification results in lower production impacts compared with average products (Table 5.13).

Table 5.13: Key criteria and associated environmental benefits represented by various product labels

Product and label	Key criteria	Environmental benefits
Cleaning agent, soap and shampoo ecolabels	– Excluded toxic chemicals – Aquatic toxicity limits represented by critical dilution volumes – Limited quantities of non-aerobically biodegradable surfactants – Limited concentrations of volatile organic compounds and phosphorus – Avoidance of propellant spray packaging – Clear user instructions provided on packaging	– Reduced human toxicity and ecotoxicity – Reduced eutrophication and oxygen demand in receiving waters – Reduced air pollution – Reduced resource depletion and waste generation
Textile ecolabels	– Toxic residue limits in final product, fibres and dyes – Water pollution thresholds for production (e.g. COD removal requirements) – Air pollution thresholds for production (e.g. VOCs, N_2O) – Biodegradability requirements and restricted lists for processing agents – Restricted substances for dying and flame retardants – Requirements for fabric durability in terms of shape-holding and colour fastness	– Reduced human toxicity and ecotoxicity – Reduced eutrophication and oxygen demand in receiving waters – Reduced air pollution – Reduced resource depletion and waste generation
Toilet paper ecolabels	– Excluded substances in final products and during production/processing (e.g. chlorine gas, azo substances) – Reduced air emissions of sulphur and greenhouse gases during production – Water pollution thresholds for production (e.g. chlorine compounds and organic waste) – Air pollution thresholds for production (e.g. Sulphur and nitrogen oxides, carbon dioxide) – Reduced energy consumption during production – Use of recycled fibres or virgin fibres from sustainably managed forests	– Reduced human and ecotoxicity – Reduced eutrophication and oxygen demand in receiving waters – Reduced air pollution – Reduce global warming potential – Reduced resource depletion and waste generation
Textile and food/drink organic labels	– Limits to quantities of nutrients applied during cultivation – Restrictions to types of fertilisers applied (only organic nutrients and some natural minerals allowed) during cultivation – Restricted range of plant protection agents allowed during cultivation and processing – Limits for animal stocking densities – Specifications for animal feed – Restricted substances used in food processing	– Reduced resource depletion – Reduced human and ecotoxicity – Reduced on-farm biodiversity impacts – Reduced eutrophication
Source: EC (2007); EC (2008); EC (2009); EC (2011).		

Laundry reuse programmes

The environmental benefit of laundry reuse programmes is dependent upon: (i) the quantity of laundry avoided; (ii) the eco-efficiency of the laundry process (see section 5.4 and section 5.5). Water and energy savings can be calculated from the following formula:

$Q = N_R$ x (O/100) x (P/100) x V_L x C_L x N_D		
Q	Quantity of water saved Quantity of energy saved	L/yr kWh/yr
N_R	Number of rooms	N
O	Average annual occupancy rate	%
P	Average participation rate	% of occupied room nights
V_L	Average laundry volume per room per change	kg
C	Average specific consumption of water Average specific consumption of water	L/kg laundry kWh/kg laundry
N_D	Annual business operating period	Days/yr

Thus, for a 100-bed hotel with a 75 % occupancy rate and a participation rate of 30 %, a room laundry volume of 3 kg and a laundry use efficiency of 7 L water and 1.5 kWh energy per kg laundry, the annual water saving would be:

$$100 \times 0.75 \times 0.30 \times 3 \times 7 \times 365 = 172\ 463 \text{ L, or } 172 \text{ m}^3$$

For the same hotel, annual energy savings would equate to 86 231 kWh.

Efficient cleaning

Efficient cleaning techniques use less than half the water and chemicals of inefficient techniques. For example:

- applying a single low flush of 3 L on a dual flush toilet during cleaning, instead of two full flushes, can save up to 9 L per guest-night, representing approximately 7 % of best practice specific water consumption;
- turning off taps during cleaning, rather than leaving a tap on for 90 seconds during cleaning, can save between 5 and 20 litres of water, representing up to 15 % of best practice specific water consumption;
- using microfiber mops in place of wet mops can reduce water and chemical consumption by 95% (Espinozal et al., 2010);
- application of best practice techniques can reduce chemical consumption by at least 50 % (see Figure 5.16).

Energy management and maintenance

Energy management, maintenance and reporting during housekeeping activities can make important contributions towards energy and water minimisation. For example, reducing thermostat settings by just 1 ºC in winter can reduce heating energy consumption by 10 %, and similar savings in cooling energy consumption can be achieved in summer by correct thermostat adjustment. In addition, closing shutters or curtains to avoid unwanted solar gain during the day can reduce or avoid cooling energy consumption. Meanwhile, reporting leaking water fittings so that they are fixed promptly can reduce room water consumption by hundreds of litres per day (see section 5.1).

Appropriate environmental indicator

Indicators

Table 5.14 summarises environmental indicators relevant to housekeeping best environmental management practices.

Table 5.14: Relevant environmental indicators for different aspects of housekeeping

Aspect	Relevant indicators
Textiles	– Percentage of bedclothes made from polyester-cotton mix or linen – Percentage of room textiles made from organic material or awarded an ISO Type-1 ecolabel
Bathroom consumables	– Percentage of bathrooms that use ecolabelled soap and shampoo – Percentage of bathrooms with soap and shampoo dispensers
Laundry	– Average specific laundry requirements (kg) per guest-night – Percentage of occupied room nights that involve towel and bedclothes reuse – Percentage reduction in laundry achieved through towel and bedclothes reuse programmes
Cleaning	– Total chemical use within the hotel, expressed in relation to guest-nights (see Figure 5.16) – Regular staff training on safe chemical handling and efficient cleaning that minimises water and chemical use – Automatic dilution of cleaning chemicals, and clear instructions on dilution – Precise procedures in place for chemical-free cleaning methods, such as use of microfiber cloths – Proportion of the amount of chemical products used for regular/general cleaning that are ISO Type-1 ecolabelled (%)
Energy	– Regular staff training on energy management procedures to be performed during housekeeping

Some aspects of efficient housekeeping are captured by key performance indicators and associated benchmarks described in other sections. For example, measures to reduce water use during cleaning are reflected in water consumption per guest-night (section 5.1), and measures to reduce energy consumption are captured in energy consumption per guest-night (section 7.1).

<u>Benchmarks of excellence</u>
The following benchmarks of excellence are proposed specifically in relation to housekeeping.

BM: at least 80 % of bedclothes are cotton-polyester mix or linen, and at least 80 % of bedroom textiles have been awarded an ISO Type 1 ecolabel or are organic.

BM: consumption of active chemical ingredients within the tourist accommodation of ≤10 grams per guest-night.

BM: reduction in laundry achieved through reuse of towels and bedclothes of at least 30 %.

BM: at least 80 % by active-ingredient weight of all-purpose cleaners, sanitary detergents, soaps and shampoos used by the tourist accommodation shall have been awarded an ISO Type I ecolabel[10].

[10] Based on EU Ecolabel optional points criteria (EC, 2009)

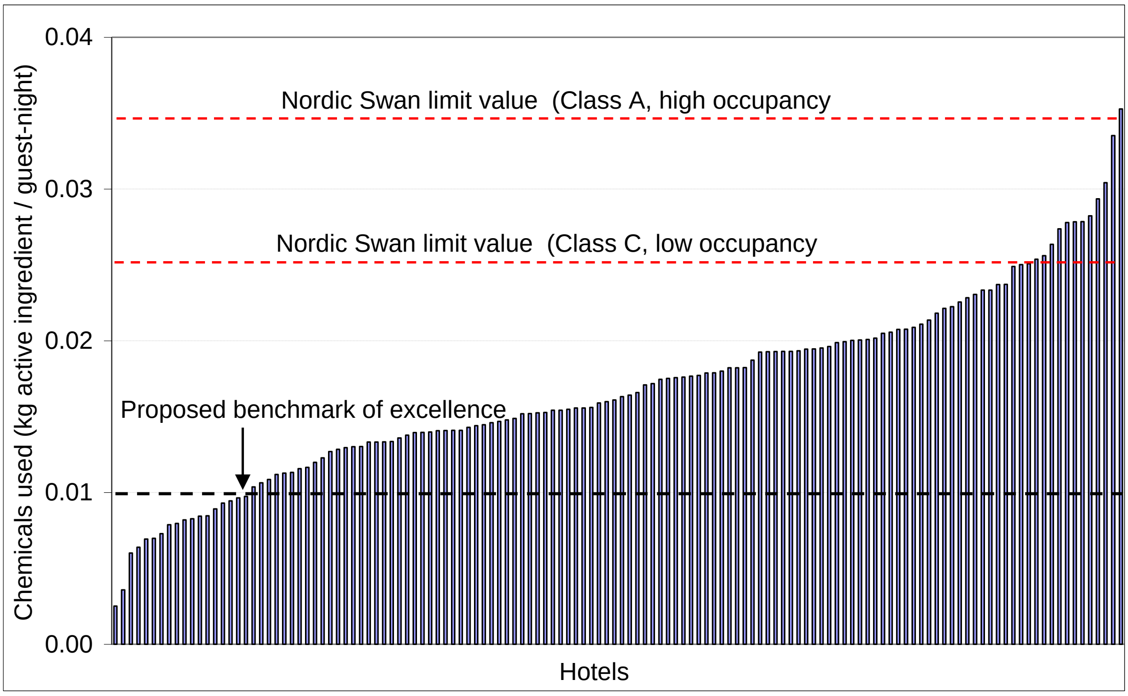

Figure 5.16: Specific consumption of active chemicals reported by a range of anonymous hotels, with Nordic Swan ecolabel limits and the proposed benchmark of excellence indicated

Cross-media effects

Care should be taken to ensure that environmental criteria used in green procurement of textile products reflect use phase impacts in addition to production impacts.

There are no significant cross-media effects for laundry minimisation, use of ecolabelled detergents, soaps and shampoos (cleaning effectiveness is accounted for in ecolabel criteria), or housekeeping measures to reduce energy consumption in rooms.

Espinoza et al. (2010) assume that microfiber mops must be washed after every room cleaned, resulting in seven times higher washing energy requirements than for conventional mops. However, the additional water, energy and chemical consumption for washing is less than the 95 % reduction in water and chemical consumption achieved during room cleaning by microfiber mops.

Operational data

<u>Green procurement</u>

Textiles may be rented out from laundry service providers (Carbon Trust, 2009). Where textiles are bought, it is important to have sufficient stock to cover peak service use whilst allowing sufficient out-of-service time for laundry operations. The life expectancy of most textiles is determined by the number of laundering cycles they are exposed to, but the useful lifetime of hotel towels is usually constrained by the rate they go missing and the rate of rejection due to permanent soiling (Kalliala and Nousiainen, 1999). It is essential that the correct specifications and quantities be purchased, and it is recommended to test textiles for compatibility with laundry processes prior to placing an order, and to retain at least three items unprocessed for nine months in case of quality problems arising (DTC LTC, 2011).

The lifecycle environmental performance of textiles is determined by: (i) production impacts; (ii) durability; (iii) servicing impacts (energy, water and chemical requirements for laundering). Table 5.15 summarises important features of textiles made from different fibres with respect to lifecycle environmental performance. Green procurement must also consider the dominant purchasing criteria of perceived quality and price. The perceived quality (appearance, density, size, softness and breathability) of bedclothes and towel textiles has become major marketing feature for hotels. Polyester bedclothes may not be acceptable from a perceived quality perspective for some hotels – despite their high durability and low servicing energy requirements. Meanwhile, linen bedclothes are expensive and less readily available than cotton and polyester bedclothes. Thus, cotton and cotton-polyester blends are the preferred options for accommodation establishments. Meanwhile, for towels, cotton is the preferred type of textile owing to its high absorbency and perceived quality.

The high environmental impacts of cotton and polyester can be considerably reduced by selecting organic cotton and recycled polyester (MADE-BY, 2011). The EU Ecolabel for textile products may be used to select textiles with lower manufacturing impacts – criteria include: avoidance of harmful substances during manufacture, reduced water and air pollution during manufacture, shrink resistance during washing and drying, colour resistance to perspiration, washing, wet and dry rubbing and light exposure, no inorganic fibres, no harmful substances such as azo dyes and solvents (2009/567/EC: EC, 2009). Durability is a critical factor as it is directly related to the quantity of production for bedclothes. The energy consumption of 50/50 cotton-polyester over 100 laundering cycles is 42 % lower than for pure cotton sheets, owing to the durability of polyester (Kalliala and Nousiainen, 1999).

Above: Towels made from organic cotton in the Gavarni Hotel, Paris. The beige colour allows the towels to be washed at 30 ºC.

Taking into account the above considerations, the following is recommended as best practice for room textile selection:

- Towels: select organic cotton or ecolabelled cotton, and avoid excessive sizing. Consider non-white towels that can be washed at lower temperature.
- Bedclothes: select durable polyester-cotton blends or linen. Specify recycled polyester, organic or ecolabelled cotton and organic or ecolabelled linen.
- Carefully check product specifications and test products before buying in bulk.

Table 5.15: Summary of environmental performance of textiles made from different fibres during production and servicing, and perceived quality

	Production	Durability	Servicing	Perceived quality
Cotton	High impact. High water, pesticide, fertiliser consumption during cotton cultivation. Water pollution from processing (MADE-BY, 2011; Muthu et al., 2011).	Low durability. Vulnerable to damage when wet and at high temperature. Half the lifespan of polyester-cotton sheets (Kalliala and Nousiainen, 1999).	High energy requirements. Cotton absorbs a large amount of water and becomes wrinkled, so has high drying and ironing requirements.	High. Pure cotton is soft, absorbent and perceived as high quality – especially at high thread numbers (400 threads per square inch or more). Variable price, but high quality cotton is expensive.
Polyester	High impact. Non-renewable resource depletion, energy consumption and ecotoxicity impacts (MADE-BY, 2011; Muthu et al., 2011).	High durability. Strong fibres, resistant to distortion, but can become discoloured and more likely to become permanently stained.	Low energy requirements. Low water absorption and drying requirements. However, may require more chemicals to remove stains, and an extra cooling rinse to avoid creasing during spinning.	Low. Polyester does not absorb moisture well, can feel hard, and has low perceived quality. More sophisticated fiber production has improved the softness and feel of some new polyester fabrics. Inexpensive.
Linen (from flax)	Low impact. Less energy than polyester and cotton, less water than cotton, low ecotoxicity (MADE-BY, 2011; Muthu et al., 2011).	High durability. Strongest natural fibre, 2 – 3 times stronger than cotton, and excellent resistance to washing wear owing to high wet strength. Can become damaged along frequent crease lines (e.g. from repeated folding).	High energy requirements. Absorbs a lot of water, and can become creased, so requires careful ironing.	Very high. Linen is highly absorbent and breathable – especially well suited to warm conditions. It becomes softer with time. Relatively inexpensive.
Cotton-polyester	High impact – see above.	High durability. The lifetime of 50/50 cotton-polyester fabrics is twice as long as pure cotton fabrics in hotels (Kalliala and Nousiainen, 1999).	Relatively low energy requirements. 50/50 cotton-polyester fabrics require 20 % less laundering energy than pure cotton in hotels (Kalliala and Nousiainen, 1999).	High. Softness and perceived quality similar to pure cotton. Expensive.

Above: EU Ecolabel cleaning detergent in the Gavarni Hotel, Paris.

Where possible, best practice is to avoid chemical use through use of microfiber cloths and mops. Cleaning products are one of the product groups in which ecolabels are most highly represented. ISO Type-1 ecolabels, such as the EU Ecolabel, Nordic Swan and Blue Angel consider a range of lifecycle environmental impacts, including ecotoxicity and energy consumption, alongside cleaning effectiveness. Labelled products represent front-runners in terms of environmental and cleaning performance. ISO Type-1 ecolabels are therefore the best guide to green procurement.

Best practice for non-ecolabelled cleaning agents is based on Nordic Swan ecolabel criteria for accommodation (Nordic swan, 2007). Establishments must declare that 95 % of non-ecolabelled substances used:

- are not classified as environmentally dangerous according to Directive 99/45/EG;
- do not contain specified chemical constituents including alkylphenolethoxylates (APEO) and alkylphenol derivatives (APD), dialkyl dimethyl ammonium chloride (DADMAC), Linear alkylbenzene sulphonates (LAS), Reactive chlorine compounds (exemption if required by authorities for hygiene reasons);
- only contain surfactants that are readily biodegradable in accordance with method 301 A-F in OECD Guidelines for testing of chemicals.

Housekeeping operations include the replacement of toilet paper, complimentary soaps and shampoos, and food and drinks offered within the room (e.g. in 'mini-bar' refrigerators). As for cleaning chemicals, ecolabels are appropriate guides for green procurement of toilet paper and soaps and shampoos, as specified in Nordic Swan and EU Ecolabel criteria for accommodation (Nordic Swan, 2007; EC, 2009). The use of soap and shampoo dispensers instead of individually wrapped items is an important measure to avoid waste described in section 6.1. For food and drinks, a wide range of labels and certification standards are relevant depending on the product group (see section 8.1). The most extensive relevant standard is organic certification, indicated by various labels compliant with Commission regulation EC 889/2008.

Left: A sample of organic drinks and snacks contained within the room selection offered to guests in the Gavarni hotel, Paris.

Laundry minimisation.

There are three key points for successful implementation of towel and bedclothes reuse schemes:

- guests are provided with clear information and instruction
- adequately sized and easy to use towel rails are installed
- staff training.

Cards or notices to encourage guests to reuse sheets and towels should be placed in prominent locations in the room/bathroom and hotel information booklets. Important information to present on such cards or notices includes:

- the value of water and the need to conserve it
- the reduction in water use achievable through reuse
- a request for guests to help the establishment conserve water by reusing sheets and towels
- a brief but clear description of the procedure for reusing sheets and towels
- information on any environmental scheme funded by laundry savings.

Typically, guests are requested to indicate towel reuse by hanging towels on a towel rail in the bathroom, while sheet reuse may be indicated by not actively requesting a sheet change (Alliance for Water Efficiency, 2009).

The policy on bed linen changes varies across establishments. The most common changing regimes are for bedclothes to be changed once every day to every three days for longer-stay guests. One variation is to implement a 'top to bottom' change method in which the top sheet is reused as the bottom sheet and a fresh sheet used for the top-sheet (Travel Foundation, 2011).

One of the most important factors for success is the provision of adequate and easy to use towel rails for storing and drying towels between reuse (Alliance for Water Efficiency, 2009). These should be sized to accommodate towels once-folded, and positioned within easy reach of guests (average waist to shoulder height where space allows).

Towel and bedclothes reuse schemes are only as effective as the housekeeping staff implementing them. It is essential that staff are trained to follow the established procedures, so that if a guest hangs a towel on the rail for reuse it is not replaced by a fresh one. Good record keeping is essential, and daily checklists for each room should include changing dates for bedclothes.

Finally, guests are more likely to participate in reuse schemes when they believe it is motivated by environmental protection and not cost saving by the hotel. Reference to water, chemical and energy savings helps, but the best schemes invest laundry cost savings into environmental programmes – and clearly convey this to guests. For example, savings made by Accor's towel reuse programme are invested into the UN Environment Programme's 'Plant for the Planet' project. One tree is planted with the money saved from five towel reuses, and Accor has a target to fund three million tree plantings by 2012 (Accor, 2011).

<u>Low impact cleaning.</u>

In the first instance, best environmental management practice is for accommodation management to implement green procurement of microfiber cloths and mops, and ecolabelled or less harmful cleaning chemicals (above). Chemical use can be considerably reduced through staff training in chemical management and efficient cleaning techniques, and investment in chemical-free cleaning equipment. Staff training in chemical management should include health and safety and environmental criteria. A written list of all chemical products should be kept and updated on regular basis (at least yearly), and accommodation management should ensure that clear and easily understood instructions for staff regarding the dosage and handling of chemical products are readily accessible close to mains points of storage and uses. Safety data sheets should be available for all chemicals used in languages spoken by employees.

Staff training should be offered within the first month of service, and should be regularly updated. Large hotels such as The Savoy in London hold daily briefing sessions with staff in which issues such as chemical management are discussed. Particularly important aspects of housekeeping cleaning operations are: (i) the use of the correct cleaning products for different tasks; (ii) the use of correct dilution ratios; (iii) the use of efficient techniques that minimise water and chemical consumption.

- Toilets only need to be flushed once after leaving cleaning chemicals in contact with the bowl for sufficient time.
- Whilst it is more efficient to purchase cleaning chemicals in concentrated form, if these are not diluted as per instructions they will be over-consumed and/or ineffective. Ideally, an automatic dosing system should be installed. Otherwise, in addition to training and signage, clear marking of fill levels on spray bottles can reduce the incidence of incorrect dilution. Dilution volumes should be adjusted for water hardness.
- Correctly diluted cleaning agents should be applied directly to the surface and left as necessary before rinsing off with a cloth rinsed in clean water. Taps should not be left running during cleaning.
- The use of fragrances should be avoided where possible, e.g. rooms should not be routinely sprayed with air freshners.
- Staff in the Gavarni Hotel in Paris regularly apply an ecolabelled deblocker to toilets that uses enzymes to prevent blockages, avoiding the need for periodic deblocking with strong, environmentally damaging chemicals.

The monitoring of chemical use and record keeping are important components of good chemical management. EU Ecolabel criteria for accommodation require establishments to submit a declaration detailing all ecolabelled and non-ecolabelled active substances delivered, measured in kg. Figure 5.17 provides an example of monthly reporting on chemical use. Best practice includes management intervention to:

- audit the consumption of and access to consumables, chemicals and hazardous materials in housekeeping operations;
- prepare an action plan with measurable, scheduled targets to reduce material and chemical consumption and to integrate environmental considerations into purchasing procedures;
- assign resources, appoint responsibility and provide training to ensure correct implementation of the action plan;
- record the type and quantity of all chemical purchases, and indicate whether they are ecolabelled.

Housekeeping is an important control point for waste management, particularly with respect to waste sorting and recycling. This is described in more detail in section 6.2, but the main points are summarised here:

- use room bins that do not require a plastic bag liner
- separate waste from guest rooms into fractions sent for recyclable fractions.

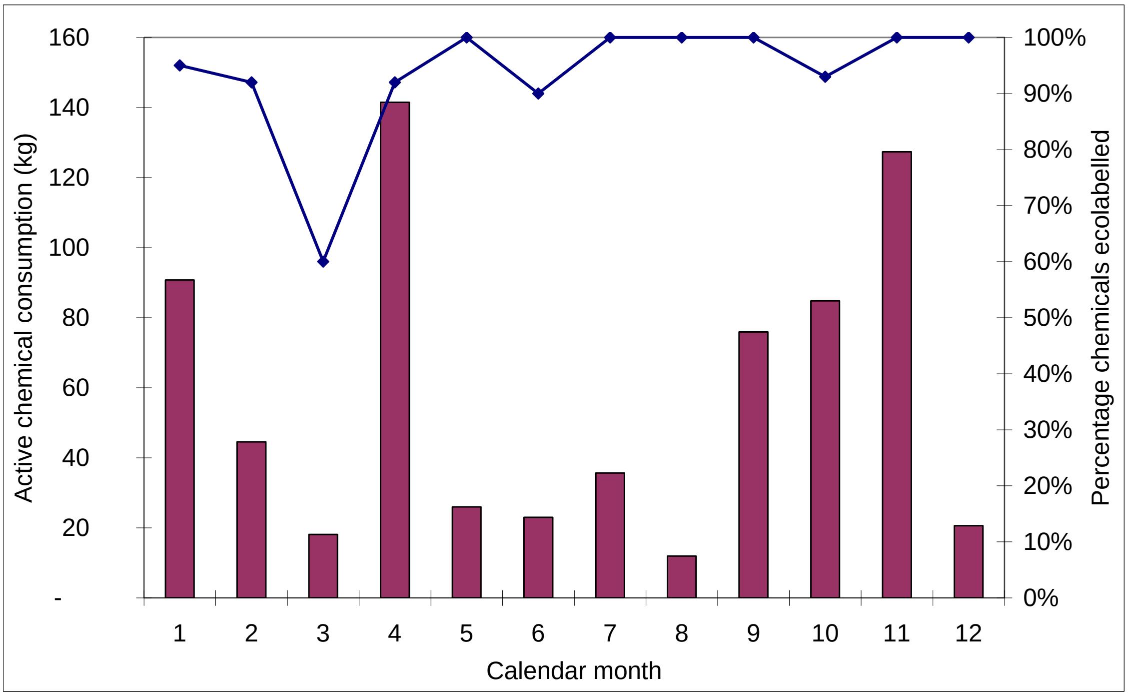

Figure 5.17: An example of monthly chemical consumption, measured as kg active ingredient, and the percentage of those chemicals that are ecolabelled, for a 160 room hotel (average consumption 0.013 kg per guest-night in 2010)

<u>Energy management and maintenance.</u>
Housekeeping staff are responsible for room condition on a day-to-day basis, and constitute a key control point for energy management and maintenance. Continuous staff training and clear reporting procedures are essential. The following key check points are relevant:

- turn off unnecessary equipment in guest rooms, including lights, TVs on standby, air conditioning and heaters;
- where it is policy to leave heaters or air-conditioners on for guest arrival (and in the absence of a building management system: section 7.1), housekeeping staff should adjust these to an appropriate temperature, i.e.:

    - 26 ºC when cooling
    - 18 ºC when heating

- check for poorly fitting doors, windows, any draughts etc., and report to maintenance;
- check for malfunctioning toilets, excessive water flow, leaking plugs (see section 5.1).

Applicability

Efficient cleaning, use of ecolabelled detergents, soaps and shampoos, green procurement of textiles, and housekeeping measures to reduce energy consumption are applicable in all serviced accommodation enterprises.

Towel and bedclothes reuse programmes to reduce laundry are applicable in all serviced accommodation establishments, but will achieve small savings where a high proportion of guests stay only one night (e.g. motels and airport hotels).

Economics

<u>Green procurement</u>

Consider the lifecycle cost of textiles, accounting for durability and washing requirements. Cotton-polyester sheets last approximately 200 laundry cycles, compared with 100 for pure cotton sheets. Annual laundry costs can be calculated using the following equation:

$C_A = (C_P/(150/D_N) + 150 \times C_L$	
C_A	Annual cost (EUR)
C_P	Purchase cost (EUR)
150	Estimated number of washes per item per year
D_N	Durability expressed in number of washes
C_L	Laundering cost (EUR per wash)

Laundry consumable costs vary widely depending on, in particular, the efficiency of laundry processes, chemical prices (type of chemicals used) and energy prices (related to energy source) – see Figure 5.22 in section 5.4. Nonetheless, laundry costs dominate annual servicing costs for sheets (Table 5.16). Purchasing a EUR 5 cotton-polyester sheet instead of a EUR 5 cotton sheet can save EUR 6 over a year through durability and reduced drying energy. For a EUR 10 sheet, this saving would increase to EUR 9.75.

Table 5.16: Annual purchase and laundering costs for cotton-polyester and cotton sheets bought for EUR 5 each

	Purchase	Laundering	Total
	Annual cost (EUR)		
Cotton-polyester	3.75	35.25	39.00
Cotton	7.50	37.50	45.00

Green procurement of organic or ecolabelled cotton towels incurs a variable price premium, typically in the region of 20 %. The useful lifetime of cotton towels is typically around 50 laundry cycles, but cotton towels cost about half the price of sheets, and laundry costs still dominate lifecycle costs. Laundry and purchase cost savings achieved by downsizing from excessively large towels could easily cover the price premium of organic or ecolabelled towels.

Green procurement of chemicals also incurs a price premium, but this is relatively small compared with other costs such as labour, and can be more than offset by training staff in efficient cleaning methods.

<u>Laundry reductions</u>
Laundry volumes per room vary according to bed size, towel size, textile density, and number of items provided per room – often in relation to accommodation rating. Accor (2007) refer to 4 kg per room night, O'Neill et al. (2002) refer to values of between 2.4 and 5.8 kg per room night in the US. Annual room textile laundering costs can be calculated from the following equation:

$C_A = (100/O) \times V_L \times C_L \times D_N$		
C_A	Annual cost per room	EUR/yr/room
O	Average annual occupancy rate	%
V_L	Laundry volume	kg
C_L	Laundry cost	EUR/kg
D_N	Number of days open per year	Days/yr

For a room with 75 % occupancy and 4 kg of laundry per room night open year around, and at a laundry service cost of EUR 0.50 per kg, annual laundry costs would equate to EUR 479. Thus laundry costs for a 100-room hotel could be EUR 47 900 per year, and a textile reuse rate of just 5 % could save almost EUR 2 400 per year.

A small 14-room hotel in the UK saved EUR 700 per year following the introduction of a simple linen reuse policy (Envirowise, 2008).

To encourage guest participation in reuse programmes, savings may be invested in environmental programmes (e.g. Accor 'Plant for the Planet' funding), or in onsite environmental initiatives.

<u>Energy management</u>
Simple measures to reduce energy use during housekeeping can save significant amounts of money, especially in relation to temperature regulation. In the absence of a building management system, reducing thermostat temperature by just 1 ºC can reduce heating energy consumption by up to 10 %, whilst closing shutters and curtains in summer can significantly reduce the demand on air conditioning systems (see section 7.3).

<u>Efficient cleaning</u>
Efficient cleaning techniques reduce chemical and water costs. For example, one less toilet flush every time a room is cleaned in a 100-room hotel could save EUR 330 per year, at a water price of EUR 2.00 per litre.

Despite significantly higher upfront costs for microfiber compared with conventional mops (EUR 2.72 compared with EUR 0.33 per 100 rooms cleaned), and higher washing costs (EUR 23.52 compared with EUR 3.92 per 100 rooms cleaned), the lifecycle cost of cleaning using microfiber mops is 5 % lower than conventional mops owing to 95 % chemical and water savings and 10 % labour savings (Espinozal et al., 2010).

Through substitution of cleaning chemicals in laundry and housekeeping operations, a small 14-room hotel in the UK was able to save EUR 1 700 per year (Envirowise, 2008).

Driving force for implementation
Efficient housekeeping measures, such as staff training in efficient and chemical-free cleaning and energy management, can achieve significant cost reductions with small investment costs.

Similarly, towel and bedclothes reuse programmes can be driven by economic factors, although where savings are reinvested into other environmental programmes CSR and image may be more important.

Green procurement of durable bedclothes with lower lifecycle servicing costs is driven by economic factors, but green procurement of organic or ecolabelled textiles is driven by CSR and marketing – ecolabelled products are a highly visible indication of environmental responsibility that can add value to the service offer.

Reference organisations

Accor, Gavarni Hotel Paris, Strattons Hotel UK, EU Ecolabel and Nordic Swan ecolabelled hotels (e.g. Best Western and Scandic hotels).

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5.4 Optimised small-scale laundry operations

Description

Water consumption

Accommodation providers generate a considerable amount of laundry (section 5.3), comprising bed sheets, pillow cases, duvet covers, towels, tablecloths and napkins, and staff uniforms. The latter items are also common to eateries. The provision of clean, crease-free bedclothes is a particularly important quality control point for accommodation establishments: unclean or creased bedclothes can give guests an instant bad impression. Effective and professional laundry operations are therefore a priority, and may be performed on site or off site by subcontracted commercial laundries. It is common for hotels to launder towels and smaller items on site, whilst outsourcing the laundering of sheets to commercial laundries that have the large-scale specialist equipment (e.g. continuous batch washers and roller irons) to deal with such items efficiently whilst guaranteeing a high-quality, crease-free finish (section 5.5). This technique refers to laundry operations located on accommodation premises, whilst the next technique (section 5.5) deals with large-scale (processing over 250 kg textiles per hour) on-site and commercial laundry operations using highly automated systems and continuous batch washers.

Within the accommodation subsector, daily laundering of bed linen and towels weighing in the region of 2.5 kg to 6 kg per room[11] can consume up to 100 litres of water – considerably more than half the total water consumption of a best practice hotel (see Figure 5.3 in section 5). Laundry operations represent the second greatest potential for water saving within a hotel, and also represent considerable potential for savings in energy and chemical consumption. High-temperature washing, tumble drying, multi-roll ironing and garment tunnel finishing are energy-intensive laundry processes. For the washing phase, water efficiency is closely related to energy efficiency: lower water consumption means lower water heating requirements.

Table 5.17 provides an overview of best practice measures to minimise water (and energy) use in laundries. In the first instance, laundry volumes should be minimised through efficient housekeeping (section 5.3). Then, accommodation managers must decide whether to outsource laundry services or perform laundry operations onsite (best practice for large-scale onsite and commercial laundry operations is described in section 5.5). Efficient washing processes are based on optimisation of the following four factors in relation to the washing requirements of specific wash loads, through equipment selection and programming:

- mechanical action
- chemical action
- temperature
- time.

Equipment selection

Accommodation SME, such as B&Bs, may use domestic machines, while small laundries use washer extractors of similar design to domestic machines but more robust and sometimes containing programmable micro-processor controls. These machines comprise a rotating drum that generates mechanical action and applies a high gravitational spin to extract water and detergent from the laundry following washing and rinsing. Front-loading machines, with doors on the front rather than on top, apply a full rotation around a horizontal axis, generating a laundry free-fall motion that maximises efficient flow-through and compression whilst minimising abrasive rubbing (EC, 2007). Front-loading machines use up to 60 % less water than top-loading machines (Smith et al., 2009), but nonetheless can consume up three times more water and two times more energy than a continuous batch washer used in large laundries – hence large laundries are described in a separate technique (section 5.5).

[11] Accor (2007) refer to 4 kg per room per night, O'Neill et al. (2002) refer to median laundry of 5.4 kg per room per night from a US study, ranging from 2.4 to 5.8 kg per room per night

The selection of efficient equipment is one of the most important measures to save water and energy in laundry operations. Average specific water consumption in domestic washing machines decreased from 13.9 L per kg of laundry in 1997 to 9.6 L per kg in 2005, and average energy consumption now stands at 0.17 kWh/kg laundry (AEA, 2009). However, there is considerable variation in water efficiency across models. A UK survey of new domestic washing machines found that optimum-rated water consumption varied from 6.2 to 11.8 litres of water per kg cotton laundry across models with 5 kg capacity (Which, 2011). For domestic machines, the EU Energy label provides a useful indication of energy- and water-efficiency.

Efficient batch management

Washing machines are more efficient at full capacity than partial capacity, even when a half-load programme is used. Washing can be optimised by:

- separating laundry into batches depending on washing and drying requirements;
- fully loading washing machines with these batches;
- storing rinse water and reusing to prewash the next load;
- selecting the appropriate programme settings (especially timing and temperature) to minimise water and energy consumption;
- appropriate dosing of a detergent that enables effective cleaning at low washing temperatures.

Drying and finishing

Forced thermal drying of laundry is a particularly energy-intensive process that uses up to 1.4 kWh/kg textiles in large laundries (see Figure 5.24 in section 5.5). Small laundries dry products in tumble-dryers that use considerable amounts of gas or electricity to evaporate water. Combined washer-dryers also use a continuous flow of water to condense moisture, which can increase total water use to over 170 L per 5 kg load (UK Environment Agency, 2007). In small laundries, large flatwork such as sheets are typically finished on a single roll ironer that passes tensioned flatwork under a rotating roller heated by electricity or gas. Roller ironers simultaneously dry damp flatwork that has undergone mechanical extraction (e.g. a high speed spin in a washer extractor). A range of hand finishing equipment may also be used, including free steam-ironing tables, and automatic finisher for shaped garments.

Small accommodation premises may be able to naturally dry clothes, at least for some of the year, saving a considerable amount of energy. However, for most accommodation establishments, this is not practical, and best practice involves minimisation of energy required for forced thermal drying. As indicated in Table 5.17, energy required for laundry drying can be minimised by: (i) maximising mechanical drying by, for example, selecting washing machines able to generate high a g-force spin (350 g for domestic machines, over 1 000 g for commercial machines); (ii) selecting and correctly maintaining an efficient dryer; (iii) optimising the drying-ironing process to prevent excessive drying.

Finally, there are a number of opportunities for water reuse, and heat recovery from waste water and dryers, that may be exploited to improve the efficiency of laundry operations.

Table 5.17: Portfolio of best practice measures for small-scale laundry operations

Stage	Measure	Description
Housekeeping	Reduce volume of laundry generated	– Encourage guests to reuse towels and bed linen (section 5.3). Minimise use of tablecloths and napkins in restaurants.
Washing	Purchase efficient washing machines	– Purchase the most efficient front-loading washing machines (e.g. 'A+++' EU energy rating for domestic machines, or efficient microprocessor-controlled, variable motor speed commercial machines).
	Load optimisation	– Install stepped capacity machines to cope with different loads. Separate laundry into batches based on washing requirements (e.g. textile type and degree of soiling), and wash batches at full machine capacity. Optimise temperature and detergent dosing.
	Wash programme optimisation	– Match wash programme to textile type and degree of soiling. Use low temperature wash and efficient detergents. Use single-step wash with two rinses, and calibrate micro-processor water-level control where necessary.
	Water recycling	– Recover and store rinse water, and possibly wash water following microfiltration, and use for wash or prewash step.
	Heat recovery	– Recover heat from waste water, and if possible also from tumble dryer exhaust, to heat incoming fresh water.
	Green procurement of detergent and efficient dosing	– Avoid hypochlorite and use ecolabelled detergents. Match detergent dosing to recommendations and laundry batch requirements. Optimise with machine cycle. Soften hard water.
Drying	Purchase efficient equipment	– Purchased washing machines can achieve high g-force spin cycles (350 – 1 000 g depending on size) to minimise thermal drying requirements. Avoid flow-through water-condensing dryers. – Purchase heat-pump or gas-fired dryers.
	Optimise laundry cycle	– Optimise drying time in relation to target moisture content – use moisture sensors.
Ironing and finishing	Minimise ironing energy use	– Use an efficient roller ironer. Where relevant, use condensate from HVAC systems in steam irons. Aim for final textile moisture content in equilibrium with atmospheric conditions.
	Minimise chemical use for finishing	– Avoid or minimise use of water and dirt repellent chemicals.
Entire process	Optimisation through water and heat recovery, and maintenance	– Optimise the entire laundry process. Recover heat from dryer and waste water to heat incoming freshwater. Send staff on specialist training courses and seek expert advice.

Achieved environmental benefit

<u>Washing process</u>

Careful control of water levels in washer extractors (damped dip tube connected to a micro-processor control unit) can reduce water and energy consumption by 30 % (Carbon Trust, 2009). Reusing rinse water in washer-extractor machines can reduce water consumption by between 30 % and 40 %, heating energy consumption by up to 45 %, and detergent consumption by up to 30 % (EC, 2007; Smith et al., 2009).

The use of lower temperature washing, in combination with effective low-temperature detergents, can reduce washing energy consumption considerably. For example, reducing the temperature of the main wash from 60 °C to 40 °C can reduce electricity consumption by 0.7 kWh per wash for a 10 kg load, equivalent to 40 % of average specific energy consumption (assuming 3 L of water per kg textiles in the main wash).

Figure 5.18 presents the magnitude of water and energy savings achievable for the washing process. For a small 10-room hotel, the purchase of an efficient washing machine using 7 L water per kg laundry instead of the European average of 9.6 L/kg, and washing predominantly at 40 ºC instead of 60 ºC, could reduce water consumption by 14 m^3 and energy consumption by 383 kWh per annum. For a large hotel of 100 rooms, installation of rinse water recirculation alongside efficient machines and a default wash temperature of 40 ºC could save 252 m^3 of water and 5 475 kWh of energy per annum.

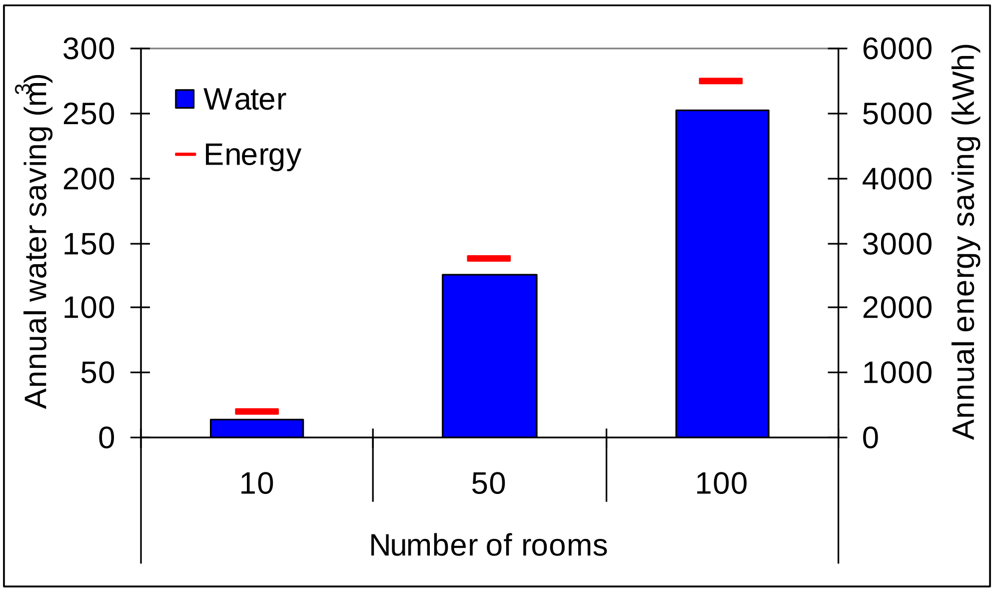

Figure 5.18: Annual water and energy savings achievable for the washing process in different sizes of establishment (assuming 75 % occupancy and on average 2 kg laundry per occupied room per night)

<u>Drying and finishing processes</u>
Heat-pump driers and gas-fired driers can each reduce primary energy consumption for tumble drying by around 45 %, compared with standard electric tumble driers (Bosch, 2011; Miele, 2010; Miele Professional, 2011). Optimal use of efficient roller ironers can reduce ironing energy consumption by a similar percentage. Figure 5.19 indicates the magnitude of energy savings achievable through implementation of best practice for different sizes of establishment, based on the same assumptions as those applied in Figure 5.18, and that half of the laundry is dried in driers, whilst the other half (sheets) is dried in flat bed ironers.

On a laundry weight basis, drying and ironing are associated with energy savings twice as high as for washing. However, given that drying is divided between tumble drying and ironing for different laundry groups, the magnitude of energy savings achievable for each of the three laundry processes is similar – e.g. for a 100-room hotel, energy consumption for washing, tumble-drying and ironing can typically be reduced by 5 475, 5 475 and 6 023 kWh/yr, respectively, leading to a total laundry energy saving of 16 973 kWh/yr.

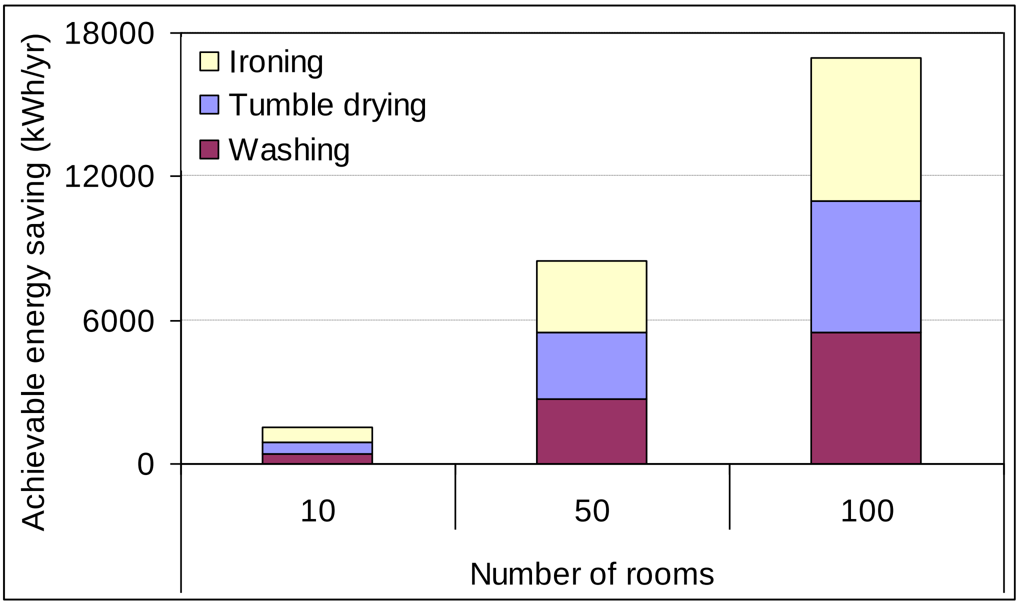

Figure 5.19: Energy savings achievable from the implementation of best practice washing, drying and ironing for different sizes of establishment

Appropriate environmental indicator

<u>Appropriate indicators</u>

The European energy label (EC, 2010) requires manufacturers of domestic washing machines to display on clear labels total annual machine energy and water consumption based on the following use pattern:

– 220 washes per year

– 3/7 of which are at full load and 60 °C cotton programme

– 2/4 of which are at half-load and 60 °C cotton programme

– 2/4 of which are at half-load and 40 °C cotton programme.

Power consumption during 'standby' and 'on' modes is included in calculations, and lower percentage loading rates are assumed for larger machines. Based on these data, machines are awarded energy ratings of A^{+++} (most efficient) to G (least efficient). For example, one A^{+++} rated machine[12] with a load capacity of 8 kg uses 11 880 L of water and 182 kWh of electricity per year over 220 wash cycles according to EU energy label calculations, approximating to specific consumption of 9.4 L and 0.145 kWh per kg washing. EU energy ratings are strongly related, but not directly proportionate, to specific energy and water consumption across different domestic machine sizes. Specific energy and water consumption figures approximated from EU energy labelling are higher than what is achievable under optimum operating conditions – tourism enterprises may be expected to operate washing machines more efficiently under higher average load rates compared with an average domestic situation.

In addition, the Energy label grades machines according to their spin drying efficiency, with classes A-G based on the weighted average percentage moisture remaining following the above ratios of wash cycles. An 'A' rating represents ≤45 % moisture, a 'G' rating ≥90 % moisture. Table 5.18 lists appropriate indicators and possible benchmarks of best practice for on-site laundry processes.

[12] Miele W5000 WPS Supertronic Washing Machine: http://www.miele.co.uk/washing-machines/w5000/w5000wpssupertronic-393/

Table 5.18: Indicators and benchmarks (BM) of best practice for water, energy and chemical use efficiency in laundry processes

Aspect	Indicators and benchmarks
Water	– EU energy rating for domestic machines (BM: 'A^{+++}') – Optimisation of water level and programming in commercial machines – Installation of rinse-water recycling system – Water consumption (L) per kg laundry washed for commercial machines (BM: ≤7 L per kg textile)
Energy	– EU energy label rating for domestic washing machines (BM: 'A^{+++}') – EU energy label spin dry rating for domestic washing machines (BM: 'A') – Moisture content of textiles following spinning (BM: ≤45 %) – Energy consumption (kWh) for: (i) washing; (ii) drying; (iii) the entire process (BM: 2.0 kWh per kg textile) – Implementation of natural drying of laundry where possible – Installation of heat-pump or gas-fired tumble-dryers – Implementation of heat recovery
Chemical use	– Average weight (grams) of **active ingredient** used per kg laundry – Average critical dilution volume of chemicals used per kg laundry – Implementation of automatic dosing – Percentage of chemicals used that are ecolabelled (BM: ≥80 %)

Benchmarks of excellence

Water and energy efficiency are closely related for washing machines. Hohenstein Institute (2010) report that state-of-the-art water efficiency for washer-extractors has improved considerably since 1995, and over the five years from 2005 to 2010 stood at 8 L per kg textiles. This could be further reduced through collection and recycling of rinse water. Carbon Trust (2009) report that small commercial laundries and on-premises laundries processing fewer than 100 000 pieces per week consume 2.0 to 2.9 kWh per kg textiles (total consumption, including for non-laundry processes such as lighting). The following benchmarks of excellence are proposed for small-scale laundry processes.

BM: laundry is outsourced to efficient commercial laundry service providers complying with benchmarks specified in section 5.5.

BM: all new domestic washing machines have an EU energy label rating of 'A^{+++}', or average annual laundry water consumption ≤7 L per kg laundry washed in laundries with commercial machines.

BM: total laundry process energy consumption ≤2.0 kWh per kg textile, for dried and finished laundry products.

BM: at least 80 % by active-ingredient-weight of laundry detergent shall have been awarded an ISO Type I ecolabel (e.g. Nordic Swan, EU Ecolabel).

Cross-media effects

Optimising laundry operations reduces water and energy use, and can also reduce chemical use. The higher resource consumption required to manufacture detergents containing enzymes is small compared with energy savings that can be realised by the use of such detergents through effective cleaning at lower temperatures (Henkel, 2009).

In terms of replacing older machines, approximately 90 % of the lifecycle impact of white goods is due to operation compared with 10 % due to manufacture and disposal, and it can be more environmentally responsible to replace an older machine with a more efficient one rather than have it repaired (Environment Agency, 2007).

There may be some trade-off between hygiene and environmental objectives in relation to temperature settings. The minimum temperature compatible with hygiene requirements should also be sought.

Operational data

Washing machine selection

When installing new washing machines, the first factor to establish is the required total capacity. The maximum total required washing machine capacity can be calculated from the following equation:

$C = (\sum(M_{1-n} / R_{1-n}) \times T_{w1-n}) / T_L$	
C	Maximum total machine capacity in L
M_{1-n}	Maximum mass of laundry expressed as kg per day
R	Load ratio (see Table 5.19)
T_w	Wash cycle time for batches 1 to n expressed as hours
T_L	Time allocated for laundry washing expressed as hours per day

The mass of different items (towels, sheets, duvet covers) can be taken from known specifications or measured directly, and multiplied up to calculate total mass per batch according to room changing rates (see section 5.3). Note that T_L can also be expressed as the number of hours dedicated to laundry over a number of days where peak loads occur on particular days (e.g. weekend changes) and can be worked through during subsequent days.

Once the maximum total machine capacity requirement has been calculated, the machine combination to achieve this volume can be defined. Where workloads are variable, for example across seasons, a modular approach enables a higher frequency of optimised loading. For example, Picafort Pallace in Mallorca has a maximum laundry volume of 700 kg per day that varies considerably over the year. Mab Hoestelero (2004) reported the following optimised solution capable of 650 kg washing per day with two operators working seven hours:

- one 55 kg washer-extractor
- one 22 kg washer-extractor
- one 12 kg washer-extractor.

The above 'stepped' capacities create a range of combined wash capacities depending on the combination of machines in operation, i.e. 12, 22, 34, 55, 67, 77 or 89 kg. This maximises the opportunity for optimised loading of the machines in operation. It is worth noting that large drums offer greater mechanical cleaning owing to a higher drop height and consequent compression effect (EC, 2007).

Once the required machine capacities have been decided, specific models may be selected. Durability and reliability are important factors for hospitality use. Once these criteria have been met (e.g. through testimonials of other hospitality users), energy and water efficiency are key criteria for both environmental and lifecycle economic performance. As mentioned under 'Appropriate environmental indicators', the EU energy label provides a useful guide for the energy and water efficiency of domestic machines. For commercial machines, the optimum efficiency may be calculated from technical specifications, though these will not be directly comparable with EU energy ratings that assume sub-optimal average use characteristics. The incorporation of micro-processor controls, variable speed drives, damped dip tubes (to measure water level), and integral load weighting system are important features that can be specified on new commercial machines or retrofitted to enable accurate adjustment of water levels, chemical dosing and wash programmes.

Another important factor to consider when selecting washer-extractors is the maximum gravitational (g-) force generated during the spin cycle, as this determines the mechanical drying capacity of the machine. Many washing machine manufacturers quote spin speed in revolutions per minute (rpm). G-force is a function of both drum diameter and spin speed:

$g = 0.56 \times D\,(n/1000)^2$	
D	Diameter of the wash drum in mm
n	rpm for the spin cycle

Therefore, at a given spin speed, the g-force is proportional to drum diameter. Modern large washer-extractors are able to generate up to 1 000 g (Hohenstein Institute, 2010). The option of different spin speeds is also important so that a lower spin speed can be selected for delicate fabrics.

Laundry installation

Figure 5.20 provides an example of an optimised laundry configuration. Water from the final rinse may be reused either in the prewash, the main wash, or the first rinse of the subsequent load. Rinse water from earlier rinses may be used in the prewash or the main wash of the subsequent load, in which case detergents will be carried over and dosing can be reduced accordingly (by up to 30 %: EC, 2007). Water tanks are easily retrofittable and may be installed on top of washer-extractors, or anywhere nearby. The installation of pipework from the machine to the water tank, and modification of machine wash programmes to manage water recycling (operation of correct input and output valves depending on the cycle position) are straightforward. Meanwhile, the installation of a simple heat exchanger can recover heat from prewash and main wash waste water. Microfiltration of waste water can be introduced at the heat recovery point as shown in Figure 5.20, enabling further water recovery and up to an 80 % reduction in freshwater consumption (EC, 2007). For heat recovery, the EC (2007) recommend corrugated pipe heat exchangers owing to their efficiency, robustness and tolerance of soiled water. The following check criteria are important to optimise heat exchange performance:

- the flow directions are connected in countercurrent direction
- there are turbulences in the liquids
- there is a large heat transfer surface
- the mass flow and the temperature differences in both directions are the same
- as much time as possible is provided for the heat exchange.

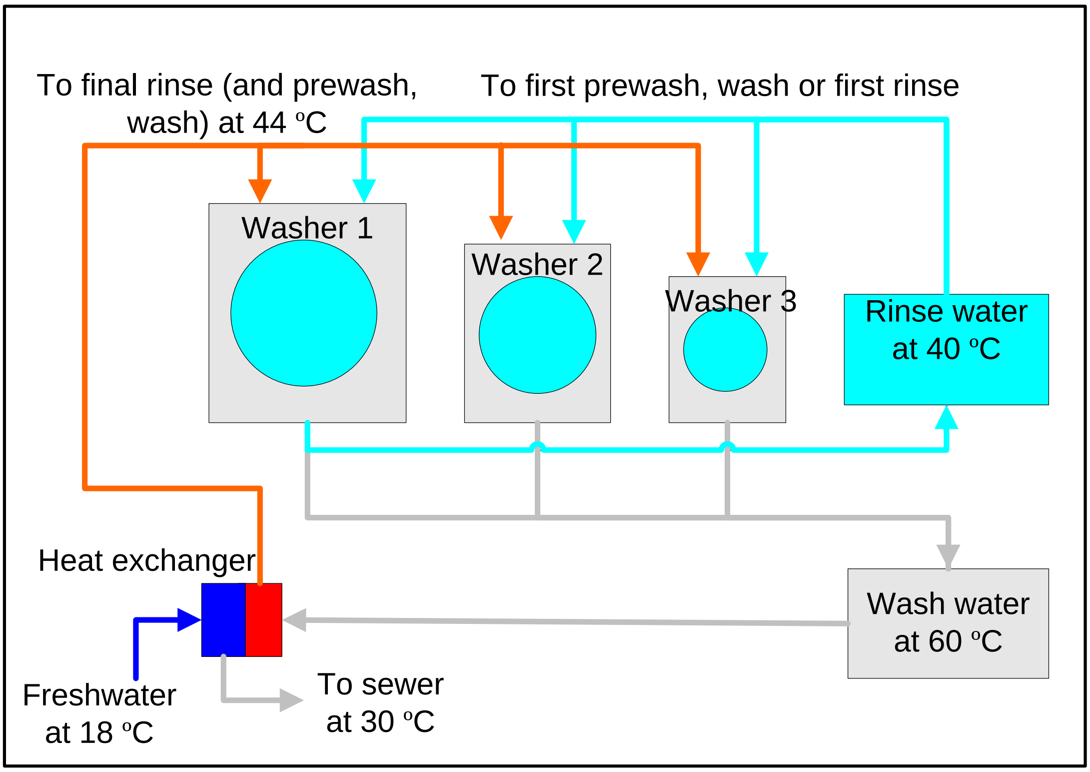

Figure 5.20: Schematic example of an optimised small-scale laundry washing process, with rinse water reuse and heat recovery from waste water (based on information in EC, 2007)

Batch management

In a typical accommodation establishment, laundry comprises: (i) towels and bath mats; (ii) sheets and other bedclothes; (iii) tablecloths and napkins; (v) garments. Incoming laundry should be separated into batches according to washing and drying requirements. Towels and bath mats should be separated from bed linen, and these batches further divided depending on the degree of soiling (Table 5.20) and thus required cleaning intensity. For example, tablecloths and napkins are likely to require more intensive washing to remove fats, oils and greases. It may be more efficient for housekeeping to sort laundry at source, and send to the laundry room in separated batches. It is common for accommodation providers to outsource the laundering of bedclothes to commercial laundries that have the equipment to efficiently provide a high-quality, crease-free finish to sheets, duvet covers and pillow cases.

The rated load capacity of most washer-extractors is based on a standard material weight to drum volume ratio of 1:10. However, to ensure proper washing, load factors and consequently load volumes should be adjusted according to the type of textile and degree of soiling (Table 5.19). Reducing the rotational speed of the wash cycle in variable speed extractors for polyester cotton can reduce creasing and enable higher load rates (Carbon Trust, 2009). In order to load machines correctly, it is necessary to define various types of full load in terms of number of towels or sheets, etc., based on sampling of laundry item weights (Table 5.19). Underloading reduces efficiency in proportion to load, because the same quantity of water, energy and detergent is used, and half-load programmes are less efficient. Overloading also reduces efficiency because mechanical and chemical action is impeded by textiles being bundled closely together, and items may require re-washing.

Table 5.19: Load ratios for different textiles with light and heavy soiling, and example number of items that can be washed in a 100 L (10 kg rated capacity) machine

Material	Soiling	Load ratio	kgs full load (examples)
Cotton	Light	1:12	8.3 (16 towels)
	Heavy	1:12.5	8.0 (16 towels)
Polyester-cotton (linen)	Light	1:15	6.7 (8 sheets)
	Heavy	1:17	5.9 (7 sheets)
Duvet quilts (internal)	Light	1:20	5.0 (3 duvets)
	Heavy	1:22	4.5 (2 duvets)
Mops		1:9.5	10.5 (35 mop heads)
NB: Assumes 0.5 kg per cotton towel, 0.8 kg per polyester-cotton sheet, 1.6 kg per duvet (2 m x 2 m), 0.3 kg per mop head. *Source:* Laundry and Dishwasher Info. (2011).			

Chemical dosing

Chemical dosing should be matched to the size and cleaning requirements (Table 5.20) of different loads. Excessive dosing not only wastes detergent, but can increase rinse requirements. Heavily soiled laundry can be pre-dosed or 'spotted' with strong detergents, for example containing hydrogen peroxide, and/or sent to more intensive wash cycles. For the main wash, the use of low-temperature detergents, especially biological detergents containing enzymes, is associated with a number of advantages:

- reduced energy costs
- possible reduced rinsing requirements
- reduced risk of colour run
- increased fabric longevity (lower fade rate).

Where low temperatures are used, chemical disinfection is recommended, using hydrogen peroxide or peracetic acid (Hohenstein Institute, 2010). Large commercial washing machines have built-in programmable chemical dosing. Automatic chemical dosing units can be easily retrofitted to smaller wash-extractor machines, and enable more accurate control of detergent and conditioner quantity and timing. Automatic dosing pumps can be programmed for different settings according to different wash load requirements: for example, low, medium and high soiling. It is important to periodically check the calibration of the auto dosing pumps.

Table 5.20: Typical degree of soiling for hospitality laundry

Light soiling	Medium soiling	Heavy soiling
– Bed sheets, bedclothes, towels – Cloth hand towels	– Service staff clothes – Tablecloths, napkins – Mops and mats	– Kitchen and technical staff clothes – Clothes, dish towels, etc.
Source: Nordic Swan (2009).		

Programme setting

Table 5.21 summarises the main processes performed by washer-extractor machines. Washing machines are programmed to vary the intensity of the mechanical action, the time and the temperature of the wash cycle. For example, programmes for delicate fabrics apply: (i) a higher water fill-level in order to reduce the drop-height and associated mechanical action of front-loader extractors; (ii) a shorter wash time (e.g. 5 – 10 minutes at wash temperature) and fewer rotations per minute to reduce mechanical action; (iii) lower temperature; (iv) lower detergent concentrations (Laundry and dishwasher info, 2011). Such programmes use more water and energy, and should only be used for genuinely delicate fabrics – they can usually be avoided for hospitality laundry.

For lightly soiled hospitality laundry, a single-stepped wash with two rinses and inter-extracts (spins) is sufficient, saving up to 30 % water and energy compared with a standard two wash and three rinse process (DTC LTC, 2011).

Table 5.21: Main stages of the washing and drying process performed by washer-extractors

Stage	Functions	Conditions	Time	Chemicals
Prewash	Rapid wetting Swelling of soil Removal of heavy soil Dissolving and swelling of spots	20 – 25 ºC (blood) 50 – 60 ºC (fat, oil)	8 – 12 minutes	50 – 70 % detergent dose
Main wash	Removal of soil Dissolving and swelling of spots	30 – 90 ºC	10 – 15 minutes	30 – 50 % detergent dose
Rinse	Removal of soil residues Removal of detergent residues (surfactants, alkali and bleaching agents)	25 – 60 ºC	8 – 12 minutes	
Neutralisation	Reduction of textile pH to 6.0-6.5, in order to prevent discolouring during ironing	20 – 25 ºC	2 – 4 minutes	Formic or acetic acid
Spinning	Mechanical dewatering	Up to 600 g	5 – 10 minutes	

Source: EC (2007).

Modern washer-extractors are controlled by micro-processors connected to sensors that control the water level (the 'dip') in the drum at all stages of the washing cycle. Carbon Trust (2009) recommend that water levels be adjusted (by trial and error if necessary) to the following:

- prewash dip of 125 mm
- wash dip of 75 mm
- rinse dip as low as possible without leading to yellowing of textile following drying.

Some detergents contain brighteners that only become activated above 60 ºC. Constant low temperature washing can lead to blockages in machines and pipes from the accumulation of unused detergent agents. Periodic high temperature washes, and the avoidance of detergents with brighteners, can prevent this problem. Thermal washing at 60 ºC for two minutes disinfects laundry, which is recommended but not essential for hospitality laundry (Carbon Trust, 2009) – chemical disinfection may be used instead. If low temperatures are used for the main wash cycles, laundry may be periodically disinfected by washing at high temperatures. Some machines offer sluice programs that introduce a short, high temperature cycle to the wash. However, it has been demonstrated that washing at 40 ºC with standard domestic detergents is sufficient to destroy viruses (Heinzel et al., 2010). Alternatively, chemicals may be used to achieve low temperature disinfection, as specified in the European standard for control of bio-contamination in laundries, EN 14065.

The maximum spin speed should be selected within the constraints of the fabric. At temperatures above 40 ºC, mixed polyester cotton fabrics can become creased at high spin speeds or long durations (EC, 2006). For commercial machines with micro-processors, the final spin speed and time should be adjusted for different fabrics. For cotton fabrics, the spin speed should be set to the maximum possible and the spin time adjusted in one minute increments until no further water is extracted. For polyester-cotton garments, the spin time and spin speed should be adjusted by trial and error to obtain the minimum moisture content with no pressure creases.

Programme optimisation should be performed by laundry technicians and consultants. Once programmes have been pre-set, they should not be changed by laundry operatives, and it is imperative that operatives use the correct preset programmes, and this should be clearly guided by charts visible at the point of use.

Quality control and wash optimisation

A quality control inspection should be performed to identify items that require re-washing. The rate of re-washing is a useful guide to optimisation, with an optimum rate of 3 – 5 % proposed (Business Link, 2011). A rate of less than 3 % indicates that laundry is being over-washed (time, temperature and/or dosing should be reduced), whilst a rate of more than 5 % indicates inadequate washing (time, temperature and/or dosing should be increased).

Washer-extractors should be checked for leaking drain and water inlet valves, and correct operation of thermostats.

The hygienic quality of laundered textiles may be checked by independent testing. For example, many commercial laundries in Germany are awarded with the RAL-GZ standard (Hohenstein Institute, 2011).

Drying

Thermal drying is a highly energy-intensive process and should be minimised through the maximisation of mechanical water extraction (high g-force spinning in washing machines) and, wherever practical, natural line drying – see, e.g. from Travel Foundation under 'Economics'. However, in large accommodation establishments, thermal drying is unavoidable. In small-scale laundries, thermal drying is performed in dedicated tumble-dryers and during ironing. Where a commercial flatwork ironer is used, bedclothes do not require a separate thermal drying stage. Mab Hoestelero (2004) refer to Picafort Pallace in Mallorca where only towels require drying.

In the first instance, it is important to select efficient tumble-dryers. Most new tumble-dryers are of the condenser type, in which a heat exchanger removes heat from hot moist air from the drum to the surrounding atmosphere, resulting in moisture condensation within the machine, before the air is recirculated into the drum via a heating element. Compared with dryers that vent hot moist air from the drum directly outside, condenser driers retain more heat energy (heat of condensation), but require good ventilation (and sometimes active cooling) of the room in which they are located. Recently, heat-pump dryers have become commercially available. These dryers use a heat-pump to extract heat from the cooling (condensation) phase and release it to the heating phase, resulting in up to 50 % less energy consumption than a conventional condensing dryer, and less heat transfer to the surrounding atmosphere. Domestic-sized heat-pump driers use less than 0.5 kWh per litre moisture removed from textiles, resulting in specific energy consumption of approximately 0.25 kWh per kg, to dry laundry at 45 % moisture content (Bosch, 2011; Miele, 2010). Meanwhile, tumble-dryers can be purchased that use gas instead of electricity to heat the drum air. These can reduce primary energy consumption and associated environmental impacts such as GHG emissions by over 50 % (Miele Professional, 2011), and result in environmental benefits where electricity is supplied primarily from fossil-fuel sources. However, where electricity is sourced from largely renewable sources (e.g. where an establishment has a genuine green electricity supply contract: see section 7.6), electric tumble driers are more environmentally friendly. Tumble-dryers can be selected with moisture sensors that halt the drying process when a pre-programmed moisture content is reached (e.g. 'cupboard dry' or 'ironing' settings).

Laundry rooms often require high ventilation rates to avoid overheating. In buildings with centralised controlled ventilation and heat recovery, this heat will be distributed throughout the building and will reduce heating demand in winter. In buildings without such systems, it may be possible to install a heat-recovery system that uses waste heat from dryers to heat ventilation air in winter (Figure 5.21).

Figure 5.21: A heat recovery system installed in a hostel laundry

The most important management action to minimise energy consumption in the drying process is to ensure correct drying times, and avoid over-drying that wastes energy and damages textile fibres, leading to higher replacement rates (Figure 5.31 in the next section shows the significant contribution of textile wear towards washing costs). The purpose of drying is to remove excess water from textile products, relative to their moisture content under normal atmospheric conditions (e.g. 6 – 8 % for cotton: EC, 2007). This should be the target moisture content after ironing. Thus, the equilibrium moisture content and the drying potential of the ironing should be subtracted from laundry moisture content after the washing stage when calculating dryer times, or when programming dryers containing moisture sensors. Sheets and other bedclothes may not require tumble drying where commercial ironers are used. Further points to reduce energy consumption during laundry drying are to fill machines to their rated capacity, to clean the lint trap at least once per day, and to check for correct operation of end-point moisture sensors, fans, and to clear ducting.

<u>Ironing</u>

It is common for accommodation providers to outsource the laundering of bedclothes to commercial laundries. Where bedclothes are laundered onsite, it is financially worthwhile to invest in a commercial flatbed ironer that can save a lot of labour and negate the need for the separate thermal drying of sheets.

In the first instance, it is important to select an efficient flatwork ironer. EC (2007) report that specific direct energy consumption of 0.9 kWh per litre of moisture removed for new steam-powered roller ironers, compared with 1.4 kWh per litre of moisture removed for older steam-powered ironers. These values correspond to energy consumption of 0.35 and 0.55 kWh per kg textiles at 45 % moisture content, respectively, indicating a machine efficiency differential of at least 0.2 kWh per kg textiles. Smaller scale ironers may be heated using either electricity or gas. As for driers, gas heating results in environmental benefits where electricity is supplied from primarily fossil-fuel sources, whilst electric heating is environmentally superior where 'green electricity' (section 7.6) is sourced.

Energy consumption during drying can be minimised by operating flatwork driers as close to the rated capacity as possible, and in large batches to reduce the number of machine heat-ups required. The roller speed should be adjusted to ensure that flatwork leaving the ironer is dried to equilibrium moisture content in one pass, and as much of the ironer surface as possible is covered with flatwork at all times of operation (batch preparation and purchasing the correct width of ironer is important). Condensation water from the tumble driers or air-conditioning units can be used for steam irons, avoiding the need to purchase distilled water.

<u>Laundry optimisation</u>
The following points provide guidance on optimisation of the entire laundry process (also refer to washing optimisation, above).

1	Firstly, ensure that batch management is optimised to maximise machine loading rates.
2	Based on typical batch characteristics, assess the potential to reduce wash temperature. The potential for this may be high for typically lightly soiled accommodation laundry – it is worthwhile to experiment with different temperature and chemical dosing settings. Aim for a rewash rate of 3 – 5 %. Additional chemical costs will be compensated by reduced energy consumption and textile wear.
3	For commercial-sized machines, install tanks and modify wash programmes to reuse rinse water in earlier rinse or prewash cycles. In areas of water stress, assess the economic viability of installing a microfiltration system to reuse prewash water in the prewash or wash cycle. Account for water, energy and chemical savings.
4	Ensure all economically viable heat recovery opportunities are being exploited. Install a basic heat exchanger (e.g. corrugated pipe system) to transfer waste water heat to incoming freshwater. Identify any opportunities to use waste heat from the drying process to heat incoming wash water.
5	Minimise use of tumble-dryers by extracting as much moisture as possible during washer extractor spin cycles, transferring flatwork directly to roller ironers, and ensuring laundry is not over-dried (should aim for equilibrium moisture content at end of finishing process).
6	Adjust the speed of roller ironers to ensure adequate drying in one pass, and utilise at as high a capacity as possible (correct sizing important).
7	Calculate when it would make financial sense to invest in new equipment based on annual energy and water savings (see Table 5.22).

Realisation and maintenance of optimum efficiency requires monitoring and reporting of key performance indicators for energy and water use efficiency. These should be expressed as kWh energy and L water consumed per kg laundry processed, and reported weekly or monthly in charts that enable easy tracking of progress over time. These data require sub-metering of all energy (electricity, gas, oil, steam) and water consumed in the laundry, and information on the number of pieces laundered. The average piece weight of mixed laundry items is around 0.5 kg (Carbon Trust, 2009), but this may vary for hospitality laundry and can be established for individual laundries through weighing a sample of laundry items.

Economics

<u>Consumable costs</u>
Figure 5.22 presents the difference in consumable cost of laundry operations per kg textile for an average laundry, consuming 12 L of water, 1.5 kWh energy and 15 grams of detergent per kg textile, and a best practice laundry consuming 6 L water, 1.0 kWh energy and 10 grams of detergent per kg textiles. Consumable costs are dominated by chemical use, and can typically be reduced by one third, from EUR 0.40 to EUR 0.26 per kg textiles, through the implementation of best environmental management practice. Where electricity is used for all process heating,

energy costs can be considerably higher than indicated in Figure 5.22. For example, in Germany the energy costs for laundries using electricity for process heating would be twice as high as indicated in Figure 5.22.

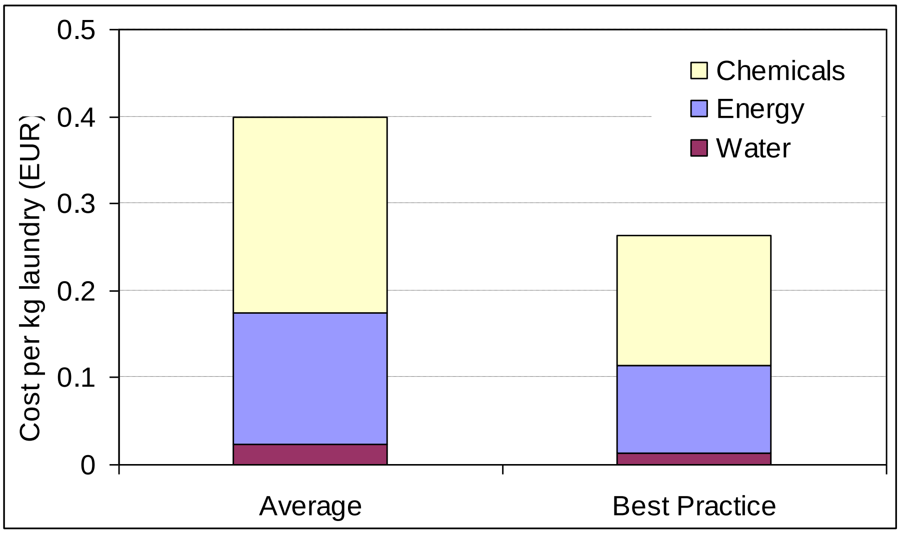

Figure 5.22: Consumable costs per kg of fully processed laundry under average and best practice conditions, at an energy cost of EUR 0.10/kWh, water cost of EUR 2/kWh and chemical cost of EUR 15/kg

Efficient management, such as batch sorting and full machine loading, results in economic savings at little or no additional cost. For example, the Travel Foundation (2011) refer to a Moroccan hotel where linen is line dried on sunny days. Over nine months between January and September 2010, air drying 12 465 kg of linen saved EUR 700 of electricity and EUR 800 of gas.

Given the large contribution of chemicals towards consumable costs, increased efficiency of chemical use can represent a significant driving force for wash processes optimisation that also reduces water consumption. This may offset any increase in chemical costs associated with the avoidance of environmentally harmful chemicals and green procurement of ecolabelled detergents.

Equipment selection and installation

The installation of efficient equipment associated with best practice may increase capital costs. Energy and water savings achievable through the use of more efficient equipment are presented in Table 5.22, assuming efficient management of the laundry process. The average lifetime of white goods is eight years. Efficient washing machines are not necessarily more expensive than less efficient ones (Environment Agency, 2007), but the annual energy and water savings of such machines (Table 5.22) would justify an additional investment of several hundred euro during procurement selection in a small establishment. In a larger establishment with 100 rooms, the energy and water savings of efficient machines combined with rinse water reuse justify a total additional investment of several thousand euro for these features – based on a two to three year payback time and a low electricity price of EUR 0.10 per kWh. The payback times for installation of water recycling tanks and basic heat recovery systems such as corrugated pipe heat exchangers are short (EC, 2007).

The cost of tumble-dryers, and the price premium demanded for efficient heat pump or steam compression dryers, is highly variable. Some domestic-sized tumble-dryers use a continuous flow of freshwater to condense water out of hot moist air from the drum, using approximately 3 L of water per kg laundry. Therefore, selection of an efficient dryer can reduce both energy and water consumption in a small accommodation establishment (Table 5.22), justifying an additional procurement cost of several hundred euro for an efficient machine. In a 100-room hotel, annual energy savings for efficient driers would justify an additional investment ranging between approximately EUR 800 and EUR 2 400 depending on energy prices (Table 5.22).

The magnitude of energy savings from efficient ironers, and thus the justified price premium for efficient new machines, are similar to those from efficient tumbler driers (Table 5.22).

Gas is a cheaper energy source than electricity, and some laundries are switching to gas-fired tumble-driers and ironers for this reason.

Table 5.22: Examples of savings achievable from implementation of best practice under different situations

Situation		Annual saving (EUR)				
		Water	Energy			Total
	Prices	EUR 2 / m^3	EUR 0.05 / kWh (gas)	EUR 0.10 / kWh	EUR 0.15 / kWh	**EUR**
10-room hotel	Efficient washing machine, 40 ºC wash	27	-	38	58	**65 – 85**
	Efficient heat-pump dryer	32	-	55	82	**87 – 114**
	Efficient ironer		-	60	90	**60 – 90**
100-room hotel,	Efficient washing machine, 40 ºC wash, rinse water reuse	504	-	548	821	**1 052 – 1 325**
	Efficient heat-pump or mechanical steam compression dryer		238	548	821	**238 – 821**
	Efficient flatwork ironer		301	642	903	**301 – 903**

Driving forces for implementation

Efficient laundry operations can reduce energy and water costs. In some Member States, governments provide financial incentives for the installation of efficient laundry equipment. In the UK, efficient laundry equipment is covered by the Enhanced Capital Allowance scheme that deducts the costs of efficient new equipment from tax liability in the year of purchase.

Many tourist destinations, especially around the Mediterranean, suffer water stress during peak season, and there is pressure to reduce water use associated with tourism. Economic driving forces may be stronger in such destinations if authorities impose higher water charges.

Emerging techniques

At the larger commercial scale, mechanical steam compression driers may soon become commercially available, and can achieve similar energy savings to heat-pump driers (Palendre and Clodic, 2003).

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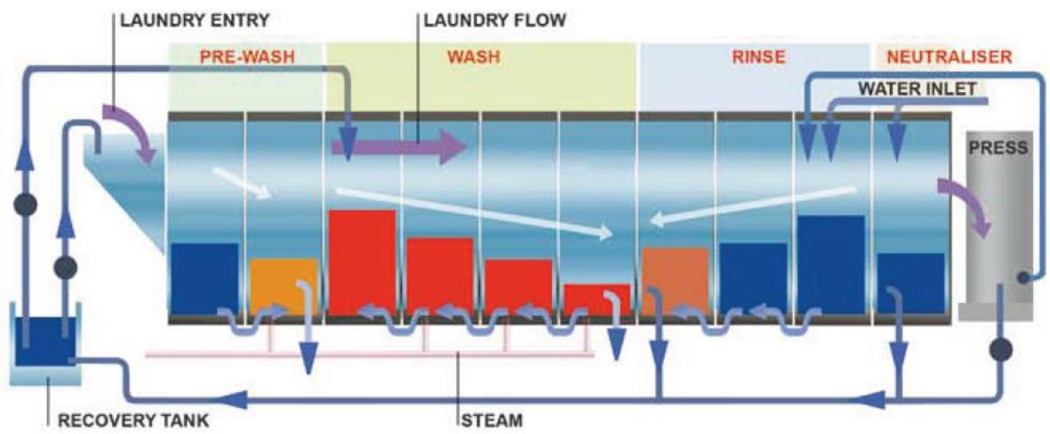
5.5 Optimised large-scale or outsourced laundry operations

Description

Large-scale professional laundry operators can provide a more efficient alternative to on-site laundry operations. Efficient large-scale and commercial laundry operations with a capacity of hundreds to thousands of tonnes of laundry textiles per year typically achieve water use efficiencies of 5 to 6 litres of water per kg of linen, compared with in excess of 20 litres per kg for non-optimised small-scale laundry operations (Bobák et al., 2010; ITP, 2008). Specific water consumption as low as 2 litres per kg has been demonstrated following process optimisation and water recycling (EC, 2007). It is common for hotels and other tourism service providers, including restaurants, to outsource laundry operations. This technique applies directly to all tourism service providers who control large-scale on-site laundry operations (typically large hotels with over 500 rooms), and also to outsourced providers of laundry operations. Tourism service providers can reduce their indirect environmental impact by ensuring that their laundry providers implement best practice according to this technique.

Best practice for large hotels (over 500 rooms) and outsourced laundry providers is to operate continuous batch washers (CBW) with counter-flow current, such as shown in Figure 5.23. Such washers are efficient at laundry loads of over 250 kg per hour (Carbon Trust, 2009). Discrete batches of 25 – 100 kg are introduced into one end of the machine and moved through a long 1 – 2 m diameter drum 'tunnel' divided into water compartments with different quantities of water, and varying temperatures and chemistry, by the motion of a water-permeable Archimedes screw. Such systems are highly water efficient because clean water is only injected at the final neutralisation and rinse phases of the cycle, and moves counter to the laundry movement, towards the wash and prewash phases, where detergents are added, thus effectively recycling water through phases of progressively more dirty laundry. In addition, water extracted from washed laundry during pressing and from the rinse phase may be re-injected at the prewash and wash phases, and water from the wash phase may be filtered and re-injected at the prewash phase, enabling water use efficiencies of better than 5 litres per kg textiles.



Source: Girbau (2009).

Figure 5.23: An example of a 10 module continuous batch washer with counter-flow water current and steam heating

The choice and dosing of laundry detergents has important implications for the quality of waste water arising from laundry operations in terms of toxicity and eutrophication potential. There may be a trade-off between waste water quality and process efficiency, as strong chemical action may reduce the need for heating. In the US there is a move towards the use of ozone generators that inject ozone, a powerful oxidising agent, directly into the rinse water as a highly effective disinfectant (US EPA, 1999). Benefits claimed for ozone injection include lower detergent dosing, lower temperature washes and the avoidance of chemical additives for disinfection such as hydrogen peroxide (Cardis et al., 2007). However, it is difficult to control ozone concentrations in order to guarantee disinfection and realise these potential benefits (DTC LTC, 2011). Best practice is therefore to minimise chemical dosing through process optimisation (e.g. water use minimisation and rinse water reuse), accurate dosing, the avoidance of environmentally harmful chemicals such as hypochlorite and the selection of more environmentally benign chemicals.

CBWs do not spin dry laundry as per washer-extractors. Following washing, drying is a two-stage process based on:

- mechanical dewatering – a quick process applied to all laundry exiting the CBW, usually using a mechanical 'hydro-extraction' or 'membrane' press to remove most of the excess water, with an energy demand in the region of 0.05 kWh per kg textiles;
- thermal drying – a slower and energy-intensive process using heat to evaporate residual water, with an energy demand of up to 1.4 kWh per kg textiles. Textiles are dried in tumble driers, roller-ironers (flatwork), and finishers (garments).

Laundries are large consumers of energy, although this consumption represents a smaller fraction of a typical guest 'footprint' compared with laundry water consumption (Figure 5.3 in section 5). In large laundries, steam is often used as a convenient energy carrier to heat all major processes, from the prewash phase of the CBW process, through drying, to ironing or finishing. Bobák et al. (2011) compare an 'average' steam-heated laundry with poor energy management with an optimised steam-heated laundry (Figure 5.24). Typically, steam is generated in gas boilers, and heat losses occur at this stage, and during distribution via the walls of transfer pipes, and through leaks. This can offset some of the efficiency advantages, such as use of efficient CBWs, of large-scale laundries.

In a large laundry, the first phase of thermal drying is performed by gas- or steam-heated tumble driers, and can require approximately 0.4 kWh per kg textiles – a similar amount of energy to that consumed in the CBW (Figure 5.24). The second phase of thermal drying is performed by roller ironers for damp flatwork (e.g. bedclothes) or a tunnel finisher for damp garments. In finishing tunnels, garments are first subjected to a steam spray to de-wrinkle them, a hot damp downward blast of air to straighten them, and a hot dry blast of air to remove moisture.

Table 5.23: Portfolio of best practice measures for large-scale laundry operations

Stage	Measure	Description
House-keeping	Reduce volume of laundry generated	– Encourage guests to reuse towels and bed linen (section 5.3). – Minimise use of tablecloths and napkins in restaurants.
Washing	Optimisation of continuous batch washers	– Match water input to batch washing requirements and optimise water cycling through the process to achieve correct water levels and liquor ratios. – Monitor and adjust machinery and dosing to minimise textile wear (Hohenstein Institute, 2010).
	Water recycling	– In addition to recovery of rinse and press water, wash water may be recycled through a micro-filter system to re-inject into the prewash.
	Heat recovery	– Recover heat from steam used in the drying process and waste water to heat incoming fresh water.
	Green procurement of detergent and efficient dosing	– Use laundry detergents compliant with Nordic Swan criteria for laundry detergents for professional use (Nordic Ecolabelling, 2009). – Match detergent dosing to recommendations and laundry batch requirements. – Optimise with water level and temperature, and mechanical washing effectiveness. Soften hard water.
Drying	Optimal use	– Maximise mechanical drying according to textile type, fully load dryers, and control drying times to terminate at equilibrium moisture content (~ 8 %).
	Maintenance	– Ensure adequate dryer insulation, check for leaks, moisture sensor operation, duct blockages, and clean lint from filters every hour (or install automated lint cleaner).
Finishing	Ironer type	– Replace old ironers with efficient new ironers (e.g. heating band design) of appropriate width for bedclothes, and ensure adequate insulation and maintenance to avoid steam leaks.
	Optimal loading	– Install semi-automatic loader, adjust roller timing to achieve final textile moisture content in equilibrium with atmospheric conditions after single pass.
	Minimise energy use in tunnel finishers	– Minimise heating time for textiles to reach maximum drying temperature, and decrease temperatures in subsequent zones to maintain this temperature. Recirculate hot air and ensure adequate insulation of tunnel. Aim for final textile moisture content in equilibrium with atmospheric conditions.
	Minimise chemical use for finishing	– Avoid, or if not possible, minimise, the use of water- and dirt-repellent chemicals.
Entire process	Optimisation through water and heat recovery, and maintenance	– Optimise the entire laundry process. Recover heat from flue-gas to heat steam feeder water, recover heat from dryer/ironer steam and waste water to heat CBW inflow. Ensure entire distribution network is insulated, inspected and maintained to prevent leaks (install automatic leak detection system).

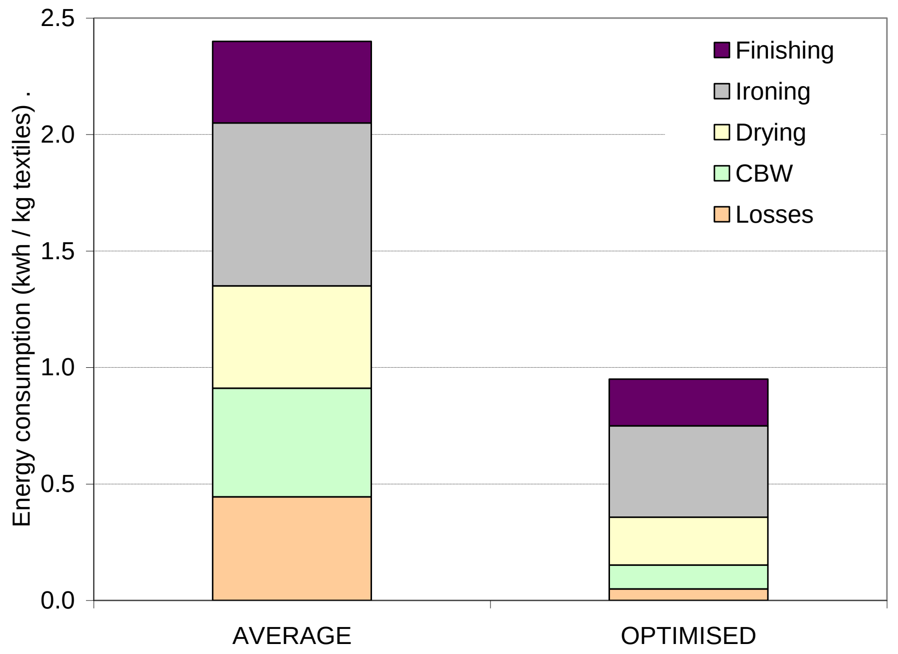
Achieved environmental benefit

Table 5.24 summarises energy and water savings that can be achieved in washing drying processes. Ensuring correct water levels in each CBW compartment alone can reduce water consumption by 30 % (Carbon Trust, 2009). Optimisation of an older CBW can reduce water consumption by 50 % and energy consumption by 70 % according to P&G (2011). Bobák et al. (2011) estimate that optimisation of a steam laundry system can reduce total energy use by 60 %, or 1.45 kWh per kg textiles (Figure 5.24), after implementation of various water reuse and heat recovery steps.

Table 5.24: Energy and water savings achievable from various measures to improve laundry efficiency

Measure	Saving
Replace washer-extractors with a CBW	50 % reduction in energy and water consumption (Carbon Trust, 2009)
Fine-tune CBW	30 % reduction in water consumption (Carbon Trust, 2009)
Reduce wash temperature from 80 ºC to 60 ºC	25 % reduction in CBW energy consumption
Reuse of dewatering press and rinse water in prewash compartment	2 – 3 L per kg textile (EC, 2007)
Waste water heat recovery	5 – 10 % heating energy (Carbon Trust, 2009)
Microfiltration and reuse of process wash water	Up to 75 % reduction in water consumption and 25 % reduction in energy (Wientjens B.V., 2010). 2 L per kg textiles (EC, 2007).
Use of low pressure steam from condensate to heat rinse water	10 % reduction in total energy consumption (Carbon Trust, 2009)
Maximise mechanical dewatering	5 % reduction in total energy consumption(*)
Recycle tumble-dryer heat with heat exchanger	Up to 35 % reduction in drying energy (Jensen, 2011)
Optimise drying	0.23 kWh per kg textiles, 9 % total energy use (Bobák et al., 2011)
Optimise ironing	0.31 kWh per kg textiles, 13 % total energy use (Bobák et al., 2011)
Optimise entire system	60 % reduction in energy consumption (Bobák et al., 2011)
(*)Achieve 50 % instead of 58 % residual moisture content.	

Microfiltration of CBW process water and reinjection into the prewash phase can reduce net specific water consumption by 2 L per kg textiles (EC, 2007). Maximum water savings of 75 % and maximum energy savings of 25 % are claimed for CBW water recycling systems incorporating microfiltration (Wientjens B.V., 2010).



Source: Based on data in Bobák et al. (2011).

Figure 5.24: Energy use for an average and an optimised continuous batch washer system based on use of steam generated by natural gas

Appropriate selection and dosing of detergent and conditioning chemicals reduces COD loading to the sewer (and, depending on the final waste water treatment effectiveness, to the environment), and reduces water toxicity. In particular, avoidance of hypochlorite avoids emissions of toxic and bio-accumulating absorbable organic halide (AOX) compounds.

Appropriate environmental indicator

Benchmarks of excellence

Nordic Ecolabelling (2010) present criteria for awarding points to textile service providers, according to environmental performance for the laundering of different textile categories. To date, 31 laundry sites in Norway, 16 in Sweden, and one in Finland have been awarded the Nordic Swan ecolabel. Accordingly, the following overarching benchmark of excellence is proposed.

BM: all laundry is outsourced to a provider who has been awarded an ISO type-1 ecolabel (e.g. Nordic Ecolabelling, 2010), and all in-house large-scale laundry operations, or laundry operations outsourced to service providers not certified with an ISO Type-1 ecolabel, shall comply with the specific benchmarks for large-scale laundries described in this document.

Water

Nordic Ecolabelling energy and water efficiency criteria for the award of maximum points for the textile categories 'hotels' and 'restaurants' are proposed as the basis of benchmarks of excellence. These benchmarks correspond with state-of-the-art performance identified by the Hohenstein Institute (2010) from data relating to over 1.7 million washes in commercial laundries.

The appropriate environmental indicator for laundry water efficiency is litres of water per kg laundry and the proposed benchmark of excellence for large hotels, and outsourced laundry providers for accommodation and restaurants, is:

BM: total water consumption over the complete wash cycle ≤5 L per kg textile for accommodation laundry and ≤9 L per kg textile for restaurant laundry.

Energy

The appropriate environmental indicator for laundry energy efficiency is kWh per kg dried, finished laundry, and the proposed benchmark of excellence for large hotels and outsourced laundry providers is:

BM: total process energy consumption for dried and finished laundry products ≤0.90 kWh per kg textile for accommodation laundry and ≤1.45 kWh per kg textile for restaurant laundry.

Chemicals

Proposed benchmarks of excellence for chemical use are:

BM: exclusive use of laundry detergents compliant with Nordic Swan ecolabel criteria for professional use (Nordic Ecolabelling, 2009), applied in appropriate doses.

BM: waste water is treated in a biological waste water treatment plant having a feed-to-microorganism ratio of <0.15 kg BOD_5 per kg dry matter per day.

Cross-media effects

Optimised CBW processes enables highly efficient use of water, energy and washing detergents, with no major cross-media effects.

Where accommodation or food and drink providers outsource laundry, the improved efficiency of laundry operations in terms of water, energy, and chemical consumption achievable in an optimised large-scale laundry outweigh the energy consumption and air emissions associated with laundry transport. Transporting 500 kg of laundry a total distance of 30 km (return trip) in a small commercial van would consume approximately 0.042 kWh of diesel per kg laundry[13], compared with possible energy savings in the region of 0.5 – 1.0 kWh per kg laundry arising from processing in an optimised large-scale laundry.

The energy requirements for microfiltration of process water, at approximately 0.75 kWh energy per m^3 recycled (Wientjens B.V., 2010), are small compared with heat recovered in recycled water (1.16 kWh per m^3 per degree centigrade of heat recovered).

Operational data

Transport

Transport of outsourced laundry should be optimised by the laundry service providers based on the distribution of clients, timing of collection and deliveries in relation to traffic, backhauling (combining delivery and collection), and the size, efficiency and EURO rating of delivery vehicles.

[13] Assuming diesel consumption of 7 L/100 km

CBW design

Table 5.25 presents some important features of CBW systems that contribute towards optimum wash performance. Newer designs of CBW have rotating perforated drums with smooth walls in place of the original basic Archimedes screw design, resulting in improved mechanical wash action and reduced abrasion and blockages. New designs enable full rotation and free-fall of laundry, maximising laundry flow-through and compression whilst minimising abrasive rubbing (EC, 2007).

Table 5.25: Features of CBW systems to optimise performance across the four main factors affecting wash effectiveness

Mechanical action	Chemical action	Temperature	Time
Straight drum walls Large drum diameter Programmable g-force factor	Weight dependent doings Water level and rinse water	No drum core 60mm foamed drum insulation Temperature control for disinfection Waste water heat exchange	Quick drain Quick heating Optimised cycle time
Source: Derived from EC (2007).			

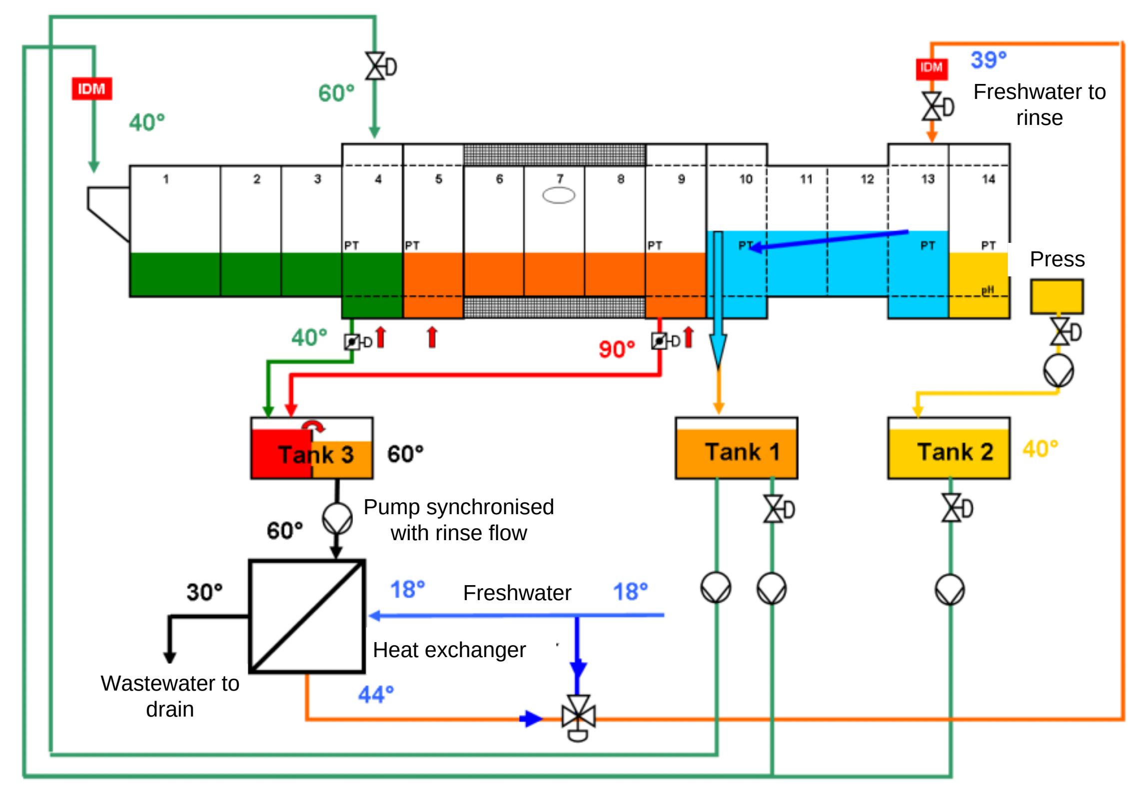
Batch organisation and loading

Loading rates of CBWs are strongly and inversely related to the specific efficiency, even though some new machines adjust programme water consumption and chemical dosing according to load weight. Where loads are deposited into the CBW via a monorail system, classification bags in the sorting area may be attached via weighing devices that automatically send the bag forward once the correct load weight is achieved. The accuracy of this process should be checked by operatives, facilitated by clearly marking the correct load position on the weighing scales (Carbon Trust, 2009).

For hotel laundries with CBW machines, it is important to sort batches according to textile type and degree of soiling (see Table 5.19 and Table 5.20 in section 5.4). For commercial laundries, it can be more efficient to spread laundry from different customers across batches to maximise CBW loading rates, and separate afterwards. Some commercial laundries rent textiles to clients, such as hotels and hostels, in which case laundry may not need to be separated by the customer.

Water and energy optimisation in CBW

Water and energy use efficiency in the CBW are strongly related, and optimisation is bound within laundry washing effectiveness and hygiene parameters. As a general rule for CBW, the conductivity difference between clean water and final rinse water at the end of the rinsing zone should be less than 0.3 mS/cm (above 0.5 mS represents a potential threat to human health) (Proctor and Gamble, 2011). Full drainage of wash water before laundry is transferred to the rinse compartment reduces soiling of rinse water, and thus the quantity of water required in rinse compartments. There are numerous opportunities for water recycling to optimise water use efficiency in a CBW, as indicated in Figure 5.25. Final rinse water extracted by mechanical pressing can be reused directly for the prewash, along with water reclaimed from the start of the rinse phase, to save a total of 2 – 3 litres per kg textile (EC, 2007).



Source: EC (2007).

Figure 5.25: Optimised water reuse and heat recovery for a 14-compartament CBW

In addition, microfiltration of used wash water through ceramic filters or similar (Figure 5.26) can enable up to 75 % of effluent water and 25 % of energy (in warm water) to be reused (Wientjens B.V., 2010). As an example, the AquaMiser system is compact, weighing 175 kg and fitting within 2m^2, has a max output capacity of 6m^3/hr filtrate, operating at 4.5 kW using 500 litres (N) compressed air per hour at 6 – 8 bars pressure, and has a backwash filter control to minimise maintenance requirements (Wientjens B.V., 2010). The achievable water recycling rate is lower for optimised CBW systems already operating with efficient water cycling. Water use as low as 2 L / kg textiles is reported (EC, 2007).

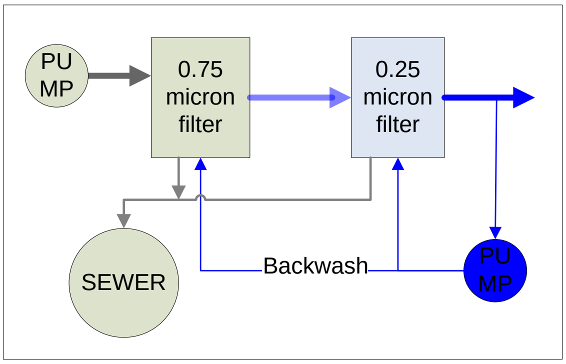


Figure 5.26: Water recycling using micro-filtration

Using heat recovery to heat incoming freshwater at the final rinse phase has the advantage of increasing the final temperature of the textiles and thus reducing drying energy requirements. However, rinse water that is recycled to the prewash compartment should not be above 40 ºC otherwise it could fix stains such as blood into textiles. There is some scope to reduce wash temperatures for hospitality laundry that is typically lightly soiled (see Table 5.20 in section 5.4). Laundry disinfection requirements vary across EU Member States. In the UK, high temperature disinfection is not required (but is recommended) for hospitality laundry (Carbon Trust, 2009). Certification standards based on hygiene testing, such as the German RAL-GZ 992/1 standard, may be used to verify hygiene performance.

CBW optimisation should be performed by qualified laundry technicians or consultants. Once programmes have been pre-set, they should not be changed by laundry operatives, and it is imperative that operatives use the correct preset programmes – this should be clearly guided by charts visible at the point of use.

<u>Chemical use</u>

Following dirt removal, hydrogen peroxide is an effective oxidising agent to kill bacteria and viruses. For hospitality laundry that does not require sterilisation, hypochlorite is not necessary (Bundesanzeiger Verlagsgesellschaft, 2002). If stubborn stains remain after washing, hypochlorite may be added selectively at the rinse stage. Hydrogen peroxide may be substituted with ozone generators that directly inject ozone into cool rinse water, to attain a concentration of 1.5 to 3.0 mg/l O_3 that kills bacteria and viruses at low temperature (US EPA, 1999). However, it is difficult to verify O_3 concentrations in the rinse water, and this technique is rarely applied in Europe.

Typically, approximately 10 g of detergent is used per kg laundry in a CBW (EC, 2007), with auxiliary chemicals such as peracetic acid (PAA), hydrogen peroxide, chlorine, acid and fungicide.

EC (2007) refer to Sanoxy detergent that reduces water and total energy consumption… The chemical and energy cost implications of lower wash temperatures are described under 'Economics', below.

<u>Mechanical dewatering</u>

Depending on the type of textile, the mass of water contained in the saturated fabric immediately after washing can be two to three times the mass of the dry fabric. Thermal drying is an energy-intensive and relatively time-consuming process that can use over 1 kWh per kg textiles. Considerable energy savings can be achieved by maximising the use of quick and efficient mechanical dewatering (Figure 5.27), using either a dewatering press or a centrifuge. Theoretical energy consumption for a commercial water extraction press with a load capacity of 50 kg is 0.035 kWh/kg textile (dry). Maximising mechanical dewatering can also reduce water consumption by providing more water that can be recycled into the wash process (see Figure 5.23). The effectiveness of mechanical dewatering depends on: (i) pressing time; (ii) temperature of the rinse water; (iii) pressure; (iv) textile type.

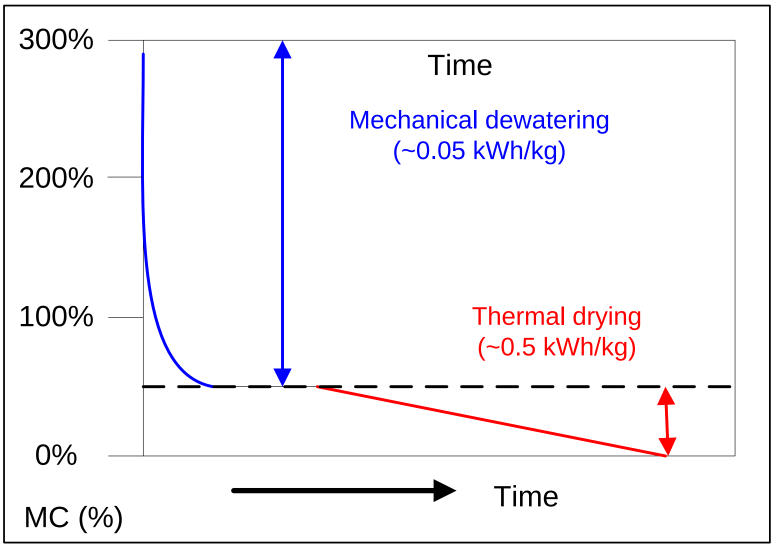


Figure 5.27: The relative time and energy consumption required for mechanical dewatering and thermal drying of textiles

Table 5.26 shows the sensitivity of residual moisture content to key parameters. Optimisation of the drying process depends on the type of textile (e.g. maximum pressure constraints) and integration with the wash process. Increasing the final rinse temperature from 25°C to 55°C can reduce residual moisture content after pressing by 8 %, reducing drying energy requirements. This is an important consideration when calculating the payback of waste heat recovery in incoming rinse water. Timing should be set to achieve maximum drying within the time available between CBW batch deliveries.

Table 5.26: Residual moisture contents after press dewatering under varying conditions

Key variable	Conditions	Moisture content
Time (cotton @ 51 bar)	90 seconds 180 seconds	53 % 43 %
Temperature (cotton @ 51 bar and 90 seconds)	25 ºC 55 ºC	58 % 50 %
Pressure (cotton @ 50 ºC, 90 seconds)	28 bar 51 bar	64 % 53 %
Textile (@ 25 ºC, 51 bar)	Cotton Polyester/cotton (65/35)	58 % 41 %
Source: EC (2007).		

Moisture contents following dewatering should not exceed 50 % for sheets and 52 % for towels to ensure efficient drying in ironers and tumble-dryers, respectively (Carbon Trust, 2009). High moisture contents may indicate a hydraulic leak or faulty pump in the press system that requires maintenance or replacement, and can be identified through periodic weighing of laundry items.

Thermal drying

Following mechanical dewatering, towels and bath mats are dried in tumble driers, sheets, tablecloths and napkins can be transferred directly to dewatering ironers, and garments are dried in finishers. According to EC (2007), thermal drying options in large-scale laundries can be ordered according to energy efficiency accordingly (kg steam required to remove one litre of water from textiles in brackets):

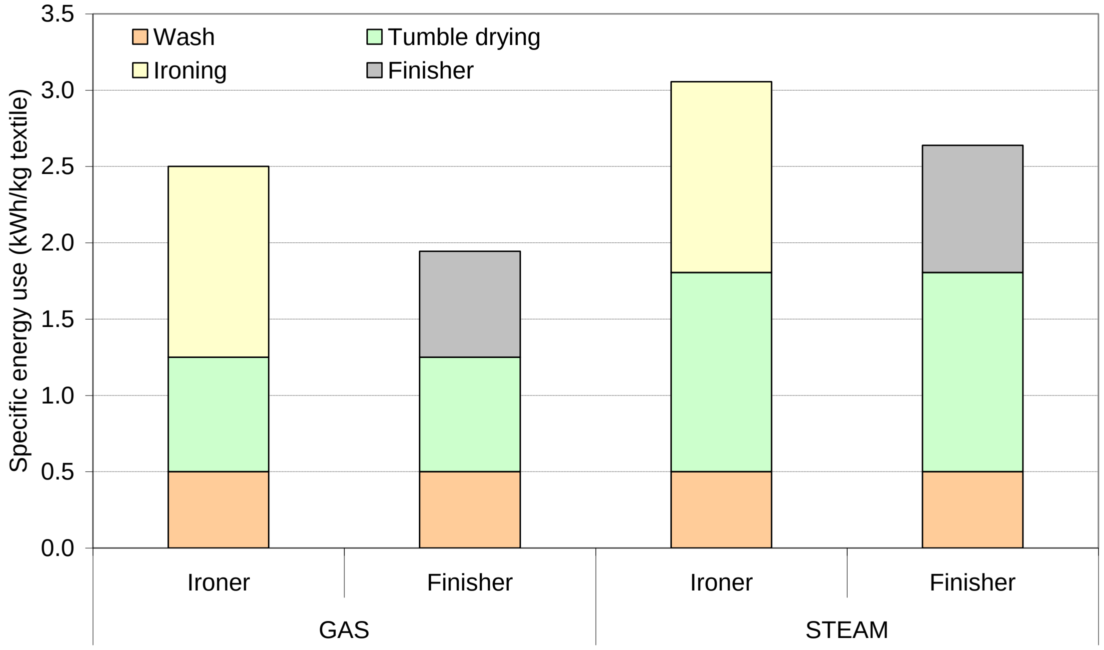
- old, poorly insulated ironer (2.5)
- steam tumble-dryer (2.0)
- new ironer (1.6)
- garment finisher (1.0).

Optimisation of the thermal drying process should be based on maximisation of the lowest energy processes available and applicable to the fabrics being laundered. Old ironers should be replaced by efficient ones as soon as is economic (see Table 5.28), and use of tumble-dryersshould be minimised. Over drying should be avoided by calculating drying times to ensure that the final moisture content after the last drying process is as close as possible to the equilibrium moisture content of the textile under standard atmospheric conditions (e.g. 6 – 8 % moisture for cotton).

Large steam tumble driers require approximately 0.5 kWh per kg textiles (Figure 5.24). Measures to reduce energy consumption during drying are to recycle hot process air, rapid initial heating of the air to minimise textile heat-up time, optimum drum loading to ensure textile movement and good heat transfer, regular filter cleaning (once per hour), and optimisation of end-point textile moisture content in relation to any further drying in the ironing or finishing phase and according to a target textile moisture content in equilibrium with atmospheric conditions. End-of-cycle terminators based on infrared detectors that leave 8 % moisture in towels are optimum and can be easily retrofitted. Tumble driers with axial, rather than radial, flow have been demonstrated to use significantly less energy (Carbon Trust, 2009).

Monthly inspections should be performed to check that heated air is not bypassing the rotating cage, that the door seal is sound, that there are not any air leaks, and that melted plastic or other contamination is cleared from the cage. Automatic lint screen cleaning systems can be installed to maintain optimum operating efficiency.

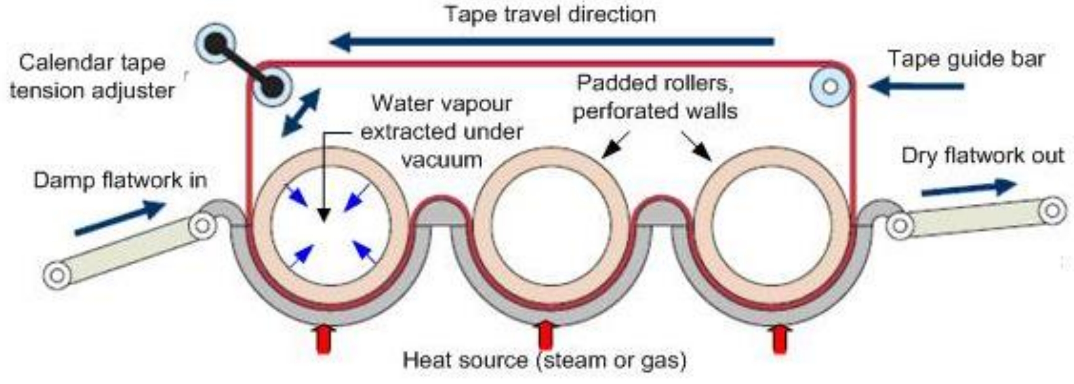
For dryers and finishers, direct gas heating is more efficient than indirect heating via steam owing to the energy losses through heat exchange and distribution for high-energy-state steam (Figure 5.28). The ratio of useful heat energy output to energy input is typically 0.85 for direct gas-fired systems compared with 0.7 for steam systems. Gas-fired tumble driers may be up to 30 % more efficient than steam-heated driers (Carbon Trust, 2009). Nonetheless, steam provides a convenient centralised source of heating for large laundries processing more than 500 kg textiles per day (EC, 2007). Steam leakage can be minimised by installation of automated steam trap leakage detection systems, and systems can also be optimised with respect to the entire laundry process (Figure 5.30), which can reduce losses associated with steam generation and distribution by 90 %, to just 0.05 kWh/kg textiles (Bobák et al., 2011).



Source: EC (2007).

Figure 5.28: Energy consumption for sheet fabric (ironer) and garments (finisher) based on direct gas heating and indirect heating using steam

The majority of laundry from the hospitality sector is flatwork that will require ironing rather than finishing (for garments). Where mechanical water extraction brings moisture content down to 50 % or less, flatwork may be transferred directly to roller ironers, by-passing tumble driers. Large-scale laundry dewatering irons apply pressure and heat to reduce residual moisture content in flatwork textiles (e.g. bed linen and tablecloths), and are usually based on a two or three-roller design (Figure 5.29). The efficiency of large-scale dewatering ironers has improved considerably in recent years, from consumption of 2.5 kg of steam per litre of water removed to 1.6 kg steam per litre of water removed from the textiles (EC, 2007) – these values translate to specific drying energy requirements of 0.6 and 0.4 kWh per kg textiles at 50 % moisture content, respectively. One feature of more efficient ironers is heat-retaining hoods. The efficiency of roller ironers should be monitored, and the machinery frequently inspected, to identify maintenance actions. For example, roller padding can become worn, reducing contact pressure with the textiles and thus drying efficiency. Carbon Trust (2009) recommend replacing the three layers of thin material traditionally used as roll padding with two layers of stronger polyester needle-felt to improve ironing performance by up to 30 %, and reduce energy consumption.



Source: Elaborated from carbon Trust (2009).

Figure 5.29: Schematic representation of rigid-chest three-roll ironer operation

A derivative of the traditional rigid chest roller ironer shown in Figure 5.29 is now being commercially marketed as a more energy-efficient alternative. Heating band ironers use a heated sheet of high quality stainless steel to maintain pressure against the rollers, enabling a higher pressure of up to 16 bars to be applied evenly across textiles (Kannegiesser, 2004). It is claimed that heating bands also offer continuous heating over their entire surface, including the 'bridge' between rollers, and suffer less from the wear-induced contact area reduction that occurs when the padding on conventional roller systems is worn (Kannegiesser, 2004; EC, 2007). Table 5.27 presents operational data for a modern heating-band ironer compared with a traditional rigid chest ironer. For the heating-band ironer, a 90 % decrease in heated mass reduces start-up heating by 189 kWh per day, and the reduced radiation losses from the smaller heated-surface area reduces heating by 120 kWh per day.

Table 5.27: An example of typical daily energy losses for a rigid-chest ironer and a heating-band ironer of the same capacity, both heated by steam

	Rigid chest ironer	Heating band ironer
Specifications	1200 mm diameter, 3500 mm width, 3 rolls, 6 tonnes heated steel	1200 mm diameter, 3500 mm width, 2 rolls, 0.62 tonnes heated steel
Steel heating-up (daily)	211 kWh / day	22 kWh / day
Radiation	192 kWh / day	72 kWh / day
Escaping vapour	88 kWh / day	18 kWh / day
Total	491 kWh / day	112 kWh / day
Energy saving		379 kWh / day
NB Assumes one 8 hour per day shift and 1.83 kg steam = 1 kWh energy. *Source:* EC (2007).		

Energy consumption during ironing can be minimised by operating driers as close to rated capacity as possible – this can be achieved by having a buffer stock of flatwork ready for ironing in case of any interruptions in the line from previous processes. The most efficient loading systems are semi-automated, comprising monorails to which the corners of textile sheets are clipped and that deposit sheets onto the flatwork ironing surface automatically in response to a signal from a remote operative. Automatic feeders should be adjusted to give edge to edge feeding in order to cover the width of the iron, and roll-to-roll speed differentials set to give 50 mm stretch in 10 turns of an 800 mm diameter roll (Carbon Trust, 2009). The roller speed should be adjusted to ensure that flatwork leaving the ironer is dried to equilibrium moisture content in one pass, and that as much of the ironer surface as possible is covered with flatwork at all times of operation.

In garment finishers, approximately one kg steam (0.55 kWh heat) is required per litre of water evaporated from the textiles. The energy requirement of garment finishing is minimised by the recirculation of 90 % of the air and optimisation of temperature distribution in the heating, finishing and drying zones according to the textile density. The temperature of succeeding zones should decrease to ensure rapid textile heat-up and maintain a constant textile temperature (EC, 2007).

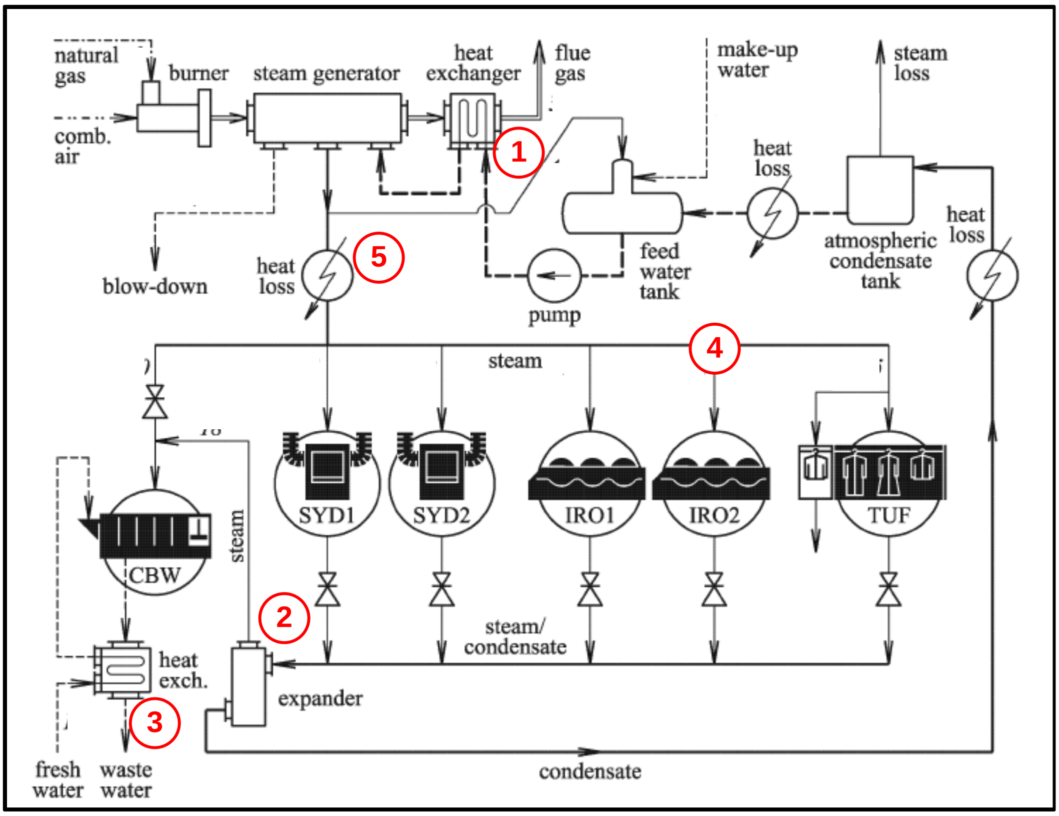
Following ironing, textiles may be treated with chemicals to repel water and dirt. This is unnecessary, especially for accommodation textiles that are frequently laundered, and should be avoided where possible.

System optimisation

In relation to overall laundry system optimisation shown in Figure 5.30, the most important measures to reduce heat losses from the steam system are given below.

- Recovery of heat from the flue-gas to heat steam feeder water (point 1 in Figure 5.30).

- Recovery of steam from the drying cycle, in an expander, to heat process water in the CBW (point 2 in Figure 5.30). This can save around 10 % of entire laundry energy demand (Carbon Trust, 2009).
- Recovery of heat from waste water (ideally combined with water recovery) to heat incoming process water to the CBW (point 3 in Figure 5.30). This can save 5 – 10 % of laundry heat demand.
- Regular inspection and maintenance of the distribution system to prevent leaks (point 4 in Figure 5.30).
- Appropriate insulation of pipes, CBW, dryers, finishers and irons to minimise heat losses (point 5 in Figure 5.30).



SYD = Steam dryer; IRO = Ironers; TUF = Tunnel finisher

Source: Derived from Bobák et al. (2011).

Figure 5.30: Steam-heated laundry with optimised energy management

EC (2007) recommend corrugated pipe heat exchangers for their efficiency, robustness and tolerance of soiled water, and specify the following check criteria to optimise the heat exchange process: (i) the flow directions are connected in counter-current direction; (ii) there are turbulences in the liquids; (iii) there is a large heat transfer surface; (iv) the mass flow and the temperature differences in both directions are the same; (v) as much time as possible is provided for the heat exchange (i.e. for a tunnel washer, throttle the rinse flow to almost the total cycle time).

The following sequence of checks may be useful to consider for optimisation of the entire laundry process:

1	Firstly, ensure that batch management is optimised to maximise CBW loading rates and that the CBW is performing according to correctly specified programme parameters.
2	Based on typical batch characteristics, assess the potential to reduce wash temperature, water use and chemical dosing. The potential for this may be high for typically lightly soiled hotel laundry – it is worthwhile to experiment with different temperature and chemical dosing settings. Aim for a rewash rate of 3 – 5 % (lower indicates over-washing, higher indicates under-washing). Balance chemical costs against savings from reduced energy consumption and textile wear (see 'Economics').
3	Minimise thermal drying requirements by maximising mechanical dewatering press times, and optimise the efficiency of thermal drying by ensuring maximum loading rates in tumble-dryers and flatwork ironers. Avoid over drying: control timing to achieve final moisture contents of 8 %, in equilibrium with atmospheric conditions (install moisture sensors in tumble driers).
4	Ensure that all economically viable water reuse opportunities are being exploited, especially reuse of rinse water in earlier rinse of prewash compartments. Assess the economic viability of installing a microfiltration system to reuse prewash water in the prewash or wash cycle. Balance system modification costs against water, energy and chemical savings.
5	Ensure all economically viable heat recovery opportunities are being exploited. Heating incoming final rinse water with waste water from the main wash is simple and cost effective, but requires careful control: a higher rinse temperature reduces drying requirements, but should not cause prewash temperature to exceed 40 ºC when reused (in order to avoid the fixing of stains).
6	Inspect and test all equipment frequently, and perform regular maintenance, especially to tumble driers (check filters, fans, ducts, moisture sensors) and roller-ironers (adjust speed settings and check for padding wear).
7	Calculate when it would make financial sense to invest in new equipment, such as a new CBW or heated-band ironer. More efficient drying equipment can pay back relatively quickly: in particular mechanical dewaters and high-efficiency ironers. Assess the possibility to use direct gas heating instead of steam heating.

Regular system maintenance is crucial to maintain optimal operating efficiency (Carbon Trust, 2009). Equipment should be checked weekly, and in some cases daily, for problems. Regular maintenance tasks include: (i) clearing wax from vacuum fans and ducts on the ironers; (ii) repairing holes in grilles above the tumble dryer heater batteries to prevent lint blockage; (iii) adjusting hanger delivery mechanisms at the tunnel finisher to give one garment per peg. Equipment tuning should be performed every three months, including:

- adjustment of 'wait' times in the hydro-extraction press programme to maximise press times;
- adjustment of the roll-to-roll stretch on ironers to improve the heat transfer over the gap pieces between the rolls;
- adjustment of end-of-cycle terminators on tumble-dryers so that they leave 8 % moisture in towels.

Realisation and maintenance of optimum efficiency requires monitoring and reporting of key performance indicators for energy and water use efficiency: kWh energy and L water consumed per kg laundry processed. These should be reported weekly or monthly in charts that enable easy tracking of progress over time, and can be calculated from: (i) energy (electricity, gas, oil, steam) and water bills; (ii) the number of pieces laundered. The average piece weight of mixed laundry items is around 0.5 kg (Carbon Trust, 2009), but this may vary for hospitality laundry and can be established for individual laundries through weighing a sample of laundry items.

Applicability

Optimised CBW laundry processes incorporating heat recovery and water recycling following microfiltration are applicable to large hotels with over 500 rooms, and commercial laundries serving the entire hospitality sector (accommodation, restaurants, bars, etc.).

Laundry from food preparation in restaurants and accommodation establishments is typically more heavily soiled than laundry from rooms in accommodation, and requires more energy and water-intensive laundering (see 'Environmental indicators' section above).

Economics

Most best environmental management practice measures for large-scale laundries are based on water, energy or chemical resource efficiency, and therefore have relatively short payback times when implemented in new systems or following retrofitting. Table 5.28 summarises some important economic factors for the referenced best practice measures.

Replacing older drying equipment such as irons with more efficient new models typically results in large annual energy savings of tens of thousands of euro (Table 5.28). Thus, it can be financially worthwhile to bring forward replacement of older equipment (e.g. after a major breakdown).

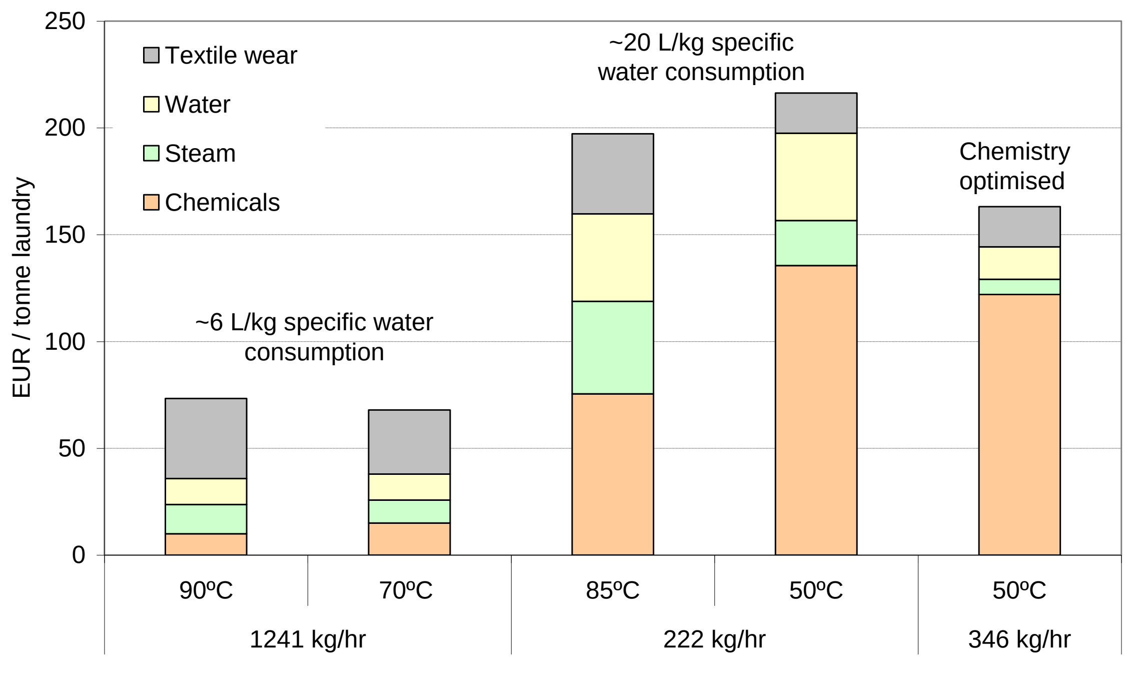
The installation of microfiltration equipment to filter prewash water for reuse offers an acceptable payback time, in the region of two years, where water supply and disposal costs are at or above EUR 2.00/m^3.

Table 5.28: Important economic considerations associated with laundry best practice measures

Measure	Economic considerations
CBW water and energy optimisation	At a water service (provision and treatment after disposal) price of EUR 2/m^3 and a gas price of EUR 14/GJ (EUR 3.89/MWh), optimisation of an older CBW system processing 7 t/day of laundry can achieve annual cost savings of EUR 25 000 for water and EUR 40 000 for energy (P&G, 2011). These water and energy savings equate to EUR 14 and EUR 24 per tonne of laundry processed, respectively. This water saving cost would increase to EUR 21 per tonne of laundry at a water service cost of EUR 3/m^3. One company offers a CBW optimisation service with payback periods as short as 12 months (P&G, 2011).
Laundry energy optimisation	According Bobák et al. (2011), energy optimisation of the entire laundry process can yield energy cost savings of EUR 73 per tonne laundry, of which EUR 35 per tonne are attributable directly to the optimisation of drying processes. Replacing an older ironer using 2.5 kg steam per litre of water removed with a new ironer using 1.6 kg steam per litre of water removed will reduce annual energy costs by EUR 27 000 for a laundry operating at 10 tonnes per day, five days per week.
Water filtration:	At a water service (provision and treatment after disposal) price of EUR 3/m^3, recycling of prewash water from a 12 t/day laundry CBW process through a microfiltration system can save EUR 27 000 per year (EUR 9 per tonne laundry). This compares with a capital and installation investment of EUR 40 000, thus leading to a payback period of 17 months (EC, 2007). The payback time increases to 21 months and 27 months at a water service price of EUR 2.50 and EUR 2.00 per m^3, respectively.

Measure	Economic considerations
Chemical selection and dosing	Chemical selection and dosing should be optimised with water, energy and textile wear costs for different batch characteristics. Efficient dosing based on laundry type and degree of soiling reduces costs. Avoidance of more environmentally harmful chemicals can reduce costs, but substitution with more environmentally friendly chemicals can increase costs. Selection of ecolabelled detergents may increase detergent costs.

Textile wear represents a significant component of washing costs, and can account for half of washing costs for relatively efficient operations using 6 L/kg laundry (left bars on Figure 5.31). Reducing maximum wash temperature from 90 ºC to 50 ºC reduces textile wear by up to 50 %. Figure 5.31 highlights how the cost benefits of lower temperature washes are offset by chemical costs that can increase by a factor of 1.8. The cost effect of temperature reduction is laundry-specific, and can be positive or negative. For efficient laundries, a decisive factor is whether or not the laundry operators bear the cost of textile wear. For in-house laundries on accommodation premises, reduced textile wear costs can justify temperature reductions, whilst for outsourced laundries temperature reductions may not be justified by cost savings that exclude textile wear.



NB: Water price 2 EUR/m3, steam price EUR 23.5/tonne (gas heating), chemical price ranging from EUR 1 000 to EUR 1 800 per tonne, and textile price EUR 7 500 per tonne.

Source: Based on modified values from EC (2007).

Figure 5.31: Specific washing costs and textile wear for a 13-compartment CBW under high load rates and 8-compartment CBW under low load rates, for higher and lower temperature washes

It is important to implement heat recovery after water optimisation, as the latter process can reduce water consumption, and thus required heat-exchanger size, by approximately 30 %, reducing heat exchanger installation cost by 15 % (Carbon Trust, 2009).

Driving force for implementation

The main driving force for implementing optimised CBW processes is economics, as described above. For large hotels, implementation of efficient laundry systems may also be driven by environmental award schemes, or simply public relations benefits.

For commercial laundries, improved environmental performance, especially if recognised by third-party certification, can improve business opportunities, especially with hospitality enterprises operating green procurement policies.

Many tourist destinations, especially around the Mediterranean, suffer water stress during peak season, and there is pressure to reduce water use associated with tourism. Economic driving forces may be stronger in such destinations if authorities impose higher water charges.

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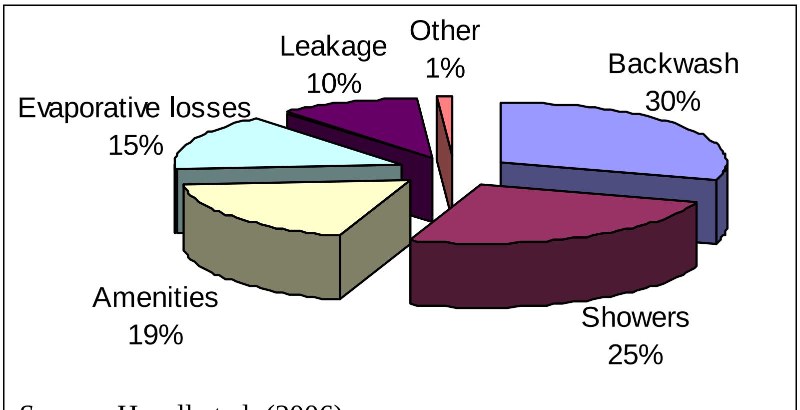
5.6 Optimised pool management

Description

Swimming pools give rise to a number of environmental impacts, especially where poorly managed, through demand for water, energy and disinfectant chemicals. An indoor heated 25 m pool (300 m^2) can lose 21 000 litres of water per week in evaporation (water temperature of 28 ºC, air temp of 29 ºC and relative humidity of 60 %) (Business Link, 2011). This would equate to 30 litres per guest-night for a hotel with 100 guests. Although this example is for a relatively large pool, it excludes water consumption for backwashing, that can be of a similar magnitude, or greater (Figure 5.32). Ecotrans (2006) suggest that swimming pools increase water consumption by an average of 60 litres per guest-night across hotels and camping sites. Meanwhile, sub-meter data from a German hotel indicate water consumption of 52 litres per guest-night for the pool area, including showers (Hotel Colosseo, 2011).

Figure 5.32 displays the breakdown of water consumption in a typical community swimming pool. The main processes are backwashing, showers, and evaporative losses and leaks. Water use for amenities (e.g. onsite cafes) may not apply to accommodation pool areas.



Source: Hazell et al. (2006).

Figure 5.32: Breakdown of water consumption across processes and areas in a typical community pool

Sanitisation of swimming pools is usually performed using chlorine, via dosing with compounds such as calcium or sodium hypochlorite. Chlorine compounds react with organic matter to form chloramines, disinfection byproducts that irritate eyes, and, when added in high doses, can form carcinogenic trihalomethanes. A fraction of the chlorine compounds volatilise to the atmosphere, and filter backwash water containing chlorine is toxic to freshwater ecosystems, and must be released to a sewer unless specially treated and/or recycled. Some alternatives to the addition of hypochlorite such as the addition of copper salts are also associated with ecotoxicity problems.

Finally, operation of swimming pools requires energy, to power filter and backwashing pumps, lights, and in some cases water heating and indoor heating and ventilation. ÅF-Energikonsult AB (2001) estimated that hotel swimming pool systems can consume 45 000 kWh to 75 000 kWh per season. Specifically for pool heating, Ochsner (2008) estimate typical energy demand of 50 – 150 W/m^2 for indoor pools, 50 – 200 W/m^2 for a pool in a sheltered location, 100 – 300 W/m^2 for a pool in a partially protected location, and 200 – 500 W/m^2 for a pool in an unprotected location. Carbon Trust (2005) estimate that a typical public leisure centre containing a 25 m pool consumes over 1 500 kWh/m^{2}yr, of which 65 % is for pool heating and ventilation. Ventilation of indoor pools often leads to high heat loss via the exhaust of moist, warm air to the atmosphere: swimming pool areas may experience air change rates of 4 – 10 changes per hour (Carbon Trust, 2005). In addition, water heating for showers can consume considerable amounts of energy (sections 5.1 and 5.2). Carbon Trust (2009) estimate that building services account for 35 – 50 % of the operating cost of a modern indoor swimming pool.

Best practice measures

Table 5.29 summarises the main best practice measures to reduce water, energy and chemical consumption in swimming pool areas. In the first instance, the decision to build a pool and the selected design are critical, though these decisions are likely to be guided by marketing considerations. It may not be necessary to have a pool onsite – there may be options to organise a pool share or guest-use scheme with neighbouring establishment(s) or local leisure facility providers. In terms of pool design, outdoor, unheated and natural pools are the options with the lowest environmental impact. Where applicable, particularly for outdoor pools with a relatively short season, installation of a natural pool is best practice (see section 9.6). If the pool is integrated into the building design, the necessary infrastructure can be put in place to recycle pool overflow and filter backwash water for toilet flushing. A good building envelope (section 7.2) will reduce heating costs – high quality double- or triple- glazed windows with blinds where necessary to reflect direct sunlight, with a good quality seal and carefully located entrance areas to minimise drafts.

The most efficient pool disinfection and heating systems should be specified during the design phase, but may also be retrofitted. Outdoor pools can converted to natural pools relatively easily (section 9.6). Drainage barriers can be installed around the pool to collect and recirculate overflow and splash water. Ozone generators or ultra-violet (UV) systems may be installed to reduce chlorine requirements. Simple solar heating tubes or a heat-pump system may be installed to heat (or pre-heat) pool water, and a heat recovery system with controlled ventilation installed to recover heat from exhaust ventilation air. Motion sensors can be installed to switch off features such as fountains when no users are present.

Finally but importantly, many optimisation measures can be taken for all existing pools by applying good management techniques and minor retrofitting. Installation of a water sub-meter to record inflow to the pool is an important measure to enable performance tracking and the identification of problems. Hazell et al. (2006) found that the majority of public swimming pool managers surveyed could not provide annual water consumption data. Monitoring and benchmarking of water, energy and chemical consumption is therefore a key best practice measure for pool/accommodation managers.

Use of pool covers, careful regulation of temperature and chemical dosing, maintaining water at the correct level below the pool sides and careful control of filter backwashing can all significantly reduce water and energy consumption. Backwash water can be filtered and used for irrigation. Careful (automated) control of HVAC systems for indoor pools can reduce heating energy consumption, and careful control of water circulation through filters (manually, based on usage rate, or automatically, based on water quality monitoring) can reduce energy, especially if combined with variable speed pumps. Regular sweeping of the pool area and requiring users to pass through a foot bath can reduce disinfection and backwashing requirements arising from contamination.

Table 5.29: Best practice measures to reduce water, energy and chemical consumption in swimming pool areas

Aspect	Best practice measures	Applicability
Management	Monitor energy, water and chemicals consumption (see sections 5.1 and 7.1)	All pools
Disinfection	Natural pools (see section 9.6)	Lower usage pools
	Require users to pass through foot bath	All pools
	Sweep debris from surrounding area	
	Optimised chlorine dosing	All chlorine pools
	Electrolysis, ozonation or UV	All pools
Water efficiency	Monitor water consumption	
	Optimised backwashing frequency and timing	
	Backwash water recycling	
	Backwash water reuse	Where water scarce
	Timer-controlled low-flow showers (section 5.2)	Shower areas
Energy efficiency	Ensure good building envelope (section 7.2)	Indoor pools
	Position in sunny and sheltered area	Outdoor pools
	Avoid excessive water temperature	Heated pools
	Correct use of pool cover	All pools
	Demand-control of water circulation	
	Solar or heat-pump water heating	Heated pools
	Controlled ventilation with heat recovery	Indoor pools

Achieved environmental benefit

Water

Figure 5.33 displays potential water savings from different processes for a 25 m swimming pool (a large accommodation pool).

Smith et al. (2009) claim that pool covers can reduce outdoor pool evaporative losses by 200 litres per day in warm climates. This figure may be close to 1 000 litres per day for heated indoor pools. Covers also reduce energy consumed for pool heating and ventilation by 10 – 30 % (Carbon Trust, 2005).

Optimisation of backwashing frequency based on filter pressure rather than fixed intervals can reduce water consumption for backwashing by over 50 %. For example, backwashing a sand filter once every three days for five minutes, instead of once every day for five minutes, could reduce water consumption by 1 500 litres per day, or 550 m^3 per year.

Reverse osmosis can enable the reuse of up to 65 % of backwash water, potentially saving around 500 m^3 per year (Hazell et al., 2006).

Installing low-flow and timed showers could result in a similar magnitude of savings, in the region of 500 m^3 per year.

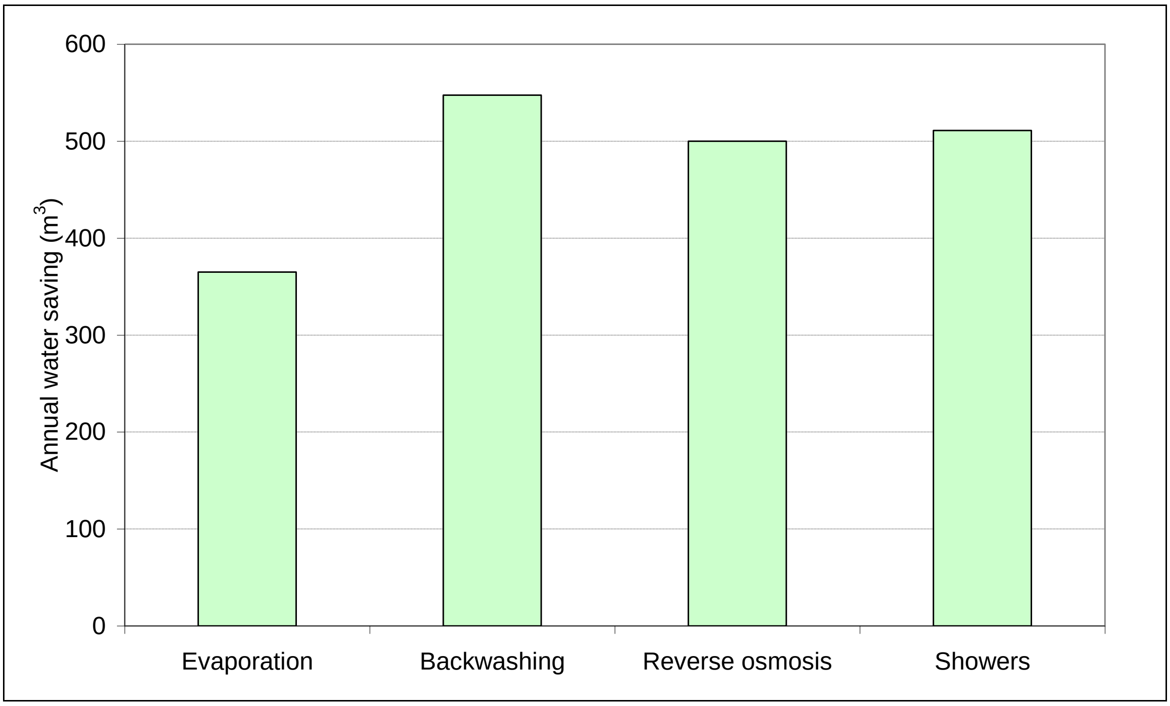


Figure 5.33: Estimated potential annual water savings across different processes for a 25 m pool

Chemicals

Proper control of pool filtration and disinfection can significantly reduce chlorine (e.g. sodium hypochlorite) inputs. UV-disinfection of pool water can reduce chlorine inputs by up to 30 %, and may also reduce the need for top-up water to dilute chlorine by-products (Leisure-design, 2012). Reduced chemical use leads to upstream environmental benefits in terms of reduced resource consumption and air emissions, and downstream environmental benefits in terms of reduced ecotoxicity impacts in receiving waters.

Energy

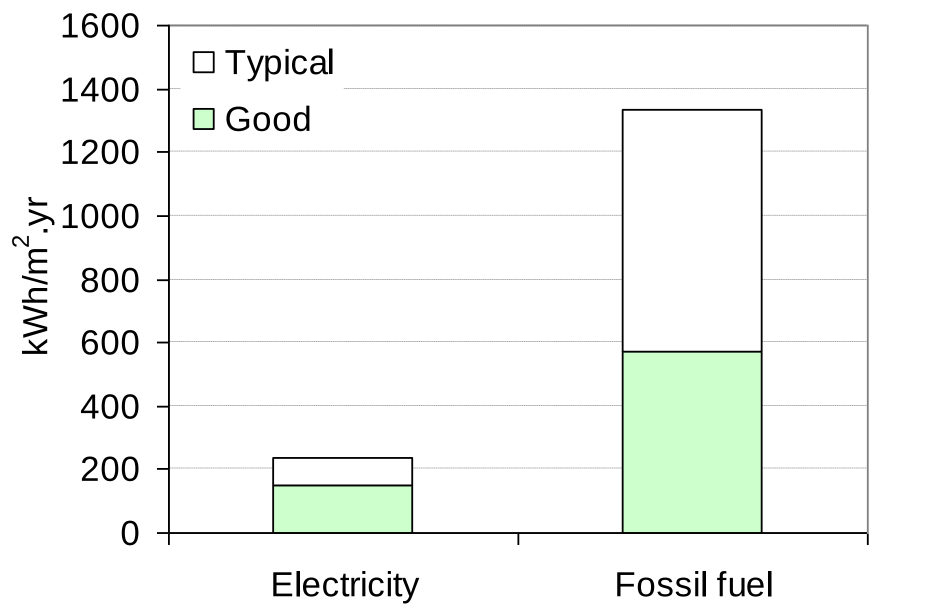
Installation of a real-time (continuous, automated) energy monitoring system alongside provision of staff training and awareness raising on energy issues by Knowsley Metropolitan Borough Council in the UK led to electricity savings of 24 % and gas savings of 30 % in leisure centre sites (Carbon Trust, 2005).

HVAC heat recovery and heat-pump heating and dehumidification can reduce HVAC energy consumption by 50 – 80 % compared with simple open extraction systems.

Variable speed drive pumps may reduce pump electricity demand by up to 80 % (Leisure-design, 2012).

Balantia (2012) refer to a potential energy saving of 146 kWh per m^2 pool surface per year from installation of a pool cover on a small indoor pool in a luxury Spanish hotel.

Carbon Trust (2005) indicate that good practice can reduce energy consumption by 848 kWh/m^2yr for a typical public leisure facility containing a 25 m swimming pool, primarily through a reduction in heating fuel consumption (Table 5.35). Best practice, including use of heat-pump heating, could potentially reduce the residual 725 kWh/m^2yr by a further 50 %.



Source: Carbon Trust (2005).

Figure 5.34: Annual fossil fuel and electricity consumption per m^2 for a 'typical' and a 'good' leisure centre containing a 25 m pool

Appropriate environmental indicator

Water consumption

Water consumption for swimming pools in tourism establishments is poorly documented. The ideal indicator for water use efficiency is water consumption per user, although this indicator is not regularly reported, perhaps in part because the number of users are not necessarily recorded in accommodation premises (though estimates based on surveys may be made). An alternative indicator is water consumption per m^2 of pool area, also not frequently reported.

As referred to in the description, above, there are some data relating to water consumption for hotel swimming pools averaged per guest-night. This is a relevant indicator based on data that should be readily available (if sub-metering of pool area water consumption is in place). It is important to define what is included in this measure – specifically, whether it represents just pool water consumption, or also water consumption for the entire pool and spa area (i.e. including showers and toilets, etc.).

Energy consumption

As with water consumption, energy consumption for swimming pool areas is not well reported. Ideal indicators are kWh/m^{2}yr or kWh/user. However, it is sufficient to report on the simple indicator kWh per guest-night, enabling easy comparison with total energy consumption indicators (section 7.1).

Chemical consumption

The type and quantity of chemicals consumed per m^2, per user or per guest-night is the relevant indicator here. For example, grams sodium hypochlorite per guest-night.

Benchmark of excellence

Owing to the lack of data on water, energy and chemical consumption in swimming pools, it is not possible to propose a performance benchmarks for swimming pools. Instead, the following management benchmark is proposed:

BM: implementation of an efficiency plan for swimming pool and spa areas that includes: (i) benchmarking specific water, energy and chemical consumption in swimming pool and spa areas, expressed per m^2 pool surface area and per guest-night; (ii) minimisation of chlorine consumption through optimised dosing and use of supplementary disinfection methods such as ozonation and UV treatment.

Cross-media effects

The main cross-media effects associated with measures in this section are:

- energy requirements for UV treatment to reduce chlorine requirements (small compared with avoided upstream chlorine production and potential downstream ecotoxicity effects);
- energy requirements for reverse osmosis to reduce water consumption (this is also expensive, and therefore only justified in areas of intense water scarcity);
- water consumption by bathers taking showers before entering the pool, to reduce chlorine requirements (as with previous effect, depends on water scarcity of the area).

Operational data

Monitoring and benchmarking

In the first instance, all water, energy and chemicals used for operation of the pool area should be monitored and used to benchmark performance over time (monthly and annual basis). Sub-metering should be in place to enable monitoring of water consumption for:

- the swimming pool
- changing (shower and toilet) areas.

Following initial data collation and normalisation relative to pool area and number of users (e.g. L/m^2.yr or L per user water consumption), a consultation with swimming pool specialists may be used to inform on the level of efficiency represented by these data, and scope for improvement.

Frequent assessment (ideally daily checks) of consumption data can provide a useful indication of systems problems and maintenance requirements. For this purpose, the installation of automated recording systems is useful (see sections 5.1 and 7.1).

Showers and toilets in changing areas can be a major source of water consumption. Operational data on installing low-flow fittings (showers and taps), shower timers (percussion valves or sensors) and efficient dual-flush toilets in changing areas can be found in section 5.2.

Filtering and backwash optimisation

Filter circulation pumps are often over-sized owing to limited available size options, leading to excessive filter pressure with associated energy wastage and less effective filtration. Variable speed drives (inverters) may be fitted to pumps to enable precise control of pump speed according to demand.

Backwashing sand filters is a water-intensive process, requiring in the region of 225 to 450 litres per minute for a standard pool. Many hotel pool filters are backwashed as a matter of routine once or twice a day, compared with typical requirements of once every two or three days. Backwashing should be based on filter pressure rather a fixed schedule – for example, when the filter pressure required is over 0.5 bar more than the pressure required for a clean filter.

The backwash process should not take more than three to five minutes, and the subsequent pipe rinsing process just 15 to 30 seconds (Travel Foundation, 2011). It is important that all pool maintenance procedures, including backwashing, are clearly displayed in the pool room, and staff properly trained.

It has been claimed that recycled glass may be a more efficient filtration medium than sand, and that installing pre-filters can reduce the need for backwashing by up to 50 % (Leisure-design, 2012). This latter reference refers to the design of a 'Passive Pool'.

Backwash water recycling

Filter backwash water may be recycled back into the pool following appropriate treatment to achieve required water quality standards – usually locally applicable drinking water quality standards as pool water may be swallowed (NSW Gov, 2012). Controls should be put in place to protect against system failures and ensure health protection.

Reverse osmosis is considered to be the best available technology for the treatment of backwash water for recycling, and has been shown to remove over 99.5 % of dissolved salts, up to 97 % of most dissolved organics and 99.99 % of micro-organisms (NSW Gov, 2012). It is important to consult with a qualified expert on the design of a backwash water recycling plant as such plants work most effectively when combined with other treatments. For example, pre-treatment using ultra-filtration and granular activated carbon may be necessary to prolong the life of the reverse osmosis membrane.

Disinfection

Disinfection of pool water involves destruction of 99 % of exposed pathogens using a disinfection agent such as hypochlorite, and removal of particulate matter using a flocculating agents and filtration (ITP, 2008). The residual disinfection agent (e.g. free chlorine from hypochlorite) must be present in a sufficient concentration to kill new bacteria. Over 90 % of free chlorine is consumed through organic matter oxidation, emphasising the importance of measures to minimise organic matter loading (cleaning pool area, installing a foot cleaning bath for users).

Careful management of dosing and pool pH (Table 5.30) is critical to minimise hypochlorite consumption, irritation problems, and water consumption through dilution compensation for over-dosing. Automatic dosing is the best solution, based on monitoring of residual chlorine concentrations at least every two hours. Target chlorine concentrations should be adjusted according to microbiological parameters, tested at least every month (ITP, 2008). It is important to note that chlorine requirements increase with water temperature.

Table 5.30: Acceptable ranges for chemical parameters of pool water

Parameter	Acceptable range
pH	7.2 – 7.6
Total alkalinity	80 – 200 ppm
Total chlorine (gas plus hypochlorites)	0.5 – 1.0 ppm
Combined chlorine (chloramines)	<half total chlorine
Source: ITP (2008).	

It is relatively straight forward to install a UV filter through which filtered water can be passed to kill bacteria, thus reducing the residual chlorine requirements. Ozone generators can also be added (ozone produced by passing an electric current through air), to bubble ozone through water after filtration, also reducing residual chlorine requirements and improving water quality by oxidising organic compounds. Water must then be passed through a carbon filter to remove any remaining ozone. However, ozone generation and use requires careful regulation, as ozone leaks can be extremely hazardous to health. Additionally, ozone is highly reactive and unstable, making it difficult to control ozone concentrations in the ozone chamber and thus to regulate disinfection.

Pool heating and circulation

Pool heating requirements can be minimised by:

- ensuring that water temperature does not exceed recommended values (Table 5.31)
- minimising air-flow over the pool surface
- using a pool cover when the pool is not in use
- minimising water losses through back-washing and dilution to control pool chemistry.

Table 5.31: Recommended pool water temperatures for different pool types

Pool type	Recommended water temperature
Conventional pool	28 ºC
Leisure pool	29 ºC
Hydrotherapy pool	32 – 40 ºC
Spa pool	40 ºC
Source: Carbon Trust (2008).	

Ideally, pool water heating may be achieved in combination with ventilation air dehumidification (see below). Air-water or water-water heat pumps are well suited to the low temperature heating requirements for pool water (section 7.4). Alternative sources of water heating particularly well suited to swimming pools include unglazed and glazed solar thermal collectors and heat pumps. The former are simple black pipes that absorb solar radiation to heat water flowing through them and are relatively cheap to install (ITP, 2008). Typically, an area equivalent to at least half the pool area is required.

HVAC

For indoor pools, operational data on improving the building envelope to minimise heat loss can be found in section 7.2. Specifically for swimming pools, it is important that the walls and base of the pool structure are well insulated where these are built down into the ground. Also, care should be taken to exclude drafts, by installing draught exclusion insulation, self-closing doors and foyer areas.

Best practice in HVAC system configuration, as described in section 7.3, applies here. HVAC within pool areas may be integrated into the accommodation building HVAC system, possibly via an automated building management system (section 7.1). The main objective of a pool-hall ventilation system is to distribute air in order to:

- provide comfortable temperatures for occupants
- avoid uncomfortable draughts
- remove smells produced by water treatment
- minimise evaporation and condensation.

To achieve this, pool ventilation systems may be zoned into three main areas, with specific requirements and recommendations (Table 5.32).

Table 5.32: Requirements and guidance for ventilation in three main zones of pool centres

Zone	Requirements	Comments
Pool surface	– Remove contaminants (although odours caused by water treatment process are not usually dangerous) – Evaporation control (minimise air movement at the pool surface)	– Control the water treatment process to minimise odours – Air requirements for bather respiration are met by diffusion and do not require additional ventilation – Direct ventilation air onto the building envelope to minimise evaporation from pool surface and to reduce the risk of condensation and mould problems on the building fabric
Pool side	– Comfort of the bather (before entering and after leaving the pool) – Comfort of the poolside staff	– Redirect any grilles and jets near the pool side to avoid direct air flow from the ventilation system – Staff should be discouraged from opening doors or windows, which creates draughts (instead, localised cooling can be provided by increased air movement such as through simple overhead fans).
Other areas	– Protecting the pool hall structure from condensation – Providing comfort to non-swimmers	– Provide separate air flows for the pool and other areas to minimise mixing between areas – In a new pool building, the air flow could be directed upwards from a slot at the foot of the walls in 'laminar flow' – For existing pool buildings, inlet grilles and jets can be repositioned so that drier air entering the pool hall can be pointed towards the sides of the building rather than down on to the pool – Comfort for spectators can be improved by having a similar arrangement to direct drier incoming air over them. – It may be necessary to blow drier air into ceiling voids to ensure that condensation does not occur on hidden parts of the structure

Source: Carbon Trust (2008).

For stand-alone HVAC control in an indoor hotel swimming pool, Carbon Trust (2009) recommend an air handling unit employing heat recovery and/or a heat pump, controlled by a thermostat and humidistat, to maintain an air temperature of 29 ˚C and relative humidity of 60 %. Note that air temperature should not be more than 1 ºC above pool water temperature in order to avoid excessive evaporation. Two main options are available.

- Plate heat exchangers may recover 75 – 80 % of sensible heat from outgoing air, but only recover latent heat (from moisture) when the outdoor air inflow temperature is low enough to cause condensation within the heat exchanger.

- An alternative, more expensive, option is to install a heat pump dehumidification, in which a heat pump is used to: (i) cool a condensing surface over which moist air from the pool building is circulated; (ii) heat re-circulating and incoming air; (iii) possibly also heat pool water. Such systems can reduce HVAC energy consumption by up to 50 – 80 % compared with open-air extraction systems.

Ventilation rates should be adjusted to account for factors such as the number of bathers, evaporation rate and water quality. Carbon Trust (2008) suggest a guideline figure of 10 litres of ventilation air per second, per square metre of total pool hall area (equating to approximately 4–6 air changes per hour depending on the height of the pool hall). However, best practice is to employ modulating dampers in combination with variable speed fans, humidity and CO sensors, so that pool air can be mixed with fresh air and re-circulated, in order to match the air exchange rate with humidity and air quality requirements. This is dependent on good air quality being maintained in relation to disinfection agents and by-products.

Application of a pool cover overnight not only reduces heat and water loss from the pool water body, but reduces over-night HVAC requirements. It may be possible for HVAC system to be shut down overnight, although to avoid condensation damage it may be preferable to leave the system on standby and activated by humidistat (if relative humidity increases above 70 %).

Applicability

Table 5.29, above, refers to the applicability of specific best practice measures within this BEMP section.

Economics

Best practice measures referred to above realise economic benefits in the form of:

- reduced energy demand
- reduced water demand
- reduced chemical demand
- lower maintenance costs for filters, pumps, and the building fabric (less condensation damage).

Record keeping and good management practices do not involve significant capital costs but can realise substantial savings in relation to the above costs (Carbon Trust, 2005). Installing an automated building management system can lead to a further 10 % energy cost savings, and can realise relatively short payback for larger leisure centres (Carbon Trust, 2006).

<u>Energy savings</u>

For a 25 m pool situated within a 1000 m^2 complex, energy savings from good management practices and basic retrofits such as variable speed pumps and heat exchangers (see Figure 5.34) could range from EUR 50 000 to EUR 85 000 per year at energy prices of EUR 0.06 to 0.10 per kWh.

Installing a recirculation system with a heat pump would require an investment of approximately 30 % more than for a full fresh air system controlled via a humidistat, but a 20 % reduction in energy costs should lead to a payback of approximately two years for a 100 m2 pool (Carbon Trust, 2009).

Installing automatic variable speed control of swimming pool pump motors at Hutton Moor Pool saved approximately EUR 8 000 per year (Carbon Trust, 2005) – these savings are likely to be considerably higher at current energy prices. The lifetime savings of high-efficiency variable speed motors can be many multiples of capital costs. Carbon Trust (2005) note that lifetime operating costs for a EUR 350 motor for a pool circulation pump can exceed EUR 35 000.

Water savings

Economic benefits associated with water savings are smaller than benefits arising from energy savings. At a water price of EUR 2.50 per m^3, annual water savings of almost 2 000 m^3 for a 25 m pool (Figure 5.33) would translate into annual cost savings of almost EUR 5 000.

As referred to in section 5.2, installation of low-flow shower, tap and toilet fittings or retrofit options is associated with short payback periods, often less than one year.

Pool covers have a payback period of 1 – 3 years, dominated by the energy rather than water saving (Carbon Trust, 2005).

Reverse osmosis backwash water recycling requires high capital, operational and maintenance costs, and may only be worthwhile in areas of extreme water shortage.

Driving force for implementation

As referred to above, optimised pool management can lead to significant economic savings through reduced energy, water and chemical consumption, and reduced maintenance requirements.

Careful control of pool water quality and chemical dosing, in particular avoiding excessive chlorination, can increase user enjoyment.

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5.7 Rainwater and grey water recycling

Description

Some water applications in buildings, such as toilet flushing and irrigation, do not require the use of potable water. These applications can be responsible for a large share of total water use. Landscaped grounds were found to be the most important determinant of water use efficiency across Hilton hotels. Across Scandic hotels each m^2 of landscaped ground was statistically associated with an additional 88 L per year of water consumption (Bohdanowicz and Martinac, 2007). Thus, the use of water recycled from on-site rainwater or grey water collection systems can considerably reduce demand for potable water from the mains supply.

Rainwater collection systems divert rainfall water into storage tanks. Run-off systems can be installed on roofs and other impervious surfaces. The harvested water can be used for non-potable demand such as toilet flushing, washing machines, irrigation, cooling towers or general cleaning purposes. Thirty-five percent of new buildings built in Germany in 2005 were equipped with rainwater harvesting systems (EC, 2012), and about 100 Accor hotels have been installed with rainwater recovery tanks to supply irrigation or car washing applications.

Grey water is the term used to describe waste water from activities such as bathing, showering, laundry, dishwashers, and excludes 'black water' from toilet flushing. Grey water may be collected and reused for non-potable water applications such as toilet flushing and irrigation by the installation of separate waste water drainage systems for toilets and grey water sources.

Although usually too expensive and impractical to retrofit, water recycling systems can be installed at relatively low cost during construction, and at reasonable cost during major renovations. Smith et al. (2009) estimate water recycling systems can add 15 % to plumbing system costs during major renovation. The decision to install rainwater collection systems and grey water recycling should be based on a cost-benefit assessment that considers economic and environmental criteria, including the source and scarcity of water supply now and in the future. Water recycling is highly visible to guests, and may thus be a useful way to convey corporate environmental responsibility. One potential alternative for enterprises with a high irrigation water demand that can avoid the need for installation of a separate waste water collection system is the use of all treated waste water for irrigation (section 6.3).

Rainwater collection for irrigation is regarded as a basic good practice measure. Best practice is considered to be:

- installation of a rainwater collection and distribution system for use inside the building
- installation of a grey water collection, treatment and distribution system for use either inside or outside the building.

Achieved environmental benefit

EC (2009) estimate that water recycling can reduce water consumption by an additional 10 %, after a 40 % reduction in water consumption achievable from implementation of water efficiency measures.

A rainwater recycling system installed in the 250-room ETAP city-centre hotel in Birmingham, UK, saves up to 780 m^3 of potable water per year (5 % to 10 % of consumption). This saving equates to about 6 % of best practice water consumption for this size of hotel (after implementation of all other water efficiency measures).

NH Campo de Gibraltar hotel substitutes 20 % potable water with filtered and treated grey water from showers, used to flush toilets.

There are some cross-media effects associated with rainwater collection and grey water recycling (see below). The overall environmental benefit will be highest where local (perhaps seasonal) water shortages exist, and where water is imported from other areas or desalinated. In such areas, modest reductions in water consumption may lead to significant reductions in water stress (with associated benefits, including for biodiversity), and/or energy requirements for desalination.

Appropriate environmental indicator

Indicators

The most relevant indicators of water recycling implementation are:

- installation of a rainwater recycling system that supplies internal water demand
- installation of a grey water recycling system that supplies internal or external water demand
- quantity of rainwater and grey used, m^3/yr
- percentage of annual potable water consumption substituted with recycled rain- or grey-water

In areas where seasonal water scarcity is a problem, particularly as a consequence of tourism demand, seasonal indicators may be relevant – e.g. water consumption per guest-night during peak season, or percentage reduction in consumption achieved over the peak season.

Benchmarks of excellence

So far, there is little information on specific water savings achievable through the implementation of this BEMP, which may vary considerably depending on factors such as climate. Therefore, the following benchmark of excellence represents best practice for this technique.

BM: installation of a rainwater recycling system that supplies internal water demand, or a grey water recycling system that supplies internal or external water demand.

Best practice in this technique may also be reflected in conformance with the benchmark for potable water consumption in section 5.1 (i.e. ≤140 L per guest-night for fully serviced hotels and ≤100 L per guest-night for other types of accommodation).

Cross-media effects

Reused rain water can have a higher energy and carbon footprint than mains supply water owing to infrastructure and pumping requirements. The carbon footprint of a domestic sized rainwater harvesting system over **30 years** has been estimated at approximately 800 kg CO_2 eq. However, this is minor compared with total household carbon emissions from energy use, which can be 100 times higher.

Rainwater reuse systems essentially bypass the natural water cycle. Where drainage water would otherwise soak into the ground, and where groundwater levels are locally declining, and where water is supplied from a (nearby) area with greater water availability, widespread rainwater harvesting could exacerbate **local** water stress. Such situations are unlikely, however. On the contrary, widespread rainwater harvesting could reduce flooding risk during high rainfall events.

Operational data

Run-off water quality

Contaminants in roof run-off water include organic matter, inert solids, faecal deposits from animals and birds, trace amounts of metals and complex organic compounds. Concentrations vary depending on roof material, antecedent dry period and surrounding environmental conditions (e.g. proximity motorways or industrial areas). Leaching of heavy metals such as copper, zinc and lead can present a problem where these materials are extensively used in roof construction. However, a study of roof run-off quality in Hamburg, Germany, found that copper, lead and zinc concentrations were well within World Health Organization drinking standards (Villarreal and Dixon, 2005). The quality of roof run-off (Table 5.33) is acceptable for domestic uses, especially following basic filtration. It is possible but usually not necessary to fit a device to rainwater collection systems that diverts the first flush of run-off water during rain events, containing the highest concentrations of contaminants, to normal drainage.

Table 5.33: Water quality parameters for 'fresh' and stored roof run-off water

	pH	BOD	COD	TOC	TS	SS	Turbidity
		mg/l					NTU
Roof run-off	5.2 – 7.9	7 – 24	44 – 120	6 – 13	10 – 56	60 – 379	3 – 281
Stored run-off	6 – 8.2	3	6 – 151	–	33 – 421	0 – 19	1 – 23
Source: Villarreal and Dixon (2005).							

Run-off water from some surfaces such as car parks can contain relatively high levels of contaminants such as hydrocarbons and heavy metals from vehicles, and will not be suitable for use indoors. Run-off water should be tested before deciding to install a recovery system. Where water is not suitable for indoor use, it may be suitable for irrigation following installation of a first-flush diverter and appropriate filtration.

<u>Run-off collection system design</u>

Rainwater collection and reuse is a simple process. The necessary components can be easily installed in a new building at relatively little expense, but are more difficult to retrofit in an existing building. Extensive plumbing modifications are required to separate the water supply network into two systems supplying: (i) kitchen taps, bathroom taps and showers supplied by 100 % potable water from the mains supply; (ii) toilet cisterns, urinals and laundry facilities supplied with rainwater or potable water depending on availability. Where rainwater is available in sufficient quality and quantity, it may also be used in showers.

A typical rainwater reuse system comprises the following components.

- A standard roof or surface run-off water collection system operating under gravity and diverted into a storage tank, fitted with a debris screen and filter.
- A storage tank with water-level detector, ideally situated underground, into which rainwater is diverted from standard rainwater collection pipes.
- A control unit that sends either mains water or stored rainwater either directly to the distribution system under pressure, or to a header tank.
- A separate pipe distribution system feeding relevant fittings (urinals, cisterns, etc.) with water supplied either directly under mains/tank-pump pressure or from a header tank.
- (Possibly) A header tank with float-operated inlet valves from pumped rainwater and from the mains water supply, and an outlet valve into the building water supply system.

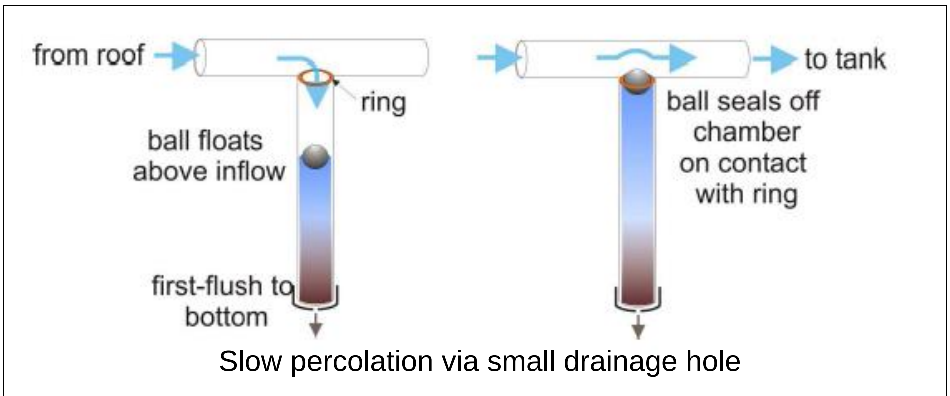
There are various methods of tank sizing, some of which may be area specific. One guideline is that the tank should be large enough to hold 18 days of average demand, or five per cent of annual yield, whichever is lower (Peacock irrigation, 2011). Another guideline is that the tank should be able to store sufficient water to supply average demand over the longest dry periods (statistically defined from 30-year climatic data). The yield can be calculated by the following simple equation:

S = (R/1000) x A x RC		
S	Annual supply	m^3
R	Annual rainfall	mm
A	Plan area draining into collection pipes	m^2
RC	Run-off coefficient	0 – 1

Annual rainfall varies considerably across and within countries and across years. Climatic average annual rainfall data should be obtained from the nearest weather station. Area refers to the **plan** area, which will differ from the roof area for sloping roofs. UNEP (2009) suggest run-off coefficients of 0.8 – 0.9 for tile roofs, 0.6 – 0.8 for concrete and 0.7 – 0.9 for metal sheets.

Thus, for a concrete roof with a 500 m^2 plan area in a region exposed to 1 000 mm annual rainfall, annual run-off water supply would be 1 x 500 x 0.7 = 350 m^3. Applying the 5 % rule, the total recommended tank capacity would be 17.5 m^3. However, strong seasonality in rainfall, in particular the occurrence of long dry periods, may require larger capacity. The seasonality of rainfall patterns should be assessed, and tanks may be sized according to the aforementioned dry-period supply rule. The British Standard code of practice for rainwater harvesting systems (BSI, 2009) recommends a modelling approach to tank sizing that considers temporal variations in demand and yield, using at least three years of data, for commercial applications such as tourism establishments. Occasional overflows are a useful way to clean debris from the tank and maintain water quality. Tanks may also be sized for stormwater control to reduce the risk of flooding, in which case statistical data on storm events should be used to specify 'oversized' tanks.

<u>Rainwater system installation</u>
Rainwater collectors such as guttering should be regularly inspected and kept clean of debris, including leaves. Wire mesh screens may be fitted to gutters to debris entering the system, and it is recommended to fit a filter to the inflow of the rainwater collection tank. These typically contain a fine wire mesh of e.g. 0.35 mm, may contain additional micro-filtration layers, and can be self-cleaning (by periodically applying high-pressure water over the mesh surface to a separate outlet for debris). A first-flush diverter may be fitted to reduce the concentration of pollutants in the collected rainwater (Figure 5.35).

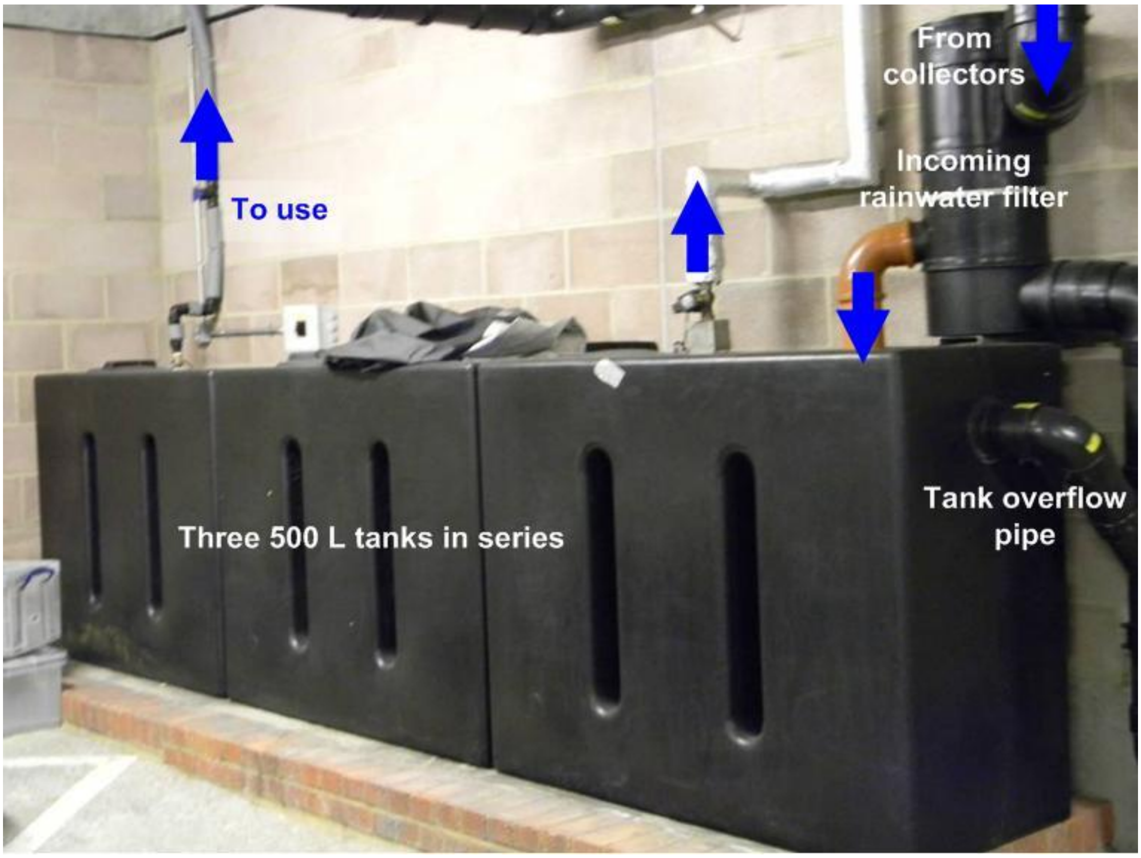


Source: UNEP (2003).

Figure 5.35: Float-ball mechanism to divert first flush run-off water

Prefabricated rainwater storage tanks are commercially available in sizes of up to 7 m^3 for underground types and 10 m^3 for above-ground types (Bicknell, 2009). It is possible to buy tanks built in two pieces that are joined together during installation – these can be particularly useful where space onsite is restricted for installation. Where large storage capacity is specified at the building design phase, purpose-built concrete tanks may be constructed. Alternatively, multiple pre-fabricated tanks may be installed in series (see Table 5.34).

Table 5.34: An example of a small rainfall collection (above) and storage (below) system, from the Rafayel Hotel in London



Tanks should be installed underground or in unheated basement areas where the temperature remains stable and relatively low throughout the year. Buried tanks with an ambient temperature not exceeding 12 ºC are ideal because they restrict biological activity that can otherwise be associated with water discolouration, and potential health risks (Bicknell, 2009). BSI (2009) recommend a floating extraction point at 100 mm to 150 mm below the water surface, or alternatively a fixed extraction point at 150 mm above the base of the tank. Overflow pipes should be at least equal in capacity to inflow pipes, protected from backflow and vermin, and, where possible, connected to a soak-away drain.

It is highly recommended to install a meter to measure rainwater use. This will facilitate the identification of problems, and enable calculation of potable water savings. This system will usually be incorporated into the control system that controls pumps and regulates the backup (potable) water supply. The system may also be integrated into a centralised building management system.

Pipework should be clearly identifiable as supplying rainwater, and differentiated from pipework supplying only potable water. Pipework may be identified by markings inserted during manufacture, or attached labels. It is recommended that labels be attached at 0.5 m intervals along the pipe, and on the outside of insulation where this is present (BSI, 2009). Similarly, labels and signs should be visible at all points of use stating 'non-potable water'.

Frequent inspection of the system and tank water can identify water quality problems, combined with occasional dip testing of water in the storage tank or cistern, for example in accordance with BS 7592. Sampling of water quality at the point of use is only required if problems are detected from the periodic sampling (BSI, 2009). Guideline values for use of collected water to flush toilets in single site and communal domestic systems are provided by BSI (2009):

- escherichia coli number ≤250 per 100 ml
- intestinal enterococci number ≤100 per 100 ml
- total coliforms ≤1000 per 100 ml.

<u>Grey water recovery</u>

Grey water recovery requires the installation of separate waste water collection systems for: (i) showers, basins, washing machines, kitchen appliances, swimming pools (grey water); and (ii) toilets (black water). In fact, separate grey water collection may be restricted to room showers and basisns, in order to avoid more heavily soiled water from kitchens and laundries.

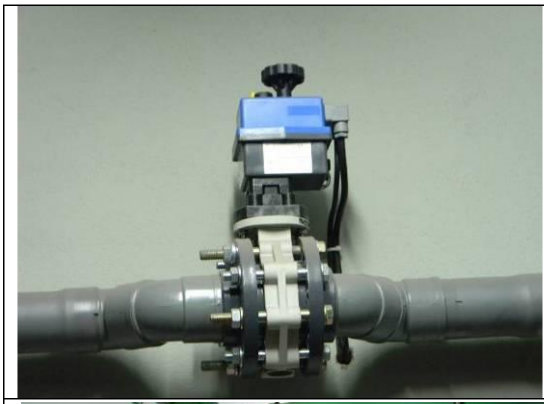
In its most basic form, grey water recycling requires:

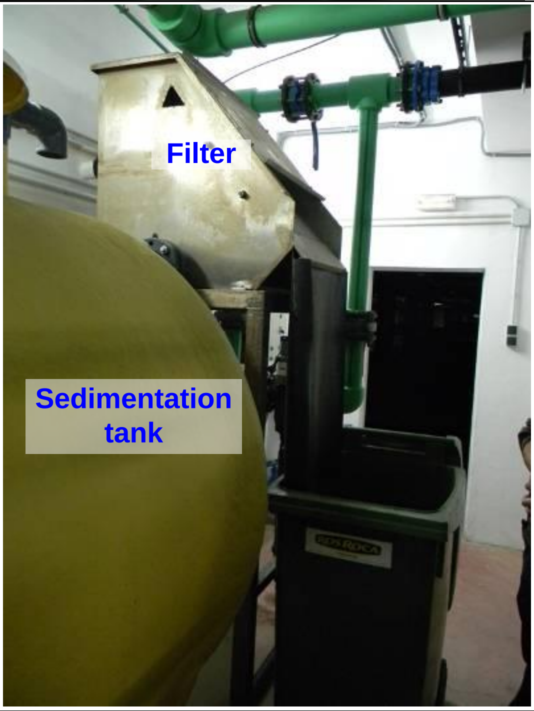
- installation of a separate waste water collection system for grey water and black water
- basic screening to remove debris
- installation of large grey water storage tanks (as described above for rainwater harvesting)
- connection to an irrigation system.

It is easy to incorporate a basic heat-exchange process into grey water collection systems, to heat fresh water entering the heating system. Such a system is described in section 9.3 for a campsite. Use for indoor activities such as toilet flushing requires installation of a separate supply system as described for rainwater recycling (above). An example of a system using pool overflow water for toilet flushing is provided for a campsite in section 9.3. Here, the example of NH Campo de Gilbralter is presented.

The 100-room NH Campo de Gibraltar hotel, in Algeciras, Spain, was opened in 2009 with a novel grey water recycling system shared with one other NH hotel (Hesperia hotel, in Cordoba). Waste water is collected separately from basins and showers, treated, and recirculated for toilet flushing, reducing potable water consumption by 20 %. The sequence of steps is elaborated with reference to photos in Table 5.35.

Table 5.35: Sequence of steps in grey water recycling implemented at NH Campo de Gibraltar hotel

<table>
<tr><td></td><td>1. Grey water diversion

An electrovalve controls flow of separated grey water into the treatment tank depending on remaining capacity. If full, grey water is diverted to the sewer.</td></tr>
<tr><td>
</td><td>2. Grey water filtering

A flow sensor located after the electrovalve activates a dosing system to add hypochlorite to grey water entering the treatment room for recovery.

Following hypochlorite dosing, water is filtered through a mesh screen to remove debris such as hair. This screen is manually cleaned, requiring 15 minutes per day. Debris is collected in a standard waste bin and sent for disposal.

Filtered water is left to settle in a sedimentation tank. Sludge from the sedimentation tank is collected every 15 – 30 days by a tanker.</td></tr>
<tr><td>.</td><td>3. Storage

Filtered, settled grey water is directed to a series of three intermediate and two final storage tanks.</td></tr>
</table>

	**4. Distribution** Stored grey water is pumped to toilet cisterns throughout the hotel through a clearly labelled grey water pipe network.
	**5. Toilet flushing** All toilets in the hotel are flushed using treated grey water.

CRC (2002) make the following recommendations for the safe reuse of grey water that minimises potential human health risks (in Australian conditions):

- kitchen grey water should not be included as it is highly polluted, putrescible and contains many undesirable compounds;
- grey water should not include waste water from kitchen sinks, dishwashers, garbage disposal units, laundry water from soiled nappies or wash water from the bathing of domestic animals;
- removal of hair, lint, etc. via strainer or filter is necessary to ensure systems do not clog;
- blockages and build-up of slime may be avoided by using pressurised systems;
- storage of grey water is undesirable due to the potential for the growth of pathogenic micro-organisms, mosquito breeding and odour generation;
- sub-surface reuse is the preferred method of irrigation as surface irrigation is prone to ponding, run-off and aerosols (see section 9.2);
- reuse for toilet flushing should not be considered as it requires a high degree of treatment to ensure no health risks, toilet staining or biodegradation in cistern.

Health and safety regulations

Safeguards must be in place to prevent the possibility of backflow of collected non-potable water into the main supply system. The most rigorous safeguard is an air-gap system. Rainwater harvesting and grey water systems must conform to the European Standard on backflow protection by an air gap (EN1717). National regulations usually specify backflow protection requirements applicable to rainwater or grey water recycling systems. For example, in the UK rainwater harvesting systems that involve mains supply top-up must comply with section 5 of The Water Supply (Water Fittings) Regulations 1999 dealing with backflow protection to protect mains water – this requires an air gap with an unrestricted discharge between the incoming mains water and the recycled water ('a non-mechanical backflow prevention arrangement of water fittings where water is discharged through an air gap into a receptacle which has at all times an unrestricted spill-over to the atmosphere': UK Governemnt, 1999). A tundish (Figure 5.36) is an appropriate spill-over arrangement (Bicknell, 2010).

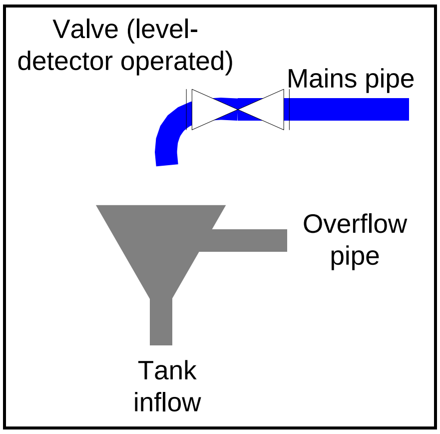


Figure 5.36: Basic tundish device

Applicability

The installation of rainwater and grey water recycling systems is applicable to all new buildings. Retrofitting such systems to existing buildings is expensive and impractical unless the building is undergoing extensive renovation.

Where waste water is treated on site and there is a high demand for irrigation water, treatment and use of all waste water for irrigation may be a more efficient option than separation and reuse of grey water.

Economics

The costs of equipment of water recycling facilities are high and the payback period is longer than for other water efficiency measures. A 14-year payback period was calculated for installation of rainwater recovery in the ETAP Birmingham city centre hotel (Accor, 2010). Therefore, this option should be applied after other more cost-efficient measures have been taken (see sections 6.2 6.6).

Grey water recovery systems require separate pipework and are therefore difficult to retrofit. Payback periods vary from 2 to 15 years depending on the type of system and the cost of potable water saved (ITP, 2008). Relatively high maintenance costs, of EUR 2 000 to EUR 3 000 per year, were also reported for the NH Campo de Gibraltar hotel, offsetting some of the 20 % reduction in the annual water bill.

Governments may provide financial incentives for the installation of water recycling systems, such as grants or tax rebates. In the UK, the Enhanced Capital Allowance scheme allows businesses to offset installation costs for water recycling systems against tax in the year of installation.

Driving force for implementation

The two primary objectives for implementing water recycling schemes are to: (i) reduce water consumption; (ii) reduce waste water volume. The driving forces behind these include water and waste water service charges (above) and CSR or green marketing (water recycling systems are highly visible indicators of environmental responsibility). Increasingly, national regulations are encouraging the installation of water recycling systems. In the UK, the following main regulatory drivers apply (Bicknell, 2010).

- The Code for Sustainable Homes encourages builders to install rainwater harvesting in new-builds.
- Part G of the Building Regulations (April 2010) sets a mains water consumption standard of 125 litres per head per day.
- Councils give expeditious and sympathetic handling of planning permission to applications which include rainwater harvesting.
- The Flood and Water Management Bill (April 2010) suspended the automatic right to connect to a sewer, encourages rainwater harvesting to help alleviate flood threats, and gives water boards greater powers to ban the use of hosepipes for outdoor water use during water shortages.

In addition, building standards such as BREEAM (BRE Environmental Assessment Method) contain requirements or award optional points for water conservation measures including water recycling, and governments may offer financial incentives (see above).

Reference organisations

- Over 100 hotels within the Accor group have rainwater recovery systems in use. The 250-room ETAP city-centre hotel in Birmingham, UK, installed a rain-water recovery system in 2007 that supplies toilet cisterns in 90 rooms and saves up to 780 m^3 of water per year. Potable water consumption is reduced by between 5 % and 10 % (Accor, 2010).
- The NH Campo de Gilbralater hotel recovers grey water from showers and basin for toilet flushing, as described in Table 5.35 above.
- The Uhlenköper Campsite in Germany uses water from the natural swimming pool to flush toilets in the adjacent washroom.
- Kühlungsborn camping park uses grey water from showers and basins in the washroom for irrigation, following heat recovery described in section 9.2.
- Basic practice is demonstrated by the 14-room Strattons hotel and restaurant in Norfolk, UK. Rainwater storage capacity of 15 900 L was installed, comprising one large 10 000 L tank, a smaller 1 100 L tank, and 12 x 400 L water butts (Envirowise, 2008). This water is used to irrigate the 0.4 hectare grounds that include a fruit and vegetable garden cultivated to supply the on-site restaurant. An additional 2 000 L of grey water per week are recovered from restaurant and kitchen operations and used in the garden.
- Another example of basic practice is the Rafayel Hotel in London, where rainwater is collected from the building roof and car-park-cover (Table 5.34, above) for irrigation of planted areas.

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Contact information

European Commission - Joint Research Centre - Industrial Leadership and Circular Economy Unit

Address: Calle Inca Garcilaso 3, 41092, Seville, Spain

E-mail: JRC-IPTS-EMAS@ec.europa.eu

Website: http://susproc.jrc.ec.europa.eu/activities/emas/

JRC Science Hub
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