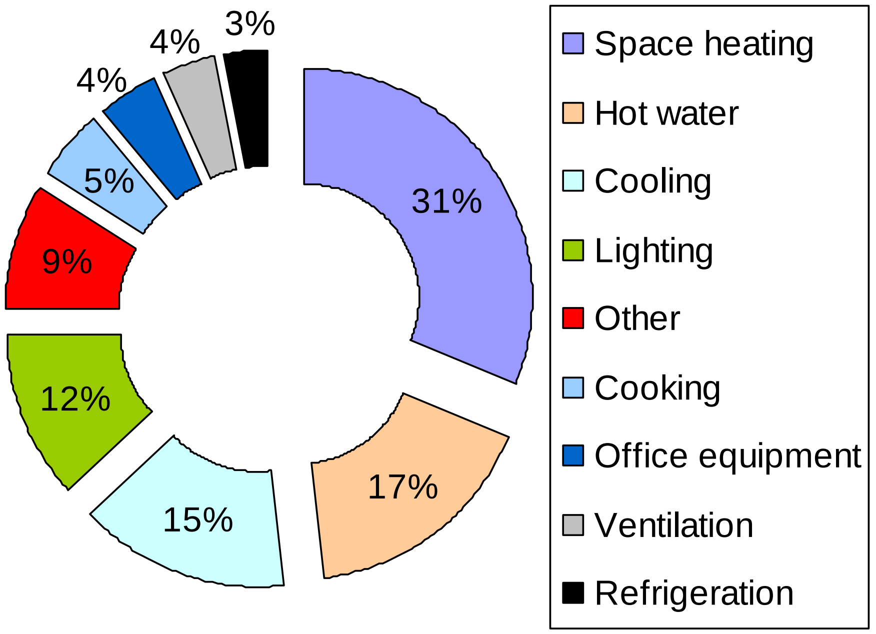
7 MINIMISING ENERGY USE IN TOURIST ACCOMMODATION

Accommodation and energy consumption

Accommodation is a significant but not major contributor to global energy consumption and associated CO_2 emissions, accounting for approximately 1 % of the latter (HES, 2011). Whilst the 5.45 million hotel rooms in Europe represent half the global total number, European accommodation is estimated to be responsible for just 21 % of GHG emissions arising from accommodation globally (HES, 2011), suggesting better-than-average energy efficiency in European accommodation. Nonetheless, energy efficiency has traditionally represented a low priority for accommodation, and there is considerable scope for energy savings in the sector, contributing to cost and GHG emission reductions.

Processes responsible for final energy consumption in accommodation

The breakdown of total energy consumption for a typical hotel is displayed in Figure 7.1. This breakdown, and the proportion of energy sourced from electricity compared with fuels such as natural gas, propane, liquid petroleum gas and fuel oil, varies considerably across accommodations depending on the level of services offered, building design, climate, occupancy, local energy infrastructure and local regulations. Electricity accounts for approximately 40 % of energy consumed in a hotel (HES, 2011). Of this, approximately 45 % is used for lighting, 26 % for HVAC, 18 % for other, 6 % for water heating and 5 % for food services (Leonardo Energy, 2008). Kitchens and laundries typically account for approximately 10 % and 5 % of energy consumption, respectively, in a large hotel, although these figures vary considerably depending on the size of the hotel restaurant and the amount of laundry that is processed on site. Kitchens may represent up to 25 % of energy consumption (Farrou et al., 2009). Energy consumption in kitchens is addressed in section 8.4, and energy consumption in laundries is addressed in sections 5.4 and 5.5.



Source: Data from HES (2011).

Figure 7.1: Energy consumption by end-use in hotels

Opportunities to reduce final energy consumption in accommodation

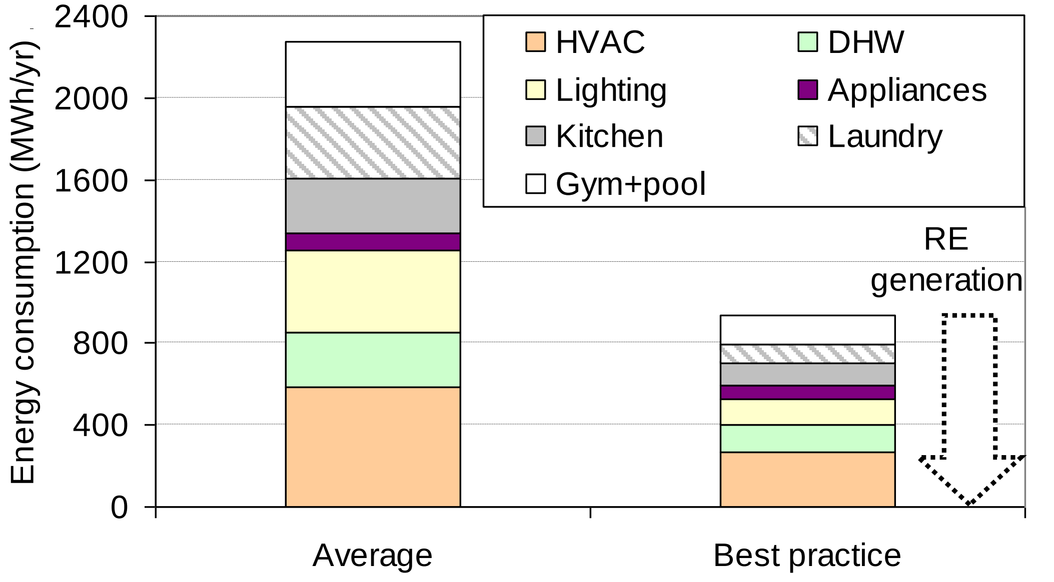
Energy saving opportunities in accommodation mirror those for buildings more generally (e.g. EC, 2012). Table 7.1 presents a ranking of energy efficiency and renewable energy (RE) measures according to financial attractiveness in Northern Ireland. It is clear that measures to reduce energy demand are the most cost effective, usually resulting in significant financial savings. Measures to meet demand with renewable energy sources, for example by installing solar water heating, may be associated with significant financial costs. However, the situation differs considerably across countries and at an enterprise level depending on factors such as climate and financial support for renewable energy installation.

Table 7.1: Financial attractiveness of different energy demand and supply measures in Northern Ireland, ranked in descending order

Financial savings	Financially neutral	Small financial cost	Significant financial cost	Large financial cost
1. Energy Management Systems 2. Building envelope insulation 3. Heating controls 4. Low energy lighting 5. Most efficient boilers	6. Small hydro 7. Small biomass heat 8. Large wind 9. Small biomass heat 10. Co–firing biomass with coal	11. Small wind 12. Large biomass CHP 13. AD CHP	14. Micro wind 15. Solar water heating	16. GSHP 17. Solar PV
Source: Carbon Trust (2008).				

Figure 7.2 and Table 7.2 provide an overview of the opportunities to reduce energy consumption in accommodations through the model example of a 100-room hotel, based on average and best practice performance across major energy-consuming processes described throughout this document. Excluding renewable energy (RE) supply measures, implementation of best practice measures to reduce energy demand could reduce energy consumption for a 100-room hotel with a pool and leisure area by 1 336 MWh per year (56 %), equivalent to an energy bill reduction of over EUR 93 000 per year assuming 40 % of the final energy saving is electricity and 60 % is natural gas. Use of RE resources, such as geothermal heating and cooling, wood heating, and wind electricity in particular, could further reduce net primary energy consumption.

Table 7.2 shows that the largest energy savings, up to 323 MWh per year for a 100-room hotel, can be achieved by reducing demand for and optimising the provision of heating ventilation and air conditioning (HVAC). The next greatest opportunity for energy savings of up to 265 MWh per year arises through the installation of energy-efficient and intelligently controlled lighting, followed by optimisation of laundry processes. Pool and leisure areas, kitchens and domestic hot water (DHW) heating also present major opportunities for energy savings where present on accommodation premises. Implementation of energy monitoring and management is integral to all best practice energy efficiency and renewable energy measures. Table 7.2 lists the main best practice measures, and sections of this document in which they are described, to reduce energy consumption across each of the main processes.



NB: Assumes average occupancy rate of 80 % of rooms (of which 25 % double occupancy).

Figure 7.2: **Modelled average and achievable best practice energy consumption for a 100-room 5 300 m^2 hotel based on demand reductions and assumptions in Table 7.2**

Savings presented in Table 7.2 exclude those achievable from the implementation of RE, which are described in section 7.4 with regard to aerothermal, hydrothermal and geothermal energy exploited via heat-pumps, and in section 7.6 regarding solar, wind and biomass resources. Although reducing energy demand has the greatest immediate potential to reduce primary energy consumption and associated environmental impact, the installation of RE capacity has an important effect on developing and mainstreaming RE technologies and markets. Thus, whilst measures to reduce energy demand are prioritised on the energy management ladder for accommodations (sections 7.1 to 7.5), sourcing renewable energy (section 7.6) is considered to have an important long-term environmental benefit beyond its immediate impact.

Table 7.2: Modelled energy savings achievable from best practice in a 100-room hotel, and portfolio of associated best practice

Process or area	Saving MWh/yr	Savings calculations	Best practice measures	Section
HVAC	323	Best practice and average practice HVAC plus DHW heating of 75 and 161 kWh per m^2 per year, respectively, taken from hotel chain non-electricity demand data (Figure 7.14 in section 7.2). DHW consumption (below) subtracted	Energy management	7.1
			Improved building envelope	7.2
			Optimised HVAC	7.3
			Geothermal heating/cooling or wood heating	7.4 or 7.6
Lighting	265	Best practice is represented by 25 kWh per m^2 per year lighting energy consumption, based on installation of low energy lamps and intelligent control (section 7.5). Average lighting consumption three times higher	Energy management	7.1
			Efficient lighting	7.5
			Solar PV or wind electricity generation (on site or off site)	7.6
Laundry	263	Average practice based on 4 kg laundry per occupied room per day requiring 3 kWh per kg to process. Best practice based on 3 kg per room per day requiring 1 kWh per kg to process on a large-scale (perhaps off site)	Energy management	7.1
			Reduced laundry generation (bedclothes reuse)	7.3
			Optimised small- and large- scale laundries	5.4 and 5.5
Pool and leisure area	168	Assumes 200 m^2 pool and leisure area, with typical and best practice energy consumption of 1 573 and 735 kWh per m^2 per year, respectively (Carbon Trust, 2006: section 5.6)	Energy management	7.1
			Optimised pool management	5.6
			Integration with optimised HVAC system	7.3
Kitchen	164	Assumes 1.5 cover meals per guest per day. Average and best practice represented by 5 and 2 kWh per cover meal, respectively (section 8.4).Energy consumption can vary widely depending on type of meals produced	Energy management	7.1
			Optimised cooking, ventilation and refrigeration	8.4
			Integration with optimised HVAC system	7.3
DHW	133	Assumes DHW consumption of 60 L per guest, heated by 50 ºC, for best practice, and twice this heating energy for average practice	Energy management plan	7.1
			Low flow water fittings in guest areas	5.2
			Solar thermal or wood heating	7.6
Other electrical appliances	20	Best practice is represented by mini-bar electricity consumption of 0.8 kWh per room per day plus TV standby at 1 W plus TV operating at 100 W 1.5 hours per room per day (section 7.5), plus equivalent electricity in non-guest areas. Average practice is twice this level	Efficient electrical equipment	7.5
			Energy management	7.1
			Solar PV or wind electricity generation (on site or off site)	7.6

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7.1 Energy monitoring and management systems

Description

Implementing an energy management plan is a core EMS requirement, and follows principles described in section 2.1. The basic sequence of actions representing implementation of an energy management plan is shown in Figure 7.3. Fulfilling best practice for this technique may facilitate formal accreditation according to ISO 14001, the HI-Q management system for hostels, and other formal EMS used by accommodation. Energy monitoring and reporting is also a core requirement for environmental standards such as the EU Ecolabel for tourist accommodations, the Nordic Swan for hotels and hostels. Various tools exist to assist accommodation managers with energy benchmarking, most notably the free Hotel Energy Solutions (HES) 'e-toolkit' developed by the UNWTO, UNEP and others, available at: http://hotelenergysolutions.net/en/node/33251

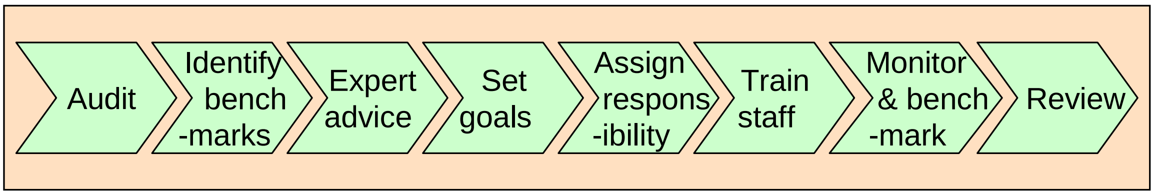


Figure 7.3: Sequence of key actions to implement an energy management plan

Sections 7.2 and 7.3 describe best practice to reduce energy demand specifically for heating and cooling, whilst section7.5 describes best practice to reduce electricity consumption for lighting and other electrical appliances in guest areas, and section 7.6 refers to the installation and sourcing of RE.

This BEMP technique relates to measures outlined in Table 7.3 relating to implementation of a comprehensive energy management plan that includes benchmarking energy efficiency throughout accommodation premises. The two measures underpinning this BEMP technique are:

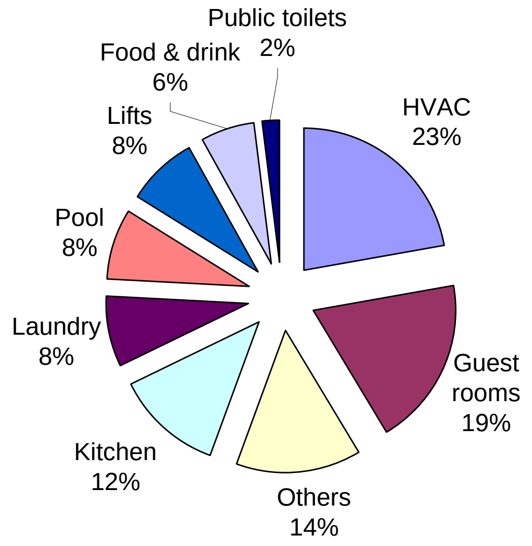
- an audit of major energy consuming equipment and processes
- monitoring of energy consumption across major energy consuming processes and areas.

Table 7.3: Best practice measures for the monitoring and management of energy consumption in accommodation premises

Measure	Description	Applicability
Energy audit and monitoring	Draw up inventory of main energy-consuming devices. Monitor energy consumption at least on a seasonal basis and calculate energy consumption per m^2	All accommodations
Sub-metering	Install electricity and, where possible, gas or oil, sub-meters for different building zones to include at least kitchens, laundry areas, spa and pool areas, rooms and hallways	Larger premises
Energy management plan	Identify priority measures to reduce energy consumption. Derive appropriate benchmarks for particular processes, and overall based on energy consumption per m^2, and define targets to drive continuous improvement	All premises
Automated control	Implementation of an automated control system, including key-card activation of room electricicity and HVAC systems (except fridges), and deactivation when windows opened. Ideally integrated into a Building Management System for large premises	Larger premises
Inspection and maintenance	Regularly inspect energy-consuming and control equipment and repair or replace damaged equipment. In particular, ensure that boilers, sensors, thermostats and fans are working correctly. Inspect pipes and ducts for leaks. Manually check gauges to verify digital readings	All accommodations
Staff and guest training	Train staff to turn off unnecessary lighting and devices on standby, and to close window blinds in summer, for example during room cleaning. Inform guests of simple actions to reduce energy consumption	All accommodations
Adequate insulation	Make sure that all water and HVAC pipes are adequately insulated to minimise energy losses	All accommodations

At its most basic for small premises, an energy audit involves the compilation of an inventory of energy-using equipment, combined with estimated usage patterns, to estimate the main sources of energy demand. Preferably, an energy audit should be carried out by a trained energy expert, in-house or external. Initial audit information is usually sufficient to inform accommodation managers on preliminary actions to reduce energy consumption. These range from requesting staff to turn off all unnecessary lighting, through replacing older devices with new energy efficient models, to modifications of the HVAC system and retrofitting of the building envelope.

Typically, the energy consumption of numerous energy-intensive processes occurring on accommodation premises is not monitored separately. For example, despite kitchens being responsible for approximately 15 % of energy consumption in a typical hotel, and a strong correlation between the number of food covers served in hotel restaurants and total hotel energy consumption (Bohdanowicz and Martinac, 2007), kitchen energy consumption is rarely monitored separately. One proposed aspect of best practice is to install sub-meters for kitchen electricity and gas (and water) consumption. Similarly, on-site laundry operations can have high energy requirements (section 5.4 and 5.5), as can pool and spa areas. Therefore, a key best practice measure is the installation of sub-metering for electricity and fuel consumption across major energy-consuming processes or areas. Figure 7.4 provides an example of detailed electricity sub-metering data.



Source: Data from ITP (2008).

Figure 7.4: Sub-metered electricity consumption data for a 300-room hotel in Germany

Maintenance, staff training and guest information are all important aspects of energy management on accommodation premises. The EU Ecolabel for accommodation requires accommodation managers to organise appropriate staff training, and to provide guests with information to reduce energy consumption, such as reminders to switch off lights. The EU Ecolabel for accommodation also requires at least annual maintenance and servicing of boilers and air conditioning systems (more often if needed or required by law) by appropriately qualified professionals.

Detailed information on best practice in energy monitoring can be found in the European standard for energy management systems (EN 16001) that also provides guidance. Compliance with that standard may be used as an indicator of best practice. EN16001 recommends that the following aspects of energy management within enterprises be audited:

- effective and efficient implementation of energy management programmes, processes and systems
- opportunities for continual improvement
- capability of processes and systems
- effective and efficient use of statistical techniques
- use of information technology.

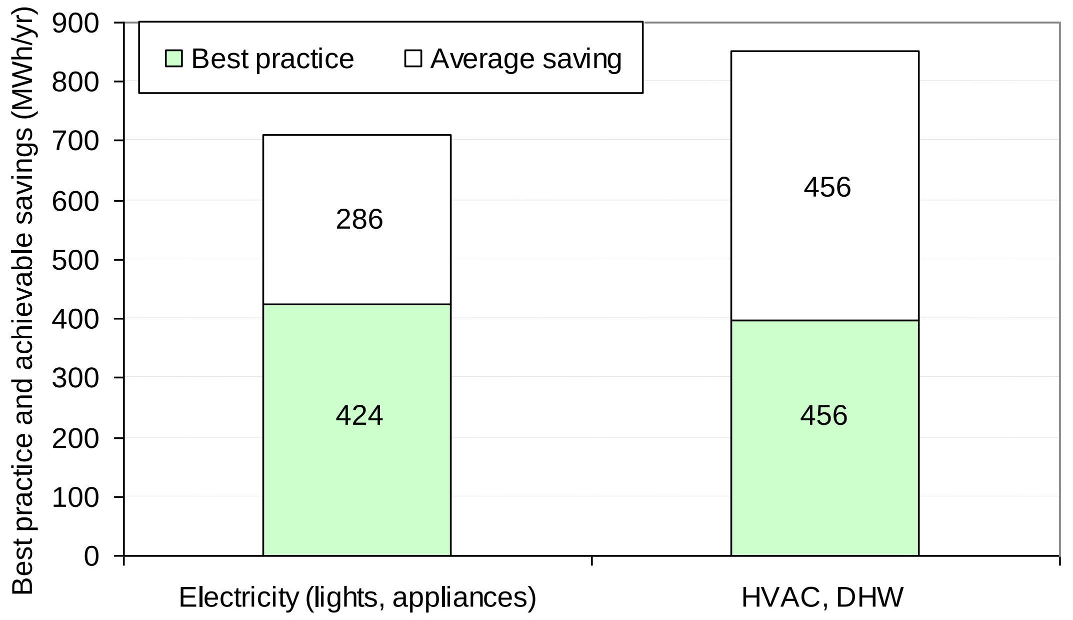
Achieved environmental benefit

Energy management

Energy monitoring and management itself can typically lead to immediate energy savings in the region of 10 %, through the identification of basic corrective actions (HES, 2011). Using monitoring to reduce diurnal imbalances in demand (i.e. increasing the proportion of electricity used at night) can reduce peak electricity demand and facilitate electricity suppliers to maximise use of efficient baseload generating capacity (including renewables).

Building energy optimisation

Monitoring and managing energy consumption is a prerequisite to implement targeted energy efficiency and RE measures throughout accommodation premises (i.e. building energy optimisation), the environmental benefits of which are detailed in subsequent sections of this chapter. Figure 7.5 displays the potential energy savings for a 100-room hotel based on implementation of best practice, compared with average performance of hotels in an anonymous mid-range hotel chain (Figure 7.7). For average hotels, implementation of best practice, informed by a comprehensive energy management plan, could reduce total energy demand by 742 MWh per year.



NB: HVAC = Heating, Ventilation, Air Conditioning; DHW = Domestic Hot Water. Based on average and best practice non-HVAC electricity demand of 134 and 80 kWh/m^2yr (see section 7.5). Based on average and best practice HVAC demand of 161 and 75 kWh/m^2yr. Assumes hotel heated and cooled area of 5 300 m^2.

Figure 7.5: Annual electricity consumption and HVAC consumption for a 100-room hotel based on best practice, and savings compared with average consumption

Appropriate environmental indicator

Indicators specifically related to heating and cooling energy consumption are described in sections 7.2 and 7.3, whilst section 7.5 specifies indicators related specifically to electricity consumption and section 7.6 refers to indicators for RE sourcing. This section focuses on benchmarking overall energy performance based on aggregation of relevant energy consumption data.

Management indicators

Best practice for energy monitoring can be summarised in the following three management indicators:

- sub-metering of all major electricity- and fuel- consuming processes on the accommodation premises (within a building management system for large premises)
- collation and processing of energy consumption data to enable energy efficiency benchmarking at the process and premises level
- implementation of an energy management plan informed by benchmarking results, incorporating process level energy targets, appropriate maintenance and staff training.

Current performance indicators

Enterprises usually have the data necessary to calculate total final energy consumption (Table 7.4). Two denominators may be used to derive indicators capable of benchmarking energy consumption across enterprises: guest-nights and serviced (heated and cooled) floor area (m^2).

Energy indicators based on these separate denominators correlate, but not particularly strongly (Figure 7.6). Final energy consumption per guest-night is strongly influenced by the level of service offered by accommodation (e.g. room size, area and equipment used for accompanying services such as eating and leisure), and by occupancy rate. Final energy consumption per m^2 serviced area is less influenced by different levels of service or occupancy rate, and conforms with typical building energy efficiency benchmarks, enabling a more robust comparison of building energy performance across accommodation establishments.

Table 7.4: Common units of energy delivered to accommodation, and appropriate conversion factors to calculate final energy consumption, primary energy consumption and GHG emissions

Energy source	Common unit	Net calorifc value per unit (kWh_{final})	Primary energy ratio ($kWh_{primary}$/ kWh_{final})	Lifecycle CO_2 eq. (kg/kWh_{final})
Electricity mix(*)	kWh	1.0	2.7	0.550
Natural gas	m^3	7.4	1.1	0.202
LPG	kg	13.9	1.1	0.242
Gas oil	L	10.3	1.1	0.327
District heating(*)	Tonne steam	698	0.8 – 1.5	0.24 – 0.41

(*)primary energy ratio and lifecycle CO_2 emission factors vary depending on generation sources (average factors shown)
Source: ITP (2008); Passivehouse Institute (2010); DEFRA (2011).

Therefore, the recommended key performance indicator for energy efficiency in accommodations is:

- total final energy consumption (kWh) expressed per m^2 serviced area.

The above indicator also corresponds with EU Ecolabel mandatory criteria for energy monitoring on accommodation premises that require a procedure for the collection of data on overall energy consumption, expressed as kWh, on a monthly or at least annual basis, normalised per overnight stay and per m^2 of indoor area.

In order to recognise the benefits of RE installation (section 7.6) without necessarily calculating primary energy consumption or lifecycle GHG emissions (below), the on-site renewable contribution may be excluded from the final energy consumption.

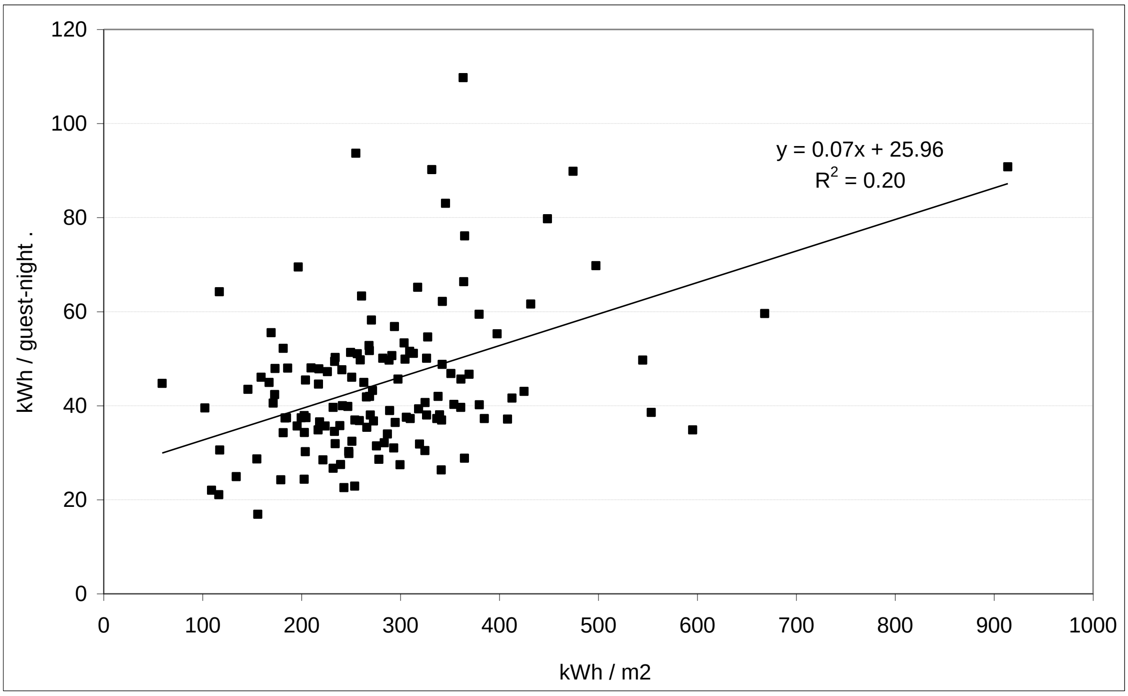


Figure 7.6: Relationship between final energy consumption expressed per guest-night and per m² heated and cooled area for hotels across a mid-range hotel chain

Recommended indicators

Primary energy demand is not usually reported by accommodation enterprises, but could provide a useful summary of energy performance that reflects both demand and supply improvement measures, such as the installation of on-site RE sources (section 7.6).

Total primary energy consumption is a function of both final demand and energy sources (Table 7.4). Each unit of electricity consumed may represent primary energy consumption of between less than one and more than four units of primary energy, after accounting for extraction of fuels, conversion efficiencies in power stations, and transmission losses. Often for building primary energy calculations, a ratio of 2.7 is used for electricity (Passivehouse Institute, 2010). Meanwhile, gas is typically attributed a PER of 1.1 (Table 7.4) and RE sources are attributed primary energy ratios of less than 0.2 (see Table 7.32 in section 7.6).

Business sustainability reporting often involves reporting on GHG emissions, ideally based on international standards such as the International GHG Protocol (WRI, 2004). Lifecycle CO_2 eq. factors for different energy carriers are included in Table 7.4. Note that for accurate comparison between on-site fuel combustion and energy from electricity, district heating or renewable sources, **lifecycle** and not direct emissions should be compared. As with primary energy factors, supply-specific CO_2 emission factors for electricity and district heating/cooling may be available from national statistics or energy providers.

Based on the above, a further recommended best practice for accommodation is to calculate and report total primary energy consumption per m^2, accounting for all energy sources, and total energy-related GHG emissions. These can be calculated by multiplying final energy consumption by appropriate PERs and CO_2 emission factors in Table 7.4, but should use supply-specific factors for electricity and district heating/cooling, where these are available from energy providers or national statistics.

Benchmarks of excellence

Two benchmarks of excellence are proposed: (i) a management benchmark; (ii) a performance benchmark. The proposed benchmark of excellence reflecting best management practice is:

BM: implementation of a site-specific energy management plan that includes: (i) sub-metering and benchmarking all major energy-consuming processes; (ii) calculation and reporting of primary energy consumption and energy-related CO_2 emissions.

The European standard for energy management systems (EN 16001) acknowledges that *'organisations will not necessarily have sufficiently comprehensive metering installed, and that introducing it will potentially be costly, time-consuming and disruptive. However, where appropriate, it should have a demonstrable plan for improving the provision of meters.'* This guidance may be used for interpreting the benchmark of excellence for older buildings, SMEs and micro-enterprises.

Based on the performance of 131 mid-range European hotels (Figure 7.7), the following benchmark of excellence is proposed for overall energy performance in existing accommodation buildings:

BM: total final energy consumption ≤180 kWh per m² heated and cooled area and per year.

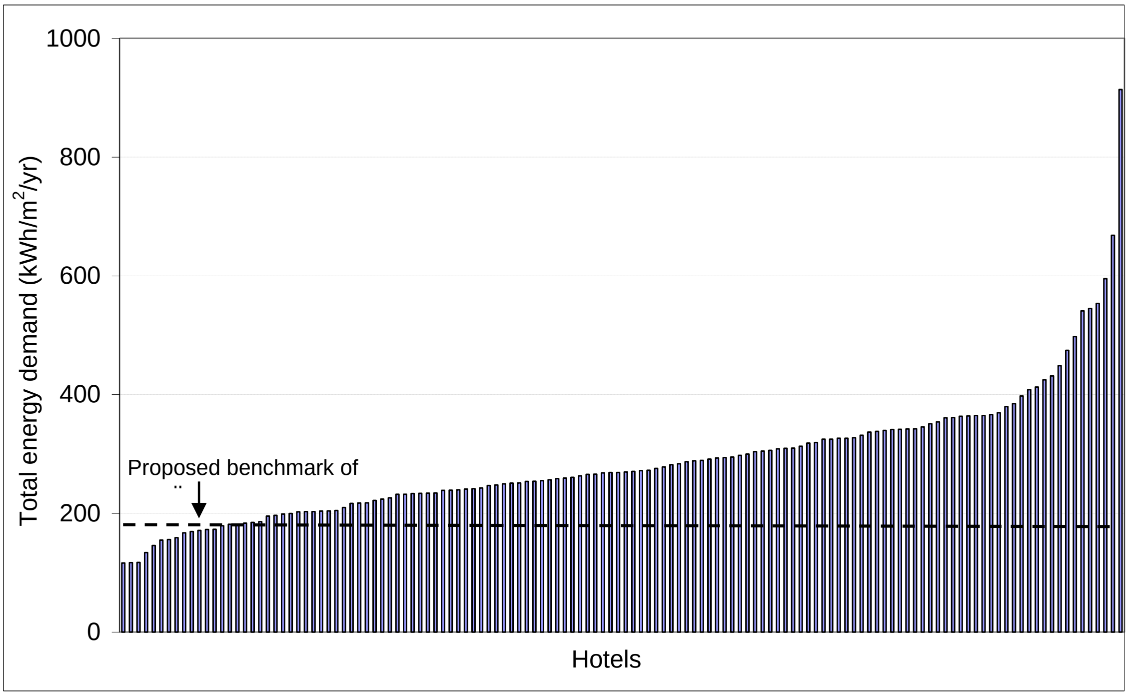
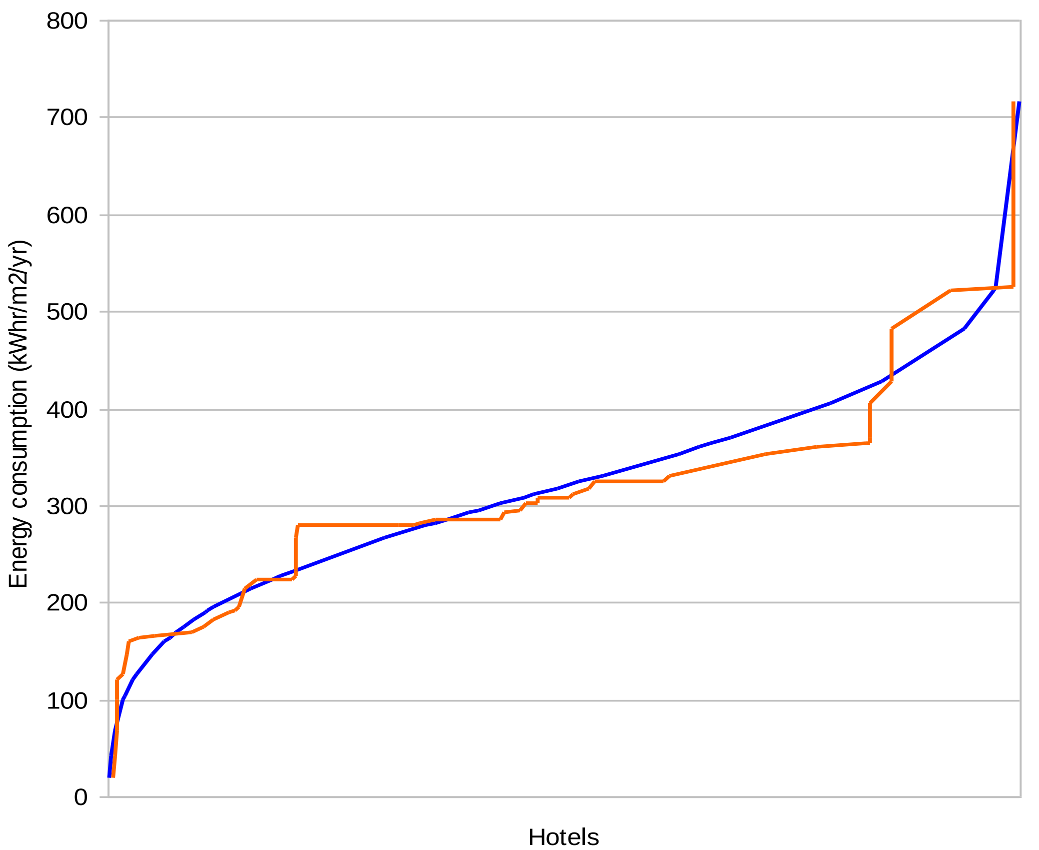


Figure 7.7: Total energy demand per m² heated and cooled area across a mid-range hotel chain, and proposed benchmark of excellence



NB: The orange line represents the data collated from these studies, and the blue line is the line of best fit for a normal distribution with mean 319 kWhr/m^{2}yr and standard deviation of 105 kWhr/m^{2}yr.
Source: HES (2012).

Figure 7.8: Total energy consumption across 1511 hotels, based on data collated in a meta-analysis of 20 studies on European hotel energy consumption

The above benchmark for existing buildings is corroborated by data for 1 511 European hotels collated for the HES project in a meta-analysis of European hotel energy studies, a visual overview of which is presented in Figure 7.8. Those data indicate a very similar performance distribution to the 131 hotels in the mid-range hotel chain (Figure 7.7).

The above benchmark is not particularly challenging for new accommodation buildings, or in buildings where geothermal heating and cooling, or other RE options, are implemented and not accounted for in final consumption data. For example, the Boutiquehotel Stadhalle in Vienna includes a PassiveHouse standard extension, wind turbines and solar PV electricity generation, and reports annual final energy consumption of less than 13 kWh/m^{2}yr (Table 7.11 in section 7.2). Similarly, Crowne Plaza (2011) claim that their Copenhagen Towers hotel consumes less than 43 kWh/m^{2}yr owing to the exploitation of geothermal heating and cooling (section 7.4). Therefore, a separate benchmark of excellence is proposed in section 7.2 for new buildings based on compliance with the exemplary Minergie P and PassiveHouse standards.

Cross-media effects

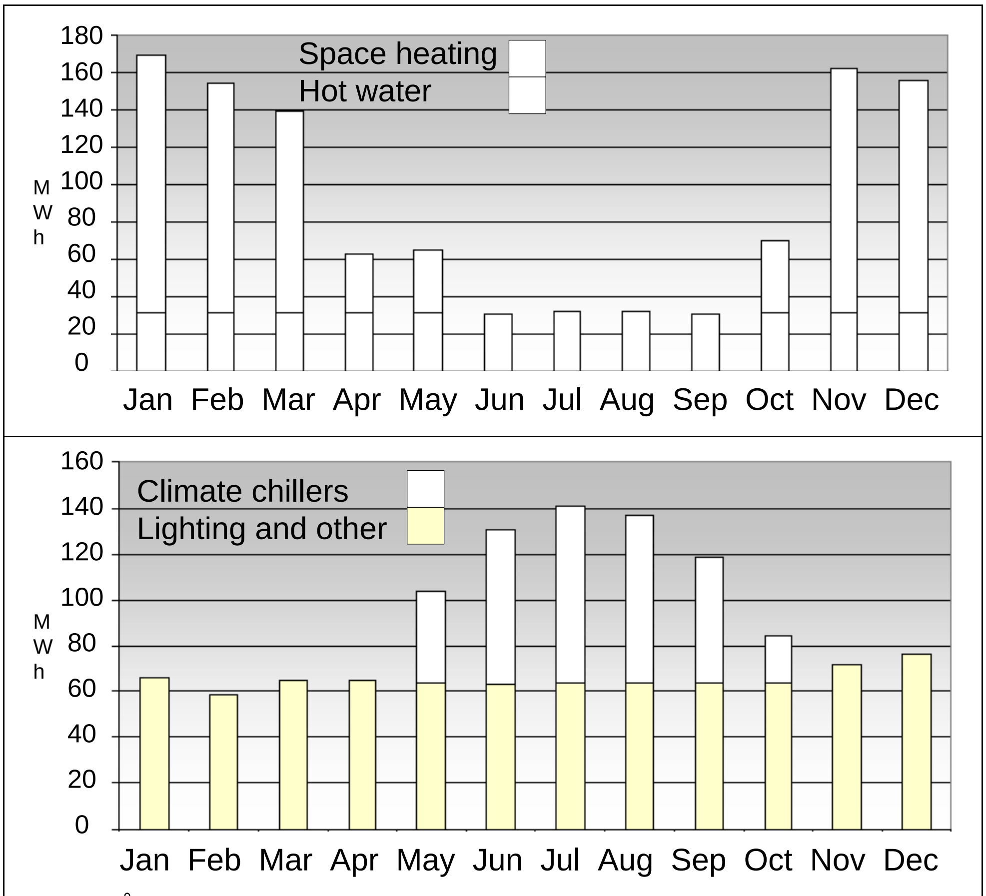
There are no significant cross-media effects associated with energy monitoring and benchmarking.

Operational data

<u>Continuous monitoring</u>

Continuous monitoring assists with the identification of energy-saving options, and, where sub-metering is not possible, may offer insight into consumption for specific processes. Continuous monitoring data may be used to inform the timing of different energy using processes throughout the day, in order to reduce peak demand and shift demand to night-time wherever possible (night-time electricity is often charged at a lower rate, and can have a lower environmental burden than peak load electricity). Gas and electricity suppliers may offer basic continuous monitoring and consumption reports for total electricity or gas consumption free of charge for business customers (e.g. British Gas, 2012). Building Management Systems (BMS) generate more sophisticated continuous monitoring for all sub-metered areas.

Where continuous monitoring is not possible, seasonal and monthly monitoring can offer insight into the demand patterns for different processes, and may indicate opportunities to save energy. As an example, Figure 7.9 displays the monthly load patterns for thermal energy and electrical energy demand in a Greek hotel, divided into four process classes: (i) space heating; (ii) domestic hot water heating; (iii) space cooling; (iv) lighting and other.



Source: ÅF-Energikonsult (2001).

Figure 7.9: Monthly thermal load pattern (above) and electrical load pattern (below) for a Greek hotel

Figure 7.9 highlights the importance of climate in determining seasonal patterns of energy consumption. In winter in Greece, total energy demand is dominated by thermal energy for space heating, whilst in summer in Greece space cooling accounts for almost half of total energy demand. In summer, over 80 % of energy consumption is supplied by electricity. Heating and cooling requirements are associated with the number of heating degree days (HDD) and cooling degree days (CDD), and may be summarised over a year for different locations based on climatic data (Figure 7.10).

According to the EUROSTAT method, HDD are the number of days when the outdoor temperature is lower than 15 °C, multiplied by the number of degrees difference between the mean daily temperature and 18 °C, expressed by the formula:

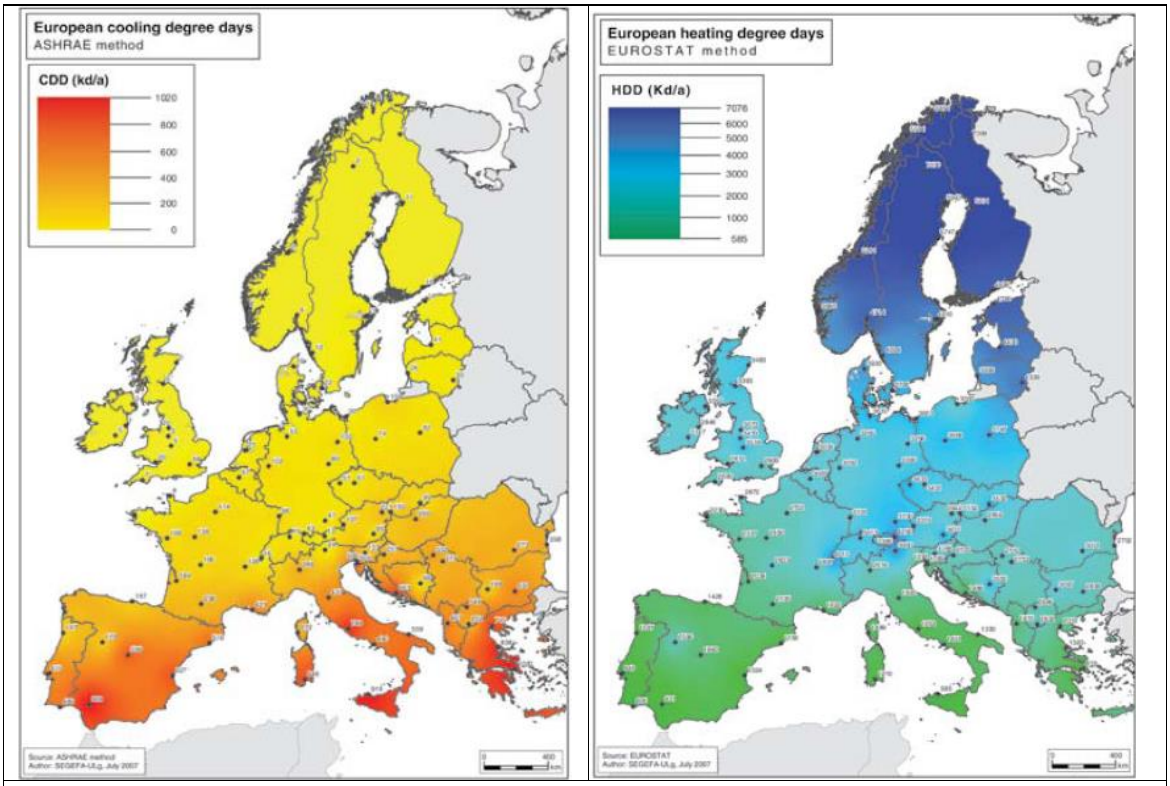
$$HDD = (18–T) \times \Delta t$$

where T is average daily temperature in °C, and Δt is the time in days, and (18 – T) is considered null when the value of T is 15 °C or more.

Cooling degree days can be calculated according to a similar methods, for example that of ASHRAE (ASHRAE, 2009):

$$CDD = (T–18.3) \times \Delta t$$

The base temperature used varies (18.3 °C used in ASHRAE method, 22 °C typically used in the UK). Heating and cooling degree days determine the balance between heating and cooling energy demand, but not necessarily the total amount of energy required for space heating and cooling. Appropriate design features, especially the insulating properties of the building envelope, mitigate against climate influences on heating and cooling demand. This is described in more detail in section 7.2.



Source: Boermans et al. (2006).

Figure 7.10: Spatial variation in cooling degree days (CCD) and heating degree days (HDD) across Europe

Energy sub-metering

Table 7.5 summarises the main areas of energy consumption, and associated types of energy data, throughout accommodation premises. HVAC systems require electricity for ventilation and control, and usually also for cooling, and may use either electricity, delivered fuel combusted onsite or delivered steam for heating. At least, energy consumed for HVAC and domestic hot water (DHW) production should be should be monitored separately from electricity consumed for lighting and other appliances.

Table 7.5: Areas and processes responsible for a high proportion of energy demand in accommodation premises, and data sources for energy consumption

Area	Process	Data sources
Bedrooms	– HVAC – Water heating	– Electricity consumption (sub-metered) – Onsite fuel consumption (natural gas, propane, LPG, heating oil, steam consumption)
Bedrooms	– Lighting – Televisions – Minibars and other appliances	– Electricity consumption (sub-metered)
Kitchen	– Lighting – Cookers – Dishwashers – HVAC – Water heating	– Electricity consumption (sub-metered) – Onsite fuel consumption (natural gas, propane, LPG, heating oil, steam consumption)
Laundry	– Lighting – Washer extractors – Ventilation – Water heating	– Electricity consumption (sub-metered) – Onsite fuel consumption (natural gas, propane, LPG, heating oil, steam consumption)
Pool and spa	– Lighting – Pool and spa processes – HVAC – Water heating	– Electricity consumption (sub-metered) – Onsite fuel consumption (natural gas, propane, LPG, heating oil, steam consumption)

Sub-metering is straightforward and relatively common for electricity. The Savoy hotel in London provides an example of best practice with respect to monitoring. In total, there are 130 sub-meters in the hotel, spanning 12 separate monitoring areas: (i) Simpson's-in-the-Strand restaurant; (ii) mechanical plant; (iii) back-of-house; (iv) front-of-house; (v) main kitchen; (vi) Lincoln kitchen; (vii) Lancaster kitchen; (viii) Beaufort kitchen; (ix) Savoy Grill restaurant; (x) north block rooms; (xi) south block rooms; (xii) lifts. Continuous monitoring data are analysed monthly by a private consultancy, and are used to optimise electricity demand (The Savoy, 2011).

Metering of natural gas by suppliers at the entry to accommodation premises for billing purposes requires calculation of standard units based on temperature and pressure corrections. Sub-metering of natural gas flows to different areas and processes within the premises is not common practice across accommodation establishments, and has traditionally relied upon relatively expensive instrument and piping retrofits. Relatively inexpensive flow meters are now available, for example based on insertion of a tube within the gas pipe to generate a stable flow pattern and connection to a thermal mass flow meter (e.g. Eldridge Products Inc., 2010). Such meters can be installed in gas supply pipelines adjacent to inflows to large gas-consuming appliances (e.g. boilers) or major consumption areas (e.g. kitchens). Similarly for oil, flow meters may be installed in oil supply pipelines immediately prior to appliances such as boilers. The Savoy monitors both electricity and gas consumption separately for each kitchen.

Smaller premises may depend on bottled gas (propane or LPG) for heating and cooking, in which case the number of bottles used over a month or season can be used to estimate consumption.

Maintenance

Correct and regular maintenance of energy-using equipment and distribution systems can prevent significant energy efficiency losses. Important inspection and maintenance measures to prevent energy losses include:

- servicing of all major energy-using equipment in accordance with supplier recommendations
- seasonal adjustment of condenser settings on refrigeration units
- regular cleaning of condensing coils on refrigeration units
- cleaning of all vents and removal of debris or objects restricting air flow
- regular inspection, cleaning and replacement of all filters
- inspection and repair of insulation on air and water pipes.

Gas boilers should be serviced once a year; oil boilers twice a year (Carbon Trust, 2007). Maintenance of air conditioning systems is stipulated by Regulation (EC) No 842/2006 of the European Parliament and of the Council according to the quantity of fluorinated gases contained in the unit, as follows:

- at least once every twelve months for applications containing ≥3 kg fluorinated gases (this shall not apply to equipment with hermetically sealed systems, which are labelled as such and contain less than 6 kg of fluorinated gases);
- at least once every six months for applications containing ≥30 kg fluorinated gases;
- at least once every three months for applications containing ≥300 kg fluorinated gases.

Regular inspection and replacement of air filters is particularly important for the efficient operation of HVAC systems, and on large systems, pressure gauges should be installed to indicate change times.

Staff training and guest advice

Guests wish to relax when staying in tourist accommodation, and often have little knowledge of the energy they are consuming, leading to wasteful actions. Accommodation managers are reluctant to burden guests, but may guide guests with practical tips that can also be applied in their homes, and that are designed not make them feel guilty. Ideally, these tips should be displayed in different formats throughout relevant areas of the accommodation. Hotel Energy Solutions offer communication materials for accommodation guests, providing tips on unplugging unused devices, adjusting thermostats correctly, opening windows appropriately, turning off unnecessary lighting, etc. (HES, 2011).

Building Management Systems

A BMS continuously monitors, records and controls energy (and water) consumption throughout a building via a network of sensors and controllers connected to a central processing unit and interface. One example of a BMS application is the 536-room Scandic Berlin hotel, where a central BMS controls heating and cooling delivered to each room according to: (i) occupancy; (ii) whether or not the window is open; (iii) temperature specified by the guest. All energy for heating and cooling (ultimately provided by hot and cold water from a district heat system) is automatically recorded, but manual backup readings are taken twice per day at the district heating inlet valves as a backup and to check for system malfunctions (Figure 7.11). Electricity consumption throughout the hotel is also continuously monitored. All data are summarised and used to inform an energy management plan, and summary data are forwarded to Scandic head office for compilation of organisation-level environmental performance indicators (see best practice in section 2.1). Energy consumption per guest-night is benchmarked against 1996 performance (Scandic Berlin, 2012).

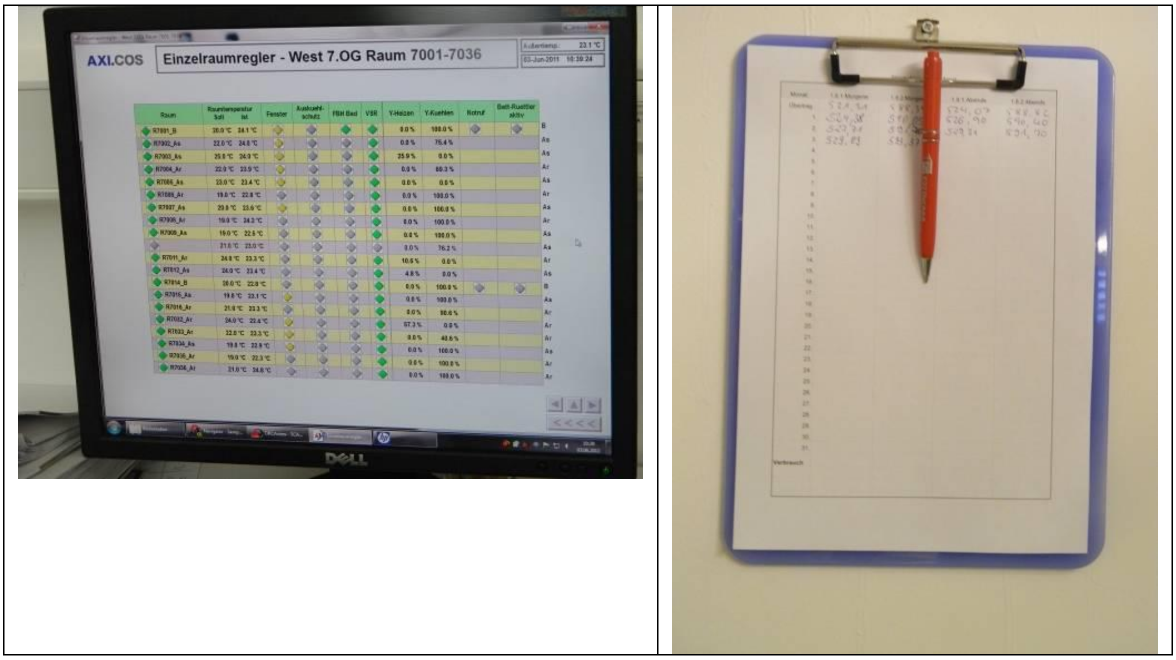


Figure 7.11: A BMS incorporating individual room heating/cooling control is backed up by manual recording of total heating and cooling energy consumption for the 536-room Scandic Berlin hotel

Applicability

Energy monitoring and benchmarking can be performed by all enterprises. With respect to the benchmark for total energy demand, even hotels situated in old buildings can achieve this level of performance. The ten percentile best performing hotels in Figure 7.7 include a range of old and new buildings, recently and not so recently renovated, including one building originally constructed in the 1770s and renovated in the 1980s.

Economics

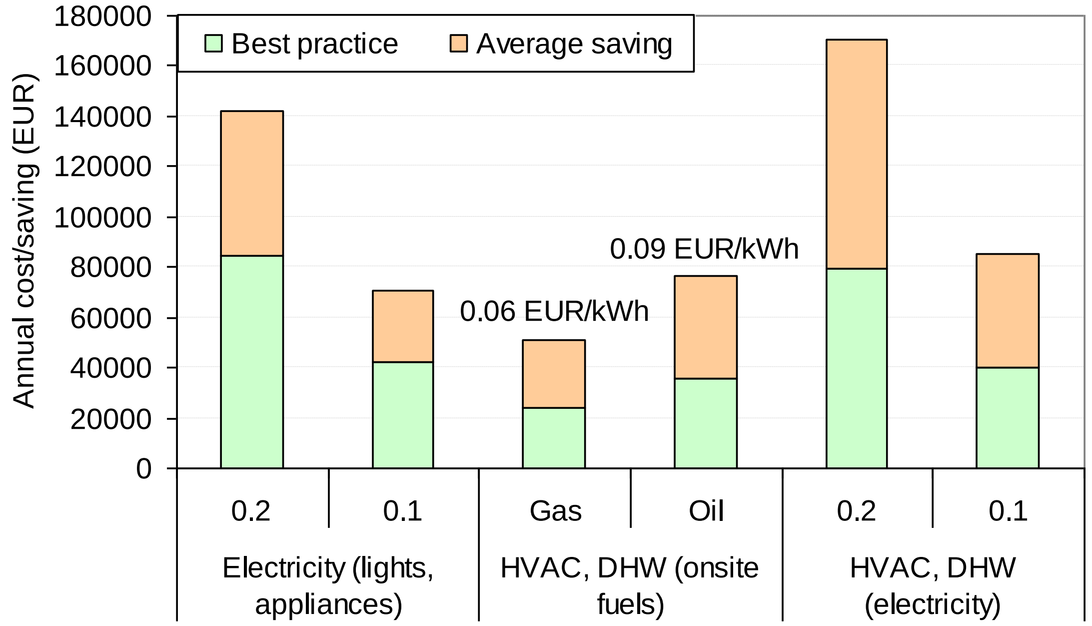
Good energy management is the first and least costly option to reduce energy consumption and reduce associated environmental pressures, such as GHG emissions. It is usually associated with significant economic benefits (Carbon Trust, 2008).

<u>Energy prices</u>

The main sources of energy used in accommodation are electricity, natural gas and heating oil. Delivered energy prices vary considerably across Member States, especially for electricity, the price of which also depends on the magnitude of consumption (Energy EU, 2011). For gas and heating oil, economic implications may be approximated using average prices of 0.06 and 0.09 EUR/kWh, respectively (corresponding to EUR 0.93 per litre for heating oil), but the economic implications of electricity savings are strongly dependent on country- and contract- specific prices.

<u>Potential cost savings</u>

Figure 7.12 presents estimated costs of HVAC energy consumption, and non-HVAC electricity consumption, for a 100-room hotel (5 300 m^2) based on best practice and two electricity prices. Depending on the electricity price and fuel source for HVAC, total savings of between EUR 56 000 and EUR 148 000 per year are possible for a 100-room hotel.



NB: HVAC = Heating, Ventilation, Air Conditioning; DHW = Domestic Hot Water.
Based on average and best practice electricity, and HVAC and DHW demand (see Figure 7.5). Assumes electricity prices of 0.1 and 0.2 EUR/kWh, a gas price of EUR 0.06/kWh and an oil price of 0.93 EUR/L (Energy.EU, 2011).

Figure 7.12: Energy costs for best practice in a 100-room hotel, and savings compared with average performance, for: (i) lighting and appliance electricity consumption, and either (ii) HVAC and DHW provided by oil or gas, or (iii) HVAC and DHW provided by electricity

Reducing peak electricity demand, and increasing the proportion of electricity used at night, can significantly reduce electricity costs. In the UK for example, night-time electricity costs EUR 0.08 per kWh, compared with an average price of EUR 0.11 for large consumers in the UK (The Savoy, 2011; Energy.EU, 2011). Implementation of a comprehensive energy management plan is a prerequisite to realising the savings detailed above.

Regularly servicing boilers can save up to 10 % on annual heating costs (Carbon Trust, 2007). Payback for the insulation of boilers, ducting and piping is usually within a few months.

Implementation costs

Implementation of an energy management plan that includes monitoring and benchmarking will at minimum involve the costs of employee time for data processing. Energy audits are performed by external experts, and may cost hundreds to thousands of euro depending on the size of the premises. Usually, such costs can be paid back within months through implementation of basic efficiencies identified by the audit, and external experts may guarantee a refund on the audit cost if they cannot identify energy savings of at least 10 %.

Investment costs

Investment costs for equipment and specific energy-saving BEMPs are described in subsequent sections. Whilst payback is often relatively short, obtaining the necessary capital can sometimes pose a challenge for micro-, small- and medium-sized enterprises in the current climate of restricted bank lending. Chapter 10, addressing SMEs, contains a brief case study of a Spanish hotel that used an Energy Service Company (ESCO) to implement energy saving measures, thus avoiding the need to find capital for upfront investment.

Driving force for implementation

The main driving force to implement an effective energy monitoring and management plan is to reduce energy consumption, which in turn reduces costs, increases competitiveness, and reduces exposure to energy price volatility.

In addition, reducing energy consumption is the main option available for accommodation managers to reduce direct GHG emissions, fulfilling corporate responsibility and public relations objectives. Visitors are increasingly aware of energy-saving measures implemented in accommodation (HES, 2011).

Reference organisations

Reference organisations for energy sub-metering and reporting include The Savoy, London, and Scandic Hotels.

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7.2 Improved building envelope

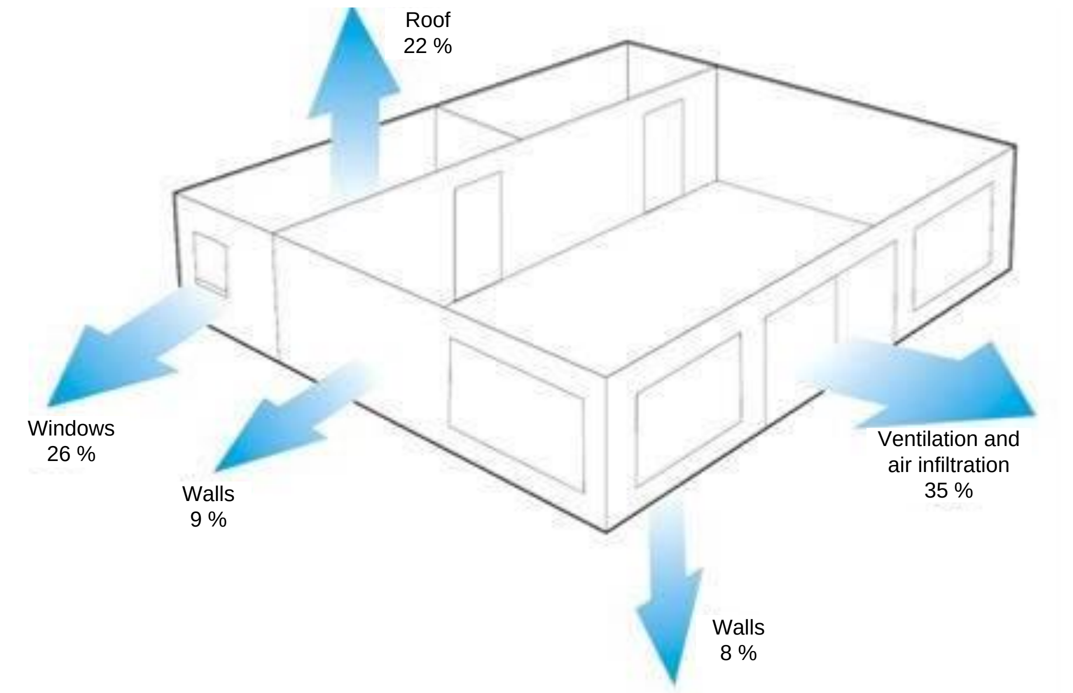
Description

Factors affecting building energy use include the age of the building, time of last major renovation, architecture, structural characteristics, size, systems, facilities and climate conditions. The single most important factor affecting energy consumption for heating and cooling is the quality of the building envelope in terms of insulation and air-tightness. A good quality building envelope can mitigate climatic effects on energy consumption. This is indicated by data relating to energy demand for heating office buildings that show average heating demand of 69 kWh per m^2 and yr in Oslo compared with 138 kWh per m^2 and yr in Milan (Schlenger, 2009).

Figure 7.13 represents origins of energy losses from a typical commercial building, highlighting the major role of ventilation including air infiltration, and for a hotel, highlighting the high heat losses from windows and doors. Optimising building energy performance requires consideration of the building envelope and HVAC system in an integrated manner. The greatest energy savings are realised when building envelope improvements are combined with controlled ventilation systems incorporating heat recovery from exhaust air. HVAC optimisation is described in the subsequent section (section 7.3). Features of the building envelope critical to energy loss are:

- insulation system (roof, walls, floor)
- window glazing (especially number of glazing panes)
- air-tightness (doors, windows, etc.)
- orientation of glazed areas and shading.

Best practice described for this technique goes beyond requirements of legislation and local building codes related to the energy performance of buildings, and also beyond EU Ecolabel criteria on building envelope quality. Further technical information on general aspects of best practice with respect to building envelopes can be found in EC (2011) and EC (2012).



Source: Carbon Trust (2007).

Source: Ecocamping (2011).

Figure 7.13: Sources of energy losses for a typical commercial building envelope (above), and a thermal image indicating areas of high heat loss (yellow and red areas) from a hotel building

Achieved environmental benefit

As presented in Figure 7.5 of the previous section, reducing energy demand for heating and cooling from 160 to 75 kWh/m^2yr could reduce energy consumption by 456 MWh per year for a 100-room hotel with 5 300 m^2 serviced area.

For the example of the Victoria Hotel, below, improvement of the building envelope led to a reduction in energy consumption of between 18 % and 40 % for the relevant part of the building (the 36-room extension). This benefit would have been considerably greater had the building envelope improvement been implemented alongside installation of a centralised HVAC system with heat recovery.

Appropriate environmental indicator

Performance indicators

Technically, energy demand for heating and cooling, expressed as kWh per m^2 per year, is the most appropriate indicator for building envelope performance. Building energy demand can be calculated from models that integrate factors including the U-values of building envelope components, internal heat gains from people and equipment, and characteristics of the HVAC system (e.g. Passivehouse Institute, 2010). Energy demand for heating and cooling may differ from final energy consumption for heating and cooling depending on the heating and cooling sources. For example, for each kWh of final energy consumption of a heat pump, two to three kWh heat may be delivered to the building. Heating and cooling demand performance is a component of some exemplary building energy standards that may be applied to new buildings, referred to below.

For existing accommodation buildings, data on final energy consumption are more readily available than data on energy demand. Therefore, final energy consumption for heating and cooling, expressed in kWh per m^2 and per year, is the most practical and relevant environmental performance indicator for this technique. Where energy consumption specifically for heating and cooling cannot be isolated from other energy consumption (e.g. because electricity used to provide heating and/or cooling is not sub-metered), total final energy consumption per m^2 per year may be used instead.

Exemplary building energy standards

As described in the EMAS technical report for the construction sector (EC, 2012), two exemplary building energy standards stand out as particularly useful indicators of best practice with respect to building energy rating:

- PassiveHouse standard
- Minergie standard.

These standards are applicable to non-residential buildings (Table 7.6), although there is no specific derivation for accommodation buildings. There are examples of accommodation achieving these standards, including the following.

- Minergie existing non-residential building standard: 15 hotels and hostels in Switzerland, including YHA Valbella, YHA Scuol, YHA Zermatt (Hostelling International, 2011; Minergie, 2012);
- Minergie P standard new building: Monte Rosa Hut, Switzerland.
- PassiveHouse new non-residential buildings: Boutiquehotel Stadhalle in Vienna (HES, 2011).

Compliance with these standards is based on modelling of building heating and cooling demand (PassiveHouse standard), and total primary energy consumption considering heating and cooling sources (PassiveHouse, Minergie P).

Table 7.6: Two exemplary building energy standards

Standard	New non-residential buildings	Existing non-residential buildings
PassiveHouse (Passive-On, 2007)	Heating + cooling energy demand **≤15 kWh/m^{2}yr** Total primary energy demand **≤120 kWh/m^{2}yr**	Heating and cooling energy demand **≤25 kWh/m^{2}yr** Total primary energy demand **≤132 kWh/m^{2}yr**
Minergie	HVAC primary energy consumption: Public administration, schools, commercial **≤25 kWh/m^{2}yr** (Restaurants ≤40 kWh/m^{2}yr)	HVAC primary energy consumption: Public administration, schools, commercial **≤55 kWh/m^{2}yr** (Restaurants, ≤ 65 kWh/m^{2}yr)

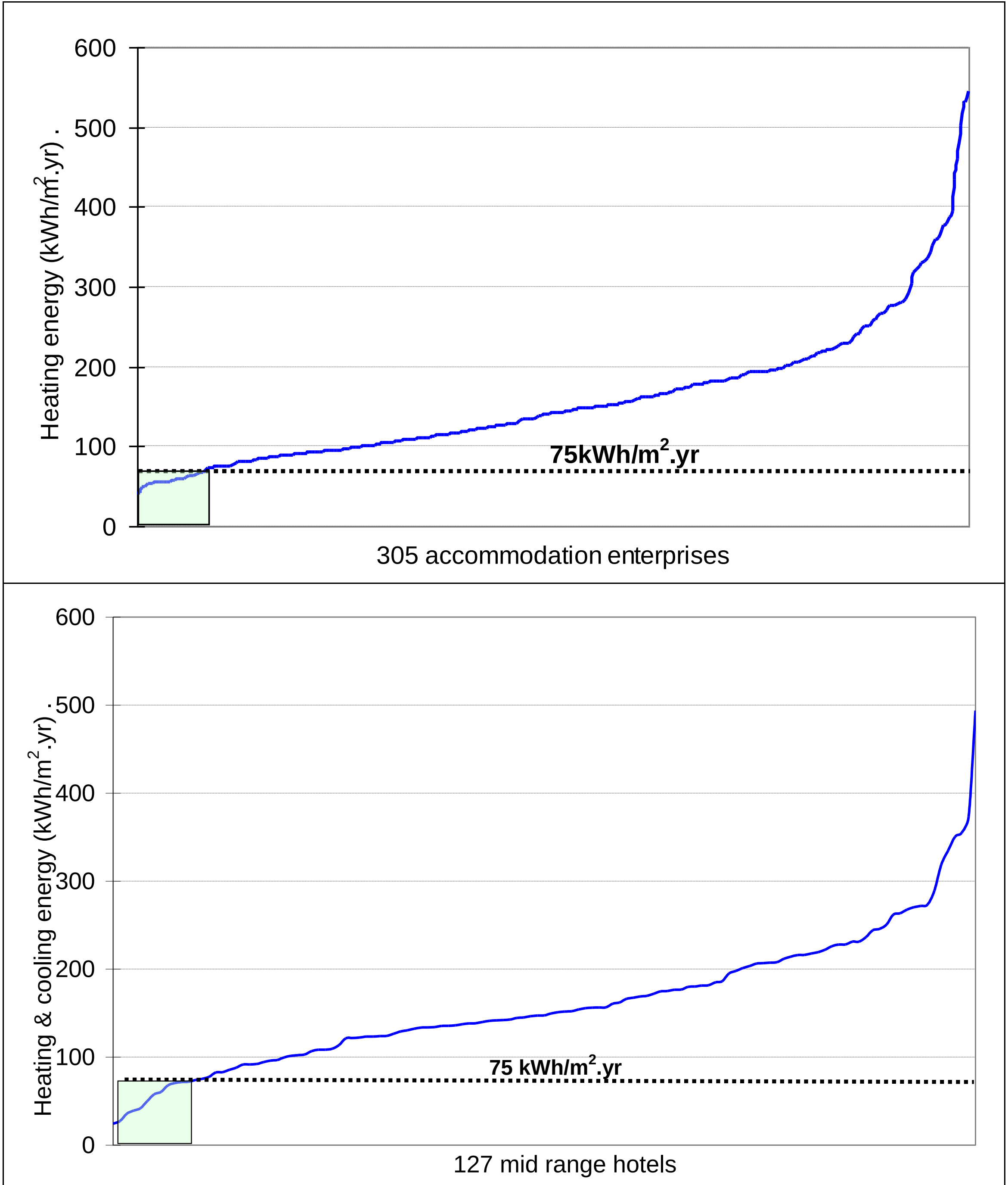
<u>Benchmarks of excellence</u>

Figure 7.14 presents frequency distribution curves for final energy consumption: (i) for heating across 305 German accommodation establishments, ranging from unstarred bed and breakfasts to five star hotels; (ii) for heating and cooling across 127 mid-range hotels. In both cases, the tenth percentile best performers achieve final energy consumption of 75 kWh/m2yr or less. On the basis of the above data, and Table 7.11 under 'Reference organisations', the following benchmark of excellence is proposed.

BM: for existing buildings, final energy consumption for HVAC and water heating ≤75 kWh, or total final energy consumption ≤180 kWh, per m^2 heated and cooled area per year.

A second benchmark of excellence is proposed for new buildings, based on building energy performance equivalent to best practice standards.

BM: the rated energy performance of new buildings conforms with Minergie P or PassiveHouse standards.



NB: For both the above data sets, the ten percentile lowest consumption threshold is 75 kWh/m2yr.

Figure 7.14: Final energy consumption for heating (HVAC and hot water), expressed per m^2 heated and cooled floor area per year, across: (i) 305 German accommodation establishments (top figure); (ii) 127 mid-range hotels (bottom figure)

Cross-media effects

There are no significant cross-media effects of improved building envelopes. The energy consumption for producing insulating products is very low compared to the energy saved over their operational lifetimes.

Operational data

Detailed operational data on building design and retrofit options to minimise energy consumption are described in the technical report for the building and construction sector (EC, 2012). Some operational and technical performance data for the PassiveHouse standard are provided here. The three key components of the PassiveHouse standard are the heat consumption (<15 kWh/m^{2}yr), the total primary energy consumption (<120 kWh/m^{2}yr) and the air leakage rate at 50 Pa (<0.6 h^{-1}). For the design, some recommendations are given by the standard to fulfill the requirements. In Table 7.7, recommended and best practice examples from existing buildings are provided.

Table 7.7: Recommendations and best practices of elements for the PassiveHouse standard

Component	Recommended	Best practice
Insulation (envelope), U-value W/m^{2}K	<0.15	0.05
Thermal bridges	No thermal bridges	No thermal bridges
Glazing, U-value, W/m^{2}K	<0.8	0.5
Window framework without thermal bridge, U-value, W/m^{2}K	<0.8	0.75
Exhaust air heat recovery, efficiency, %	>75	92
Air leakage, %	<3	<1
Electricity demand for ventilation, W/(m^3/h)	<0.45	0.3
Source: Feist et al. (2005).		

The Austrian Ecolabel for tourism requires that the top floor ceiling of each building owned by and/or under the influence of the enterprise to achieve a U-value of 0.30 W/m^{2}K or less, and that, if this is not available, a plan of measures must be prepared in cooperation with an energy technician and implemented to minimise energy losses.

Applicability

Performance benchmarks

The refurbishment of an existing building to reduce final energy consumption to the benchmark level specified above for existing buildings is widely applicable. Achieving Passivehouse or Minergie standards is restricted to new buildings.

Building ownership

One barrier to implementation of building envelope improvements across accommodation is the low level of ownership of host buildings by large hotel and hostel chains (e.g. the Rezidor group does not own any of its hotel buildings: Rezidor, 2011). In such cases, it may or not be possible for the accommodation managers to make changes to the building envelope, depending on lease conditions, but there will be no economic incentives to make the necessary long payback investments.

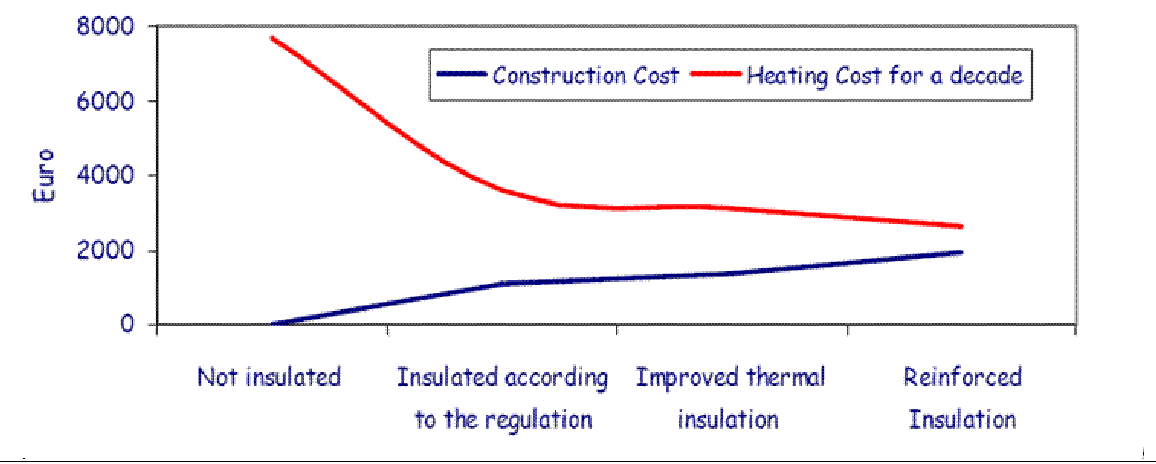
Building envelope improvement may be less important but still relevant for buildings not occupied during the main heating/cooling season (e.g. northern European campsites closed in winter).

Economics

New buildings

Specifying a high quality building envelope prior to initial construction is cost effective. Achieving the PassiveHouse standard for new buildings is associated with an additional building cost of approximately 10 %, and will typically be paid back within five to ten years

(Feist, 2012). Even in Mediterranean climates, reduced heating costs arising from additional insulation justify the higher initial investment (Figure 7.15).



Source: Farrou et al. (2009).

Figure 7.15: Increased construction costs compared with reduced heating costs over ten years for Mediterranean hotels

Retrofitting

Improving an existing building envelope is more expensive, and is only economically viable during planned refurbishments. Often, it is not economically viable to retrofit an existing building to the Passive standard in the absence of external support (e.g. government grants).

The costs for the refurbishment of the extension building of the Hotel Victoria are described in the 'Case Studies' section, below. According to those data, the insulation of the reinforced concrete layer is the most cost efficient aspect of building envelope improvement, followed by the insulation of the outer walls and the flat roof.

Driving forces for implementation

For new buildings, European and member state regulations on minimum energy efficiency levels are a major driving force for more energy efficient building envelopes.

Accommodation managers may specify beyond regulatory requirements in order to further reduce operating (HVAC) costs, and to reduce exposure to future energy price volatility (risk aversion).

Corporate social responsibility and green marketing are other driving forces (building envelope efficiency features may be highly visible to guests).

Case studies

Best Western Premier Hotel Victoria, DE-Freiburg

The refurbishment of an existing hotel can be used to improve the building envelope with regard to the thermal transmissivity of the walls, windows and doors, the roof and the basic ceiling. This approach is demonstrated by the refurbishment of an extension building of the Hotel Victoria in Freiburg, Germany (Figure 7.16). Building envelope upgrades implemented during this retrofit demonstrate best practice, and are close to recommendations to comply with the PassiveHouse standard. However, the overall retrofit project is not regarded as an example of best practice in its totality. A heat recovery ventilation system could not be fitted owing to interior space restrictions, preventing full exploitation of the building envelope improvements. Consequently, final building energy performance falls far short of the PassiveHouse standard.

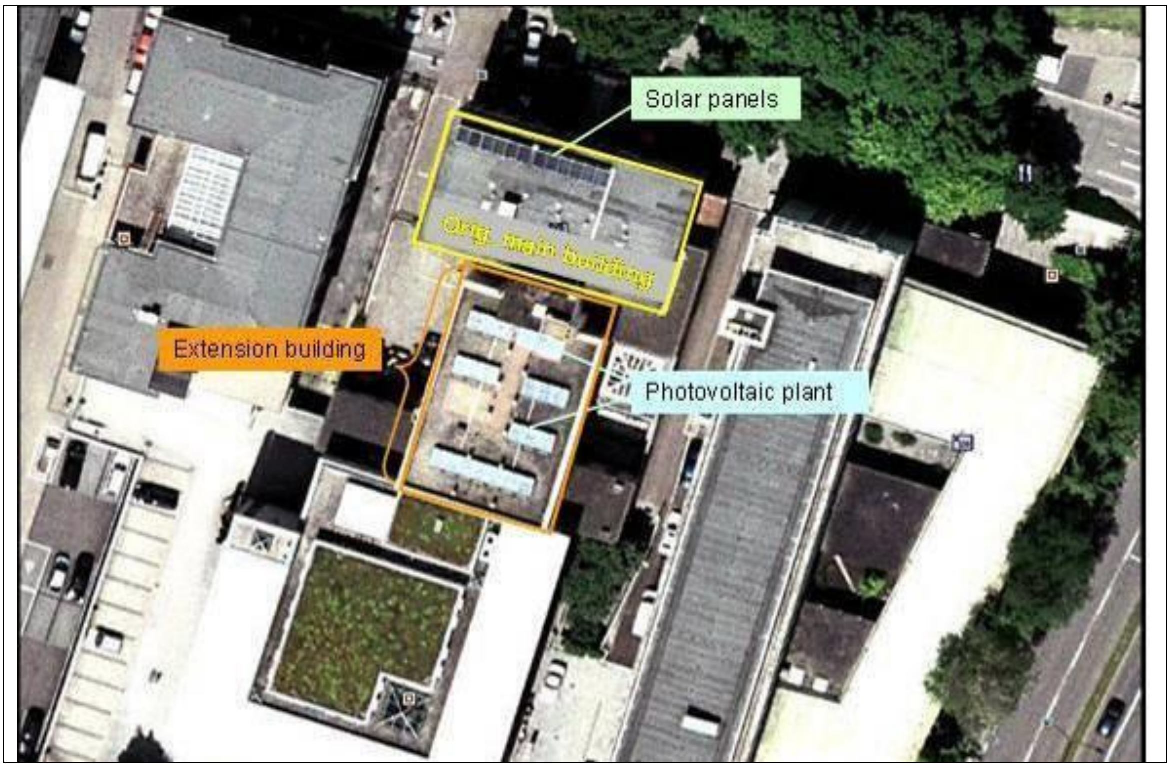


Figure 7.16: Bird's eye view of the Hotel Victoria in Freiburg; the original main building and the retrofitted extension building are indicated

Table 7.8 shows the conductivity, thickness and the calculated u-values of the outer walls, the basic ceiling and the flat roof. The hotel was retrofitted with triple-glazed windows having a u-value of 1.16 W/m^{2}K.

Table 7.8: Conductivity, thickness and the calculated u-values of the outer walls, the basic ceiling and the flat roof

Feature	Components	λ W/mK	Thickness mm	U-value W/m^{2}K
Outer walls	Interior plaster	0.700	15	0.153
	Masonry	0.890	300	
	Thermal insulation	0.040	240	
	Synthetic resin plaster	0.700	5	
Reinforced concrete plate (garage ceiling)	Floor covering	0.000	10	0.129
	Floated screed	1200	35	
	Thermal insulation	0.040	10	
	Impact sound insulation	0.040	10	
	Perlitte layer		20	
	Reinforced concrete layer	2300	300	
	Termal insulation	0.035	240	
Flat roof	Reinforced concrete layer	2	200	0.113
	Thermal insulation	0.035	300	
	Waterproofing	0.170	5	
	Covering		50	

Because of the small height of the corridors, it was not possible to install a controlled ventilation system with heat recovery. Instead, the ventilation system comprises a central ventilator that draws air from the bathrooms, fed by fresh air entering rooms via ventilation devices placed outside (Ufheil et al., 2009). This means that, during cold periods, incoming air is not pre-heated with exhaust air, and thus significantly increases heating requirements. The absence of controlled ventilation with heat recovery prevents the PassiveHouse standard from being achieved, despite the type and thickness of the insulation and the specification of the triple-glazed windows being close to the Passive Standard recommendations.

Figure 7.17 shows the windows and the ventilation devices integrated in the thermal insulation layer. The thermal insulation of the masonry (24 cm) is not installed yet.

Figure 7.17: Refurbishment of the facade by triple-glazed windows, ventilation devices and 24 cm-insulation layer

As a result of the described measures, the energy consumption for heating and hot water preparation for the entire hotel was reduced by 21 % in 2010 and 9 % in 2011, compared with the average heating-degree-day-normalised average over the period 2003 – 2008 before the refurbishment. As only the extension building has been refurbished and the heating system serves the original main building with 30 rooms (1 060 m^2) as well as the extension building with 36 rooms (1 140 m^2), the reduction is about 18 % and 40%, for 2011 and 2010, respectively, for the refurbished building (Hotel Victoria, 2011).

The costs for the refurbishment of the extension building of the Hotel Victoria are compiled in Table 7.9.

Table 7.9: Actual costs for the refurbishment of the extension building of the Hotel Victoria

	actual costs
Construction works	
Stairs	**16.000**
Windows and door	**48.720**
Garage doors and fire doors	**24.740**
Thermal insulation and plaster	**137.570**
Natural stone works	**23.244**
Shutters	**24.470**
Scaffolding	**20.930**
Roof sealing and flashing	**134.972**
Demolishing and construction works	**26.590**
Asbestos removal	**14.723**
Technical works	
HVAC	**204.133**
Chimney works	**18.538**
total	**694.630**

The approach of investment costs/benefit ratio (CBR) has been applied. This ratio is defined as follows:

CBR = additional investment costs / (savings of primary energy x use phase)

The additional costs are calculated in relation to minimum requirements according to the German Energy Efficiency Ordinance. For the different measures, the following CBRs have been calculated for component lifetimes (use phases) of between 18 and 30 years (Table 7.10). According to these numbers, the insulation of the reinforced concrete layer is the most cost efficient, followed by the insulation of the outer walls and the flat roof

Table 7.10: Cost-benefit ratio of different building envelope retrofit components

Components	CBR
Flat roof (300 mm insulation layer)	0.077
Outer walls (240 mm insulation layer)	0.053
Reinforced concrete layer (240 mm insulation	0.027
Windows (replacement of double- by triple-	0.196
Ventilation system	0.177

Other examples

In addition to accommodation enterprises referred to throughout the technique description, some examples of best practice enterprises achieving the applicable benchmarks of excellence are provided by the HES RE case studies for SME hotels (Table 7.11).

Table 7.11: Examples of SME hotels achieving 'excellent' performance

Accommodation	Year built (renovated)	Energy consumption (kWh/m^{2}yr)	Comments
Boutique-hotel Stadhalle, Vienna	2008	12.6	– 82 rooms – Continental climate – 38-room PassiveHouse extension – On-site solar PV and wind turbine electricity generation
Eco Ambient Hotel Elda, Italy	1949 (2007)	40	– 17 rooms – Mountain climate, 800 m altitude – Wooden building with 14 cm fibre Wood insulation – Window U-values 1.00 W/m^{2}K
Hotel Gela, Bulgaria	1956	162	– 15 rooms, 800 m^2 – Mountain climate
Seehotel Wissler, Germany	1970 (2009)	104	– 43 rooms, 6 900 m^2 – EMAS and Viabono labels
Source: HES (2011).			

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7.3 Optimised HVAC systems

Description

According to ITP (2008) 20 – 50 % of energy costs in hotels are attributable to heating, ventilation and air conditioning (HVAC) systems. The primary function of HVAC systems is to control indoor air quality and maintain comfortable temperatures. Humidity control is an important task for larger HVAC systems. The primary components of a basic HVAC system, illustrated in Figure 7.18, are:

- heat source
- cooling source
- heat/cold distribution system
- ventilation system
- control system.

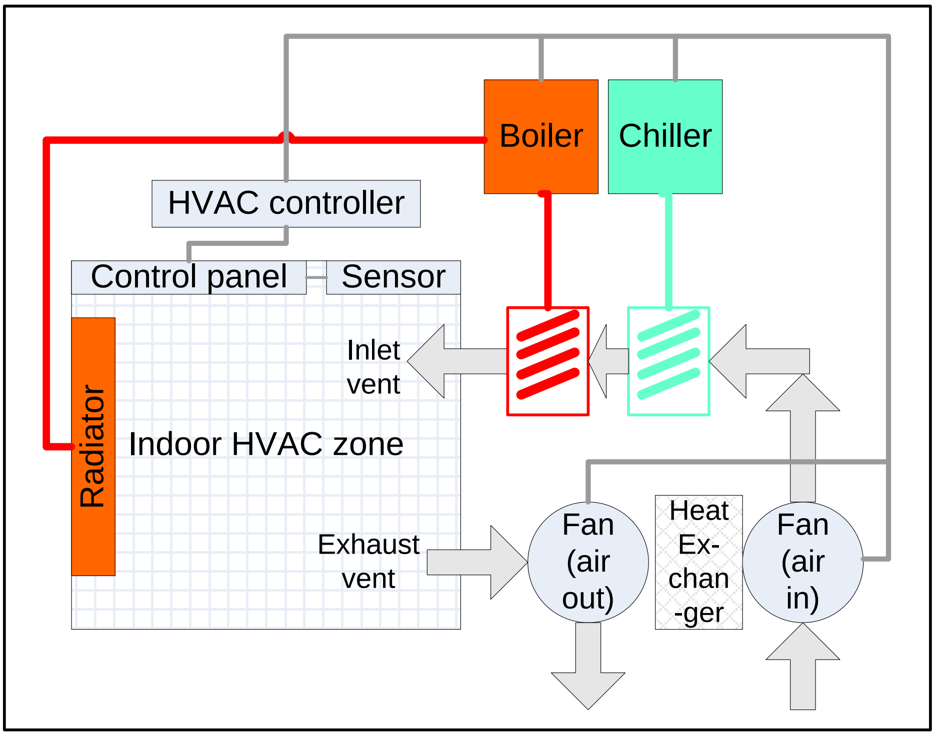


Figure 7.18: Schematic representation of a basic HVAC system

Best practice with respect to specific components of HVAC systems is referred to elsewhere in this chapter. Best practice in heating and cooling is described in section 7.4 and also section 7.6, and some aspects of HVAC control are described in section 7.1. Reducing the electrical load of lighting and appliances (section 7.5), and reducing waste heat in kitchens (section 8.4) and laundries (sections 5.4 and 5.5), can significantly reduce cooling demand and facilitate HVAC optimisation. The focus of this section is on measures to optimise the heat/cold distribution system and the ventilation system, with reference to technology and control options. Table 7.12 summarises best practice measures considered in this BEMP.

Table 7.12: Key measures to reduce the energy consumption of HVAC systems considered in this section

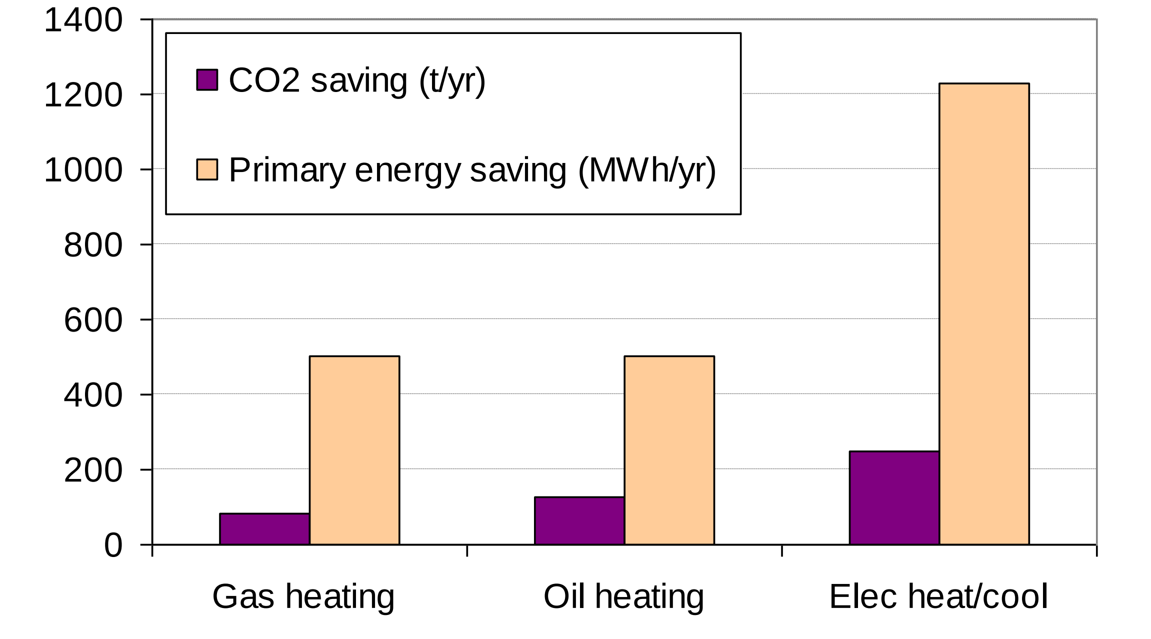
Measure	Description	Applicability
Integrated and optimised HVAC system design	HVAC optimisation requires integration with features of the building envelope and heating and cooling systems. The design and control of HVAC systems should aim to achieve comfortable and hygienic indoor conditions with minimal energy input according to the parameters determined by the aforementioned features. Key aspects of good system design are: – specification of an efficient and appropriately sized heating/cooling source in relation to demand determined by the building envelope, climate and internal heat gains; – heat/cold distribution system sized in accordance with the quantity of heating or cooling to be delivered, and the optimal delivery temperature (e.g. geothermal heating systems work most efficiently with lower distribution temperatures, necessitating large radiative surface areas); – ventilation system designed according to space usage, anticipated occupancy and contaminant generation; – ducting should be within the conditioned envelope, sealed, insulated and with a vapour barrier (above ceilings and outdoors), of sufficient capacity, and without sharp bends or other flow restrictions.	New buildings, major renovation
Ventilation control with heat recovery	As shown in Figure 7.13 in section 7.2, ventilation is responsible for 35 % of heat loss from a typical building. Best practice with respect to ventilation is to: – at least control ventilation rates according to occupancy profiles across different zones; – regulate ventilation according to demand based on monitoring of indoor CO_2 concentrations using sensors (within limits established by various national regulations regarding minimum air exchange rates in commercial buildings); – recover heat from exhaust ventilation by passing it through a heat exchanger with incoming ventilation air.	All buildings with centralised mechanical ventilation
Zoned HVAC control	Individual rooms and various areas within accommodation buildings have different heating and cooling requirements at different times. Every one degree in reduced heating or cooling can reduce HVAC energy consumption by 8 % (Carbon Trust, 2011). Various options exist to implement zoned control of HVAC depending on system complexity: – the HVAC system can be divided into separate zones, including individual guest rooms, that can be controlled remotely (e.g. through BMS) or manually, and zones can be shut off when not required using shut-off valves; – at a basic level, temperature and ventilation can be controlled manually, with timers, or via thermostatic radiator valves in each zone; – in buildings with a BMS, continuous and independent control of HAVC across all zones is possible, based on temperature, CO_2 and/or other air-quality sensors; – for rooms, control of HVAC according to occupancy and open windows is possible using key-card activation and window sensors (see also electrical appliance control: section 7.5).	All buildings

Use of free and evaporative cooling	Ventilation with outdoor air may be sufficient to maintain comfortable indoor air temperatures, and to increase daytime heat absorption by buildings in summer, whilst evaporative cooling can enhance the efficiency of compressors and can be used to cool incoming ventilation air. Key aspects include: – installation of openable windows so that natural ventilation with outdoor air may be used at appropriate times (with installation of sensors to deactivate HVAC when windows opened); – use of mechanical ventilation to distribute outdoor air when appropriate (e.g. night-time); – installation of a water spray evaporation system in the path of compressor cooling air in appropriate (warm, dry) climates; – installation of an indirect evaporative cooling system (with heat exchanger) in appropriate climates to cool incoming ventilation air without directly increasing humidity.	All buildings Systems with chiller units (evaporative cooling)
Efficient equipment	There are many individual components within an HVAC system for which efficient models can be selected. Apart from the main heating and cooling components described elsewhere (section 7.4 and 7.6), efficient HVAC components include the items listed below. – Gas- and oil-fired boilers and individual room air-conditioning units do not represent best practice with respect to heating and cooling sources. However, where they are installed, the highest seasonal energy efficiency ratio, for example reflected in an 'A' rated European Energy Label, should be sought for all new appliances. Information should be sought on full and **part load** efficiency. – Variable speed drive motors are electric motors whose speed is controlled via the power supply in accordance with demand, reducing energy consumption by up to 40 % compared with standard motors operating at one (full) speed. – Direct drive pumps and fans require less energy than belt-driven versions. – Pressure-independent control valves ensure the correct rate of flow through cooling and heating systems, irrespective of system pressure variations. Installing these valves at critical points in the HVAC system can reduce energy consumption by facilitating a more accurate control of HVAC systems. – Efficient compressors. Compressors are the main draw of energy for standard cooling systems. It is important to specify the most efficient compressors available. For example, variable speed compressors are more efficient than single-speed compressors for variable load applications. In addition, some newer compressor designs incorporate magnetic bearings instead of lubricating oil, with claimed energy-efficiency benefits of 35 – 50 % (Danfoss, 2012). – Heat recovery from compressors. A significant amount of heat is released by compressors used for cooling, and this can be recovered for DHW heating (see section 8.4).	All buildings
Maintenance	See section 7.1 (energy system) and section 5.1 (hot water system). Of particular importance for ventilation system efficiency is the regular replacement of filters, associated with the following best practice: installation of a filter differential pressure gauge, linked to a monitor and alarm that indicates when a predetermined pressure drop is exceeded.	All buildings
Source: ASHRAE (2009); Carbon Trust (2007; 2011); EC (2011).		

Achieved environmental benefit

As described throughout this BEMP section, many components and aspects of HVAC can be improved in isolation, but ideally in an integrated manner, to achieve energy savings. For example, heat exchangers between outgoing and incoming ventilation air can recover up to 80 % of the heat energy in exhaust air, whilst variable speed drives can typically reduce energy consumption for pumps and fans by 40 %. Reducing heating temperatures by 1 ºC can reduce energy demand for heating by up to 8 %.

When integrated into a fully optimised HVAC system, the sum of these improvements can be high. Figure 7.19 indicates the total primary energy and CO_2 emissions that could be avoided through HVAC optimisation for an average performing 100-room hotel, by reducing HVAC energy consumption from 161 to 75 kWh/m^{2}yr. Avoided primary energy ranges from 501 MWh for gas and oil heating systems, through to 1230 MWh for electric heating and/or cooling systems, whilst avoided CO_2 emissions range from 84 t per year for gas heating systems to 251 t per year for electric heating and/or cooling systems.



NB: Based on the difference between average and best performance levels, for a 100-room 5 300 m^2 hotel (see Figure 7.5, section 7.1).

Figure 7.19: Annual primary energy and CO_2 savings achievable through the implementation of best practice levels of HVAC energy consumption, according to HVAC energy source

Appropriate environmental indicator

<u>Management indicators</u>

The most appropriate environmental indicators relate to actual building energy performance (below), but the following management indicators may also be used to indicate best practice where data are missing.

- Integration of HVAC and building envelope design to optimise building energy performance based on a profile of predicted use and climatic data.
- Implementation of demand-based ventilation control with heat recovery, HVAC zoning, free-cooling and evaporative cooling where appropriate and feasible.
- Selection of energy-efficient HVAC equipment, for example based on EU Energy Label ratings and expert advice.

Performance indicators

Final energy consumption per m^2 and per year for HVAC is the most appropriate performance indicator, applying relevant conversion factors to fuel consumption data such as those proposed in Table 7.4 (section 7.1). High performance may be indicated by compliance (certification) with strict building energy-performance standards such as the PassiveHouse and Minergie standards.

Benchmark of excellence

The same benchmarks of excellence proposed for best practice in insulating the building envelope (section 7.2) also apply here, i.e.:

BM: for existing buildings, final energy consumption for HVAC and water heating ≤75 kWh, or total final energy consumption ≤180 kWh, per m^2 heated and cooled area per year.

A second benchmark of excellence is proposed for new buildings, based on building energy performance equivalent to best practice standards.

BM: the rated energy performance of new buildings conforms with Minergie P or PassiveHouse standards.

Cross-media effects

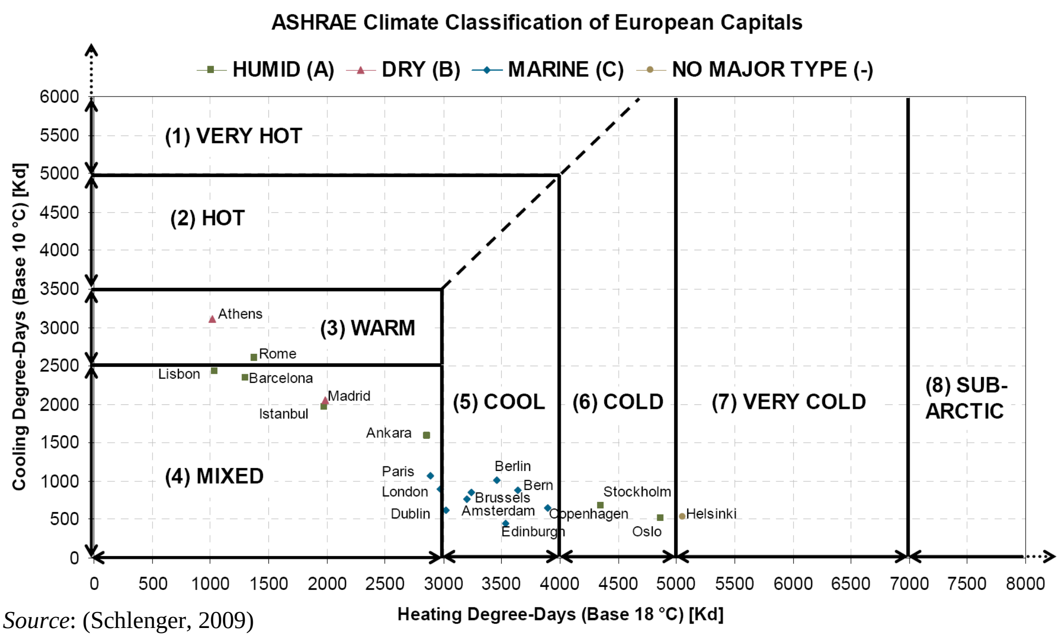
Optimisation of HVAC systems is associated with few significant cross-media effects. Appropriate ventilation control should avoid any indoor air-quality problems potentially arising from lower air exchange rates. Evaporative cooling can require large quantities of water.

Operational data

System design

In the first instance, features of the climate and building envelope should be used to determine basic HVAC system requirements, and features such as the types and capacities of heating and cooling systems and the type of ventilation system. Optimum building design differs across Europe according to climate, although high levels of insulation and air-tightness are important to minimise HVAC energy requirements everywhere. However, the balance between heating and cooling energy demand varies considerably depending on climate, which can be classified into zones across Europe according to the average number of HDD and CDD (Figure 7.20).

The moisture content of outdoor air is an important consideration for HVAC specifications, and indoor relative humidity should not exceed 60 %. For cooling requirements, the sensible and latent loads required to cool outdoor air to specified indoor dry-bulb and dew-point temperature should be included in load calculations (ASHRAE, 2009). When calculating heating and cooling demand, safety factors should be applied cautiously to avoid excess capacities.



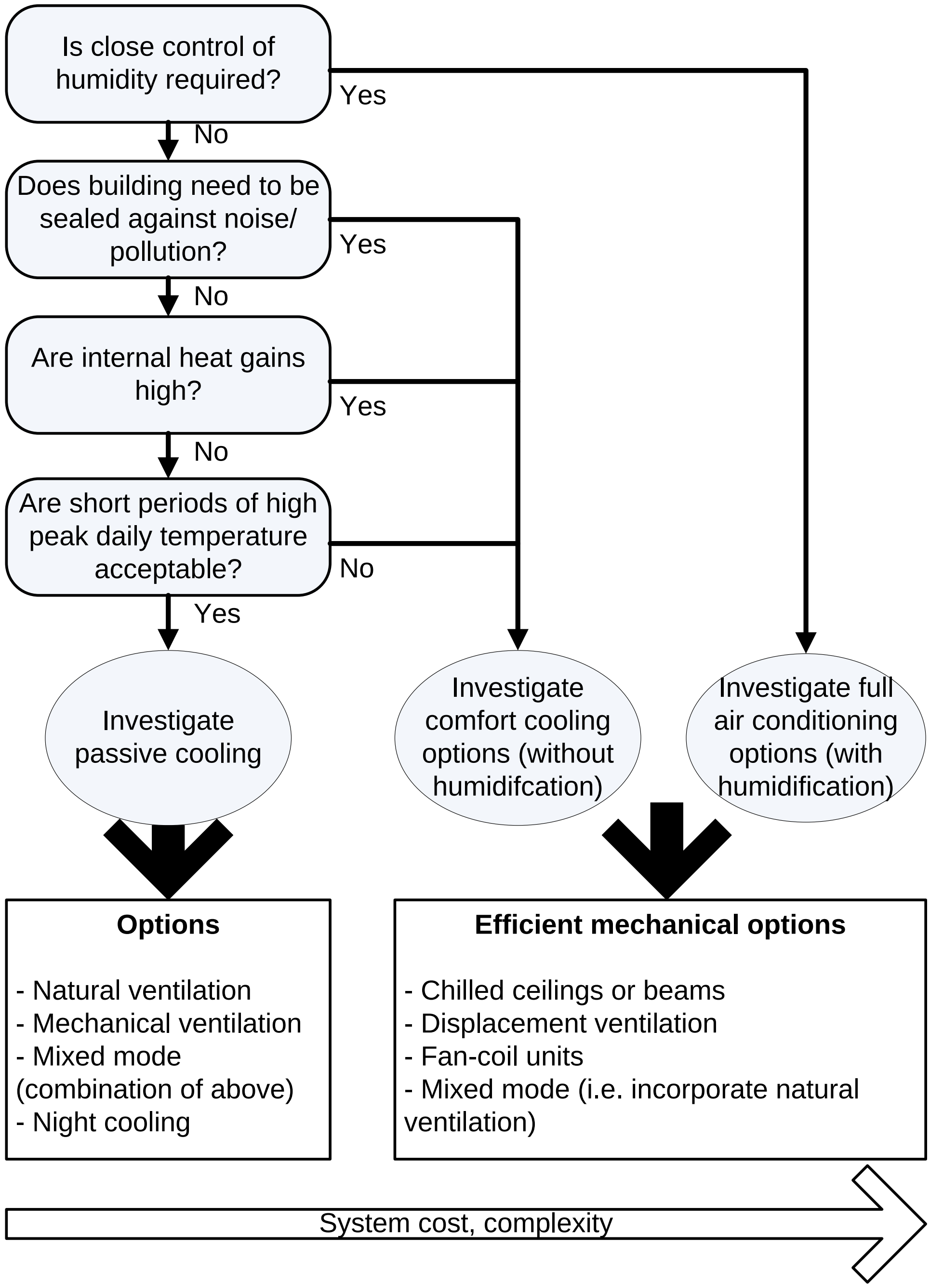
Source: (Schlenger, 2009)

Figure 7.20: Climate classification of European capitals

Figure 7.21 provides an example of factors used to decide on the type of ventilation and cooling system to install. In addition to climatic factors, additional important considerations are whether the building envelope is sealed, the quantity of heat gains from solar radiation through glazed areas and internal devices, and the acceptable peak temperature. Overall internal heat gain can be high in accommodation buildings owing to a typically high occupancy rate, a large number of electrical appliances such as televisions, and the presence of specific equipment with very high heat output in kitchens and laundry areas. It is essential that internal heat gain be considered in HVAC design, to ensure adequate ventilation and cooling rates, and to avoid excessive heating capacity. Heating system capacities should be calculated carefully based on building and climate factors, but Table 7.13 provides some indicative values for a selection of building types.

Table 7.13: Typical specific heating demand across a selection of building types

Building	Heating demand (W/m^2)
Old building with standard (at the time) insulation	75 – 100
New building with good insulation	50
Low energy house, new building	40
PassiveHouse	10
Source: Ochsner (2008).	



Source: Derived from Carbon Trust (2011).

Figure 7.21: Important factors to consider when designing the ventilation and cooling system

Heat and cold distribution

When deciding on the distribution system one key decision is whether the system should be air- or water- based. Hydronic systems are more efficient, but air-based systems may utilise existing ductwork and air handlers, and may thus be the preferred option for retrofits. For air-based systems, supply temperatures of 10 – 15 °C for cooling and 30 – 50 °C for heating are required. For water-based systems, there is a wide range of options (Table 7.14), with supply temperatures ranging from 35 °C or lower for heating and up to 18 °C for cooling if the building envelope is good (maintaining room temperatures at 22 – 26 °C with outdoor temperatures of 32 °C) (Ochsner, 2008). Whichever media is used for distribution, the installation of variable speed motors controlled by frequency converters in relation to demand can significantly reduce energy consumption by distribution pumps and fans.

When using air-source heat pumps, air-based systems can be centralised or decentralised (i.e. operate at the level of the entire hotel or at room level). Centralised systems have the advantage of being more efficient (if appropriate zoned control is implemented), emitting less noise near guests, offering greater control to accommodation operators (e.g. integration with BMS), and having lower rates of refrigerant leakage.

Decisions regarding the distribution system relate directly to the heating and cooling sources, as there is a wide variation in the operating temperature of different distribution systems (Table 7.14), with implications for the suitability and operating efficiency of different heating and cooling systems. Distribution systems with a large surface area, such as under-floor heating or low-temperature radiators, enable lower heating temperatures and higher cooling temperatures, which in general favour more efficient operation of heating and cooling sources. This is particularly the case for heat pumps that work most efficiently when the temperature differential between the source and destination is low (section 7.4). There are also benefits for wood boilers that may be operated continuously at low temperature, reducing start-up emissions (section 7.6).

Table 7.14: Delivery temperatures for different types of heat distribution system

Distribution system	Delivery temp. (°C)
Space cooling (chilled water)	5 – 8
Space cooling (cooled air)	10 – 15
Warm air heating	30 – 50
Warm water floor heating	30 – 50
Warm water radiators (low temperature)	45 – 55
Warm water radiators (forced convection)	55 – 70
Warm water radiators (free convection)	60 – 90
Source: Heat Pump Centre (2012).	

<u>Temperature control</u>

Careful temperature control to avoid excessive heating or cooling can save a considerable amount of energy (8 % per 1 ºC avoided temperature change). Zoning of the building and HVAC system facilitates precise temperature control for the different demands of different zones (Table 7.15).

Table 7.15: Recommended temperature settings for accommodation zones in a cool climate

Zone	Temperature (ºC)
Bars, lounge areas	20 – 22
Guest bedrooms	19 – 21
Guest bathrooms	26 – 27
Restaurants and dining areas	22 – 24
Corridors	19 – 21
Kitchens	16 – 18
Laundries	16 – 19
Source: Carbon Trust (2007).	

In addition, setting temperature controls with a gap of around 4 – 5 ºC between the heating and cooling thermostat set points to create a comfortable 'dead band', avoiding simultaneous operation of heating and cooling systems, can save a significant amount of energy (Carbon

Trust, 2011). Temperature sensors should be located in representative positions within each zone, trying to avoid exterior walls.

Ideally, continuous monitoring and control of temperature and ventilation rates across zones can be provided by a BMS, as described in section 7.1. With respect to heating and cooling, BMS can be programmed to manage individual guest room temperature according to a number of modes related to occupancy and rental status. Guests may have full control of temperature when the room is occupied (within system heating and cooling capabilities at the time of operation), whilst the heating and cooling may be shut off for unrented rooms (periodic activation may be desirable to control humidity). Some luxury hotels prefer to maintain the temperature of unoccupied rooms within a narrow range so that the guest's desired temperature may be rapidly reached upon re-entry (The Savoy, 2011).

Ventilation control and heat recovery

For hotels, ASHRAE (2009) recommend minimum air flow rates of 1.1 m^3 per hour per m^2 plus 8.5 – 12.7 m^3 per hour per person. Accordingly, the occupancy profile of the building is a determining factor that must be estimated in advance when designing ventilation systems. However, the occupancy profile of a building varies throughout the day and depend on business patterns, etc. Therefore, the preferred solution to optimise ventilation rates is the installation of a demand control unit that controls the ventilation rate according to sensor readings of CO_2. Sensors should be placed in every major HVAC zone (but not in every room), and may be located in an accessible position within the return air duct to provide a representative reading. It is important to ensure sensors are always calibrated, and certified by the manufacturer to have an error less than 75 ppm (ASHRAE, 2009).

With centralised mechanical ventilation systems, air may be drawn from the building and expelled via one exhaust point, making application of heat recovery through a heat exchanger straightforward. However, some areas within accommodation premises require special attention for ventilation, and may have separate exhaust points. According to hygiene regulations bathrooms require a separate ventilation system that may operate continuously. Exhaust ducting may be diverted to pass through a heat exchanger with incoming ventilation air to minimise energy loss.

Kitchens require high air exchange rates of 15 – 60 changes per hour, and also require separate ventilation systems. Laundries require an air exchange rate of 10 – 15 changes per hour, and produce moist, warm exhaust air with a high energy content that may not pass through the central ventilation systems. Similarly for pool areas, with air exchange rates of 4 – 6 changes per hour. Demand control of ventilation in these areas is important, and there are options to recover this heat to warm incoming ventilation air without the exhaust air passing through the central mechanical ventilation system (see sections 5.4, 5.6 and 8.4).

As for the heat and cold distribution systems, the use of variable speed motors for pumps and fans can significantly reduce energy consumption. The installation of centralised mechanical ventilation systems may not be feasible in existing buildings without such systems.

Maintenance

Details on general maintenance of energy related equipment are provided in section 7.1. In addition, blockages in HVAC systems are common and reduce efficiency. Regular checking and cleaning of filters, fans and air ducts can improve efficiency by up to 60 %. Pressure gauges may be fitted at strategic points within the HVAC system to indicate blockages or dirty filters (Carbon Trust, 2011), including filter differential pressure gauges.

Checklist for HVAC systems

A best practice checklist with respect to HVAC installation and maintenance was compiled for the EMAS technical report for the building and construction sector (EC, 2012). This is repeated in Table 7.25, and readers are referred to EC (2012) for further technical detail on HVAC systems.

Table 7.16: Checklist for aspects and associated improvement actions

Observation	Potential retrofit action
Duct leakage	Add seal ducts: aeroseal/tape/mastic
Bad duct insulation	Add insulation to ducts
Air-flows at registers	Replace registers, open/close dampers, reduce system flow resistance by straightening existing ducts or replacing them with straight runs of new ducts
Low air handler flow	Replace filters, fix duct restrictions, change fan speed, replace fan with a high-efficiency unit, add extra returns in return-restricted systems
Bad filter condition	Replace filter
Incorrect thermostat setting	Raise thermostat in summer and lower it in winter to account for better distribution, mixing and envelope improvements
Spot ventilation	Replace fans if necessary. If possible, remove spot ventilation and use ducts and central ventilation
Spot ventilation: high power consumption	Replace with a higher efficiency unit, remove/reduce duct flow restrictions, clean fan and ducting
Equipment capacity	Replace with correct size
Refrigerant charge	Add/subtract refrigerant
Age and condition of HVAC system	Clean the system and repair damage or replace the system if >15 years old
Location of HVAC system equipment and ducts	Seal and insulate duct locations. If applicable, move system location
Window A/C units	Replace with central unit or improved distribution
Multiple systems/zoning	Ensure correct damper operation, check capacity of each system/zone load calculation
Moisture testing	Improve source control — better venting in sensitive zones, fix flashing/detailing, seal crawlspaces in high humidity climates, replace windows, add insulation to walls, floors and ceiling
Occupant survey – asking customers to report problems	Create moisture-removal strategies; install new windows, change register type, airflow and location to improve mixing/remove drafts, add envelope insulation, etc.
Source: EC (2012).	

Applicability

<u>Building ownership</u>

As with improvements to the building envelope, one major barrier to installation of optimised HVAC systems across accommodation buildings is the low level of ownership of host buildings by large hotel and hostel chains. In such cases, the scope for modification of the HVAC system is limited by lease conditions, and there is no opportunity for accommodation managers to specify fully optimised HVAC systems integrated with the building envelope. However, accommodation managers may consider efficient HVAC characteristics when selecting buildings to rent, and when liaising with building owners over renovations.

<u>Ventilation system control</u>

Based on the case study of the Hotel Victoria retrofit (section 7.2), the retrofitting of a centralised mechanical ventilation system with heat recovery can be difficult in old buildings owing to space restrictions and fire regulations, but such retrofitting is essential to realize benefits associated with building envelope improvements. Regulations stipulating minimum air-exchange rates in some member states may constrain the optimisation of ventilation rates.

Economics

Efficient equipment

Each kWh per day of reduced electricity consumption leads to an annual saving of between EUR 37 and EUR 73. Any price premiums arising from the specification of more energy-efficient equipment at the procurement stage are likely to be paid back relatively quickly.

Replacing older equipment with new efficient equipment during renovation works also leads to short payback times. Danfoss (2012) claim that investment in variable speed drives pays back within one to two years for building applications, whilst investment in pressure independent control valves pays back within six months.

Government incentives

Government schemes may provide subsidies for the installation of energy-efficient equipment. For example, under the UK Enhanced Capital Allowance scheme, companies may deduct the capital cost of energy 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:

- air to air energy recovery
- automatic monitoring and targeting
- compact heat exchangers
- HVAC zone controls
- motors
- pipe-work insulation
- thermal screens
- variable speed drives
- warm air and radiant heaters.

System optimisation

In 1997 – 2000, the 465-room, 31 500 m^2 Scandic Copenhagen hotel replaced the existing undersized air conditioning system that used the environmentally damaging Freon 12 refrigerant with a new correctly sized system that used the natural refrigerant ammonia (Horesta, 2000). The old system was unable to service the whole hotel during periods of peak demand, and it was estimated that a 30 % increase in system capacity would lead to energy savings of 15 000 kWh per year by enabling optimisation of system loading. All refrigeration and freezing needs in the hotel were integrated into the new central system, and the hotel building envelope was simultaneously upgraded during renovation work. Overall energy savings were calculated as 409 000 kWh per year, translating into annual cost savings of almost EUR 41 000 at current electricity prices, and a payback time of only 6 years.

Overall potential cost savings

Figure 7.12 in section 7.1 presents estimated costs of HVAC energy consumption for a 100-room hotel (5 300 m^2), based on average and best practice. Depending on the electricity price and fuel source for HVAC, total savings of between EUR 27 000 and EUR 91 000 per year are possible by optimising HVAC systems to achieve best practice levels of performance in an average 100-room hotel.

Driving force for implementation

The main driving force to optimise HVAC systems is to reduce energy costs and exposure to energy price volatility. In addition, optimised HVAC systems improve guest and staff comfort levels.

Case studies

Scandic Copenhagen

See description under 'Economics', above.

NH Laguna Palace Hotel, Italy

NH Laguna Palace Hotel comprises 384 hotel rooms and a convention centre, and has a total cooling capacity of 3 200 kW provided by decentralised water-to-water compact heat pump units and packaged water-to-air rooftop units (described in section 7.4). A number of best practice measures are incorporated in this HVAC system (Carano, 2010):

- the hotel is divided into separate HVAC zones according to variation in HVAC demand, and zones are served by independent modular water- and air- sourced heat pumps;
- the indoor quality control system is managed by the 'pulsing-activation' of ventilation and heat recovery across separate zones according to CO_2 values detected by the relevant probe;
- heat pump units include built-in heat recovery that increases system efficiency by avoiding the efficiency losses associated with pressure drops arising in separate plate heat exchangers;
- Ventilation is powered by low consumption fans running on direct current motors, with variable electronic control.

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7.4 Efficient applications of heat pumps and geothermal heating/cooling

Description

Heat pumps harness RE, but require significant amounts of electricity to operate, and often involve the use of refrigerants with a high GWP. Therefore, they are considered an option to reduce energy demand, and described in this section separately from section 7.6 where RE options are described. Geothermal cooling is a renewable cooling source that requires small amounts of electricity to operate, but owing to its operational similarity with heat pump applications, it is described in this section.

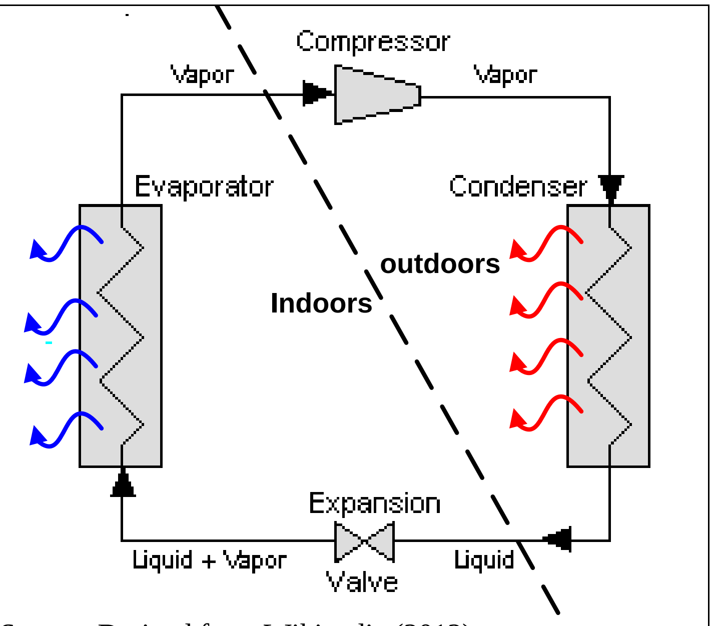
Ecolabel criteria for heat pumps, such as those contained in Commission Decision 2007/742/EC for the award of the EU Ecolabel to heat pump devices, provide useful guidance on characteristics of well performing heat pumps. Selection of equipment awarded the EU Ecolabel (or alternative efficiency labels such as Energy Star) can make an important contribution towards best practice. Reverse heat pumps represent basic air conditioning technology commonly used in accommodation buildings, and in themselves do not represent best practice (although selection of efficient air conditioning units, for example based on the aforementioned labels, represents good practice). Best practice measures for this technique are summarised in Table 7.17, and elaborated using relevant case studies.

Table 7.17: Main heat pump and geothermal energy applications

Measure	Description	Applicability	Best practice example
Geothermal or ground-source heat pumps	Groundwater, or water circulating in buried pipes, is passed through a heat exchanger, then heat upgraded with a heat pump is exchanged to the building HVAC and DHW systems	Winter months, all climates. Sufficient outdoor or suitable geology	Hotel Victoria (retrofit); Crowne Plaza Copenhagen Towers (new)
Geothermal cooling	Cool water pumped from underground is circulated within building HVAC systems in summer	Summer months, moderate and warm climates. Sufficient outdoor or suitable geology	Hotel Victoria (retrofit); Crowne Plaza Copenhagen Towers (water, new)
Use of low GWP coolants	Commission Decision 2007/742/EC for award of the EU Ecolabel to heat pumps prohibits use of coolants with a GWP >1000. Natural refrigerants such as CO_2 and ammonia are increasingly being used, with GWPs 0 – 3 (see section 8.4)	May be specified for any new system	Scandic Copenhagen
Efficient air source heat pumps	Use of efficient air-source heat pumps for HVAC heating and/or cooling, and for DHW. Equipment certified according to, or complying with, Commission Decision 2007/742/EC	Winter months, excluding coldest climates	Where water-source heat pumps impractical or too expensive.

<u>Heat pumps</u>

Heat pumps extract and upgrade low grade renewable heat stored in surrounding air, water, ground, etc., so that it can be circulated within HVAC systems to provide space and water heating. They also work in reverse to extract heat from building HVAC systems and expel it to the surrounding environment. Heat pumps function according to thermodynamic principles underpinning the basic refrigeration cycle (Figure 7.22). The external energy required by heat pumps to transport and upgrade heat from a heat source to the point of heating, and vice versa for cooling, is lower than the amount of heating or cooling energy provided by the heat pump, potentially resulting in significant energy savings compared with conventional heating or cooling systems.



Source: Derived from Wikipedia (2012).

Figure 7.22: Basic heat pump refrigeration cycle used to provide indoor cooling

The efficiency of heat pumps, expressed as a coefficient of performance (COP) for heating or Energy Efficiency Ratio (EER) for cooling, depends on the following critical factors:

- heat exchange media
- heat differential between source and destination
- system design and installation.

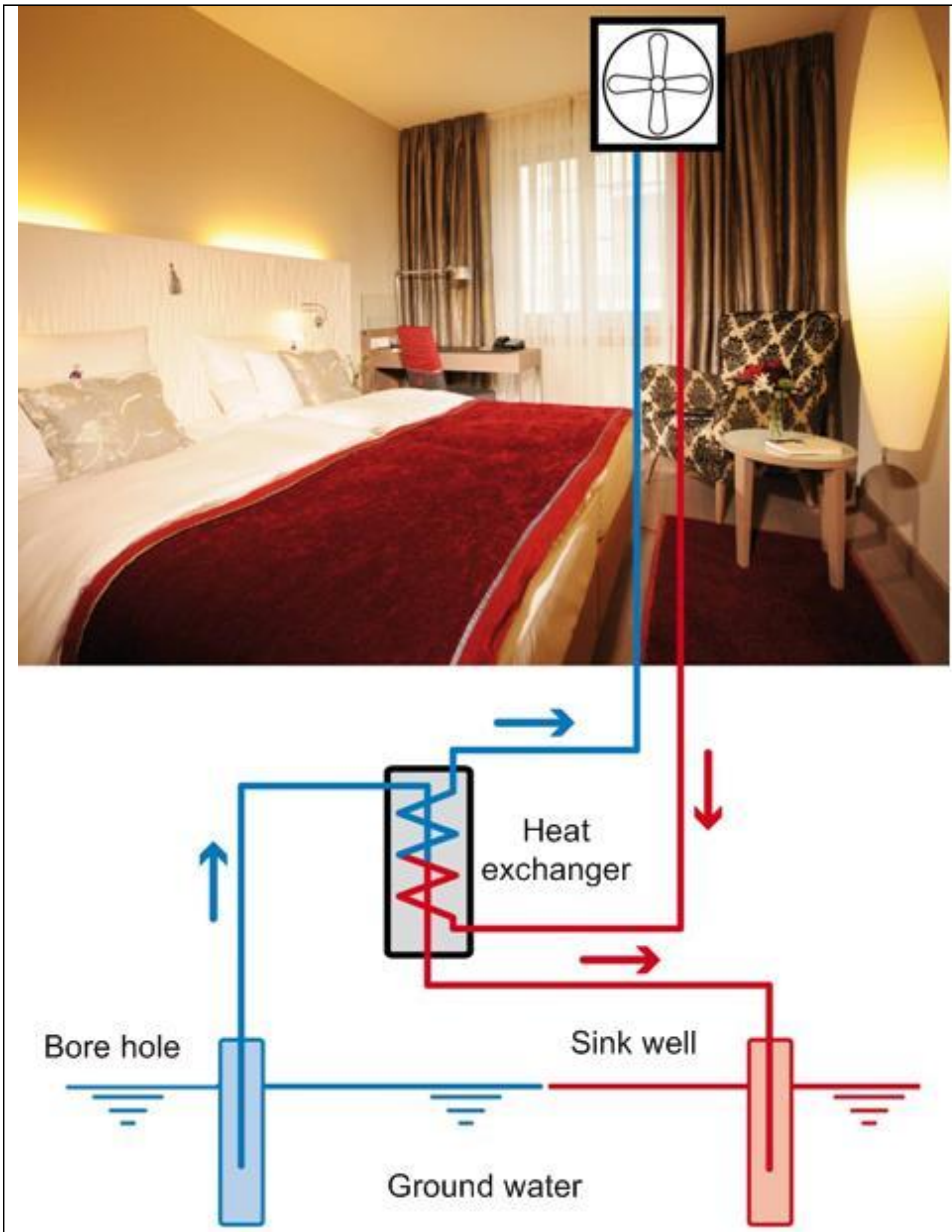
Heat exchange media may be: (i) ambient air (air-source heat pumps); (ii) water, including groundwater (water-source heat pumps); (iii) the ground, close to the surface or at depth (ground-source heat pump). Ground-source heat pumps typically use a heat medium such as brine or a water-glycol mixture, which may either be circulated down through a deep borehole or horizontally through piping installed at shallow depth (1 – 2 m), to exchange heat with the ground. As a rule of thumb the outdoor area required for the latter system is twice the area that requires heating, restricting applicability to smaller accommodation premises.

Typical water-source heat pumps achieve COPs of 4 to 5, compared with COPs of 2 to 3 for typical air-source heat pumps, although performance varies widely from less to more efficient designs and according to operating conditions. The lower the heat differential between the source and destination, the higher the efficiency, and the efficiency of air-source heat pumps decreases dramatically when outdoor temperatures drop below 0 ºC. Seasonal temperature variations are further below ground and in water bodies, making water- or ground-source heat pumps more efficient throughout the year.

Thus, one important aspect of best practice is to utilise ground- or water-source heat pumps where feasible according to space, geological and economic considerations (more expensive than air-source heat pumps). Another important aspect of best practice with respect to heat pump application is installation of a low temperature distribution (HVAC) system, which in turn is most effective where relatively low heat demands have been achieved through a good quality building envelope. Thus, optimised heat pump applications depend on an integrated approach to building design that incorporates a high-quality building envelope (section 7.2) with an HVAC system designed to optimise the efficiency of the heating and cooling source (section 7.3).

Geothermal cooling

Deep groundwater maintains a relatively constant temperature of 4 – 10 ºC throughout the year (IEA, 2012), and provides a useful source of cooling for building HVAC systems. Geothermal cooling is simple to implement, comprising a borehole sufficiently deep to extract cool groundwater, a pumping system and a heat exchanger, as represented in Figure 7.23. Extraction of cool water during summer is sufficient to provide 100 % of cooling demand, and the return of warmed water through a sink well results in localised warming of the groundwater during the summer. This slightly warmer water may then be pumped up in winter to provide heat to the HVAC system via a heat-pump. Examples of this system include the Hotel Victoria in Freiburg, Germany, and the Crowne Plaza Copenhagen Towers hotel in Denmark. In the latter hotel, the system returns four kWh of heating per kWh of electricity consumed to drive the system in heating mode, and eight kWh of cooling per kWh of electricity used to drive the system in cooling mode. Geothermal cooling may also be used to cool water supplied to accommodation via district cooling systems, especially in northern and eastern Europe where such systems are more common.



Source: Hotel Victoria (2011).

Figure 7.23: Schematic presentation of a groundwater cooling system

Ground cooling tubes are an alternative approach for summer cooling that may be suitable in some circumstances, for low-rise premises with sufficient outdoor space and where the earth is easy to excavate. Tubes typically 15 – 50 cm in diameter and tens of metres in length are buried approximately two metres below the ground. Incoming air, or recirculating indoor air in closed loop systems, passes through these tubes, dissipating heat to the surrounding ground (usually a few degrees cooler than the air during summer months, on average). One example of the use of such tubes is the Alma Verde holiday villas in Portugal, where the Coolhouse project (Faber Maunsell, 2004) measured cooling-energy savings of over 95 % for a ground cooling tube system compared with use of conventional air conditioning units (although indoor air temperatures were slightly higher). The main benefit of such systems is a significant reduction in peak daytime indoor temperature, potentially avoiding the need for air-conditioning, but applicability is restricted to specific conditions and such systems are not practical for large buildings.

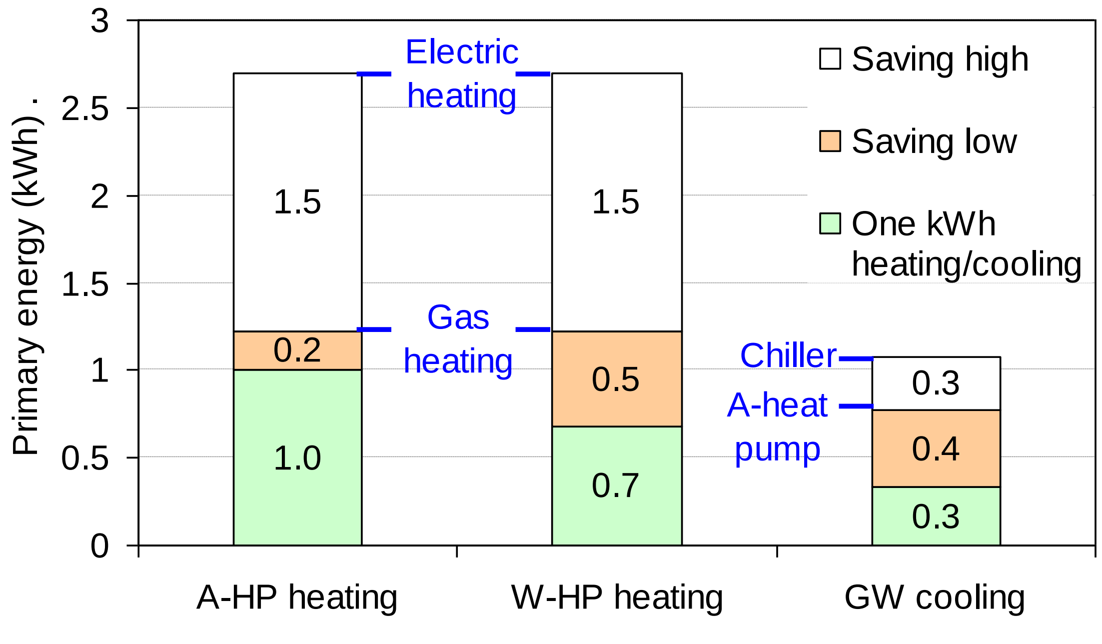
Low GWP refrigerants

Heat pump systems traditionally incorporated refrigerants such as hydrofluorocarbons and other inert compounds with high GWPs many thousands of times higher than CO_2 on a mass basis, and in some cases also high potential to destroy stratospheric ozone. In recent years, various low GWP refrigerants such as the hydrocarbons R1270, R290, R600A, or the natural refrigerants CO_2 and NH_3, have begun to replace traditional refrigerants. These new refrigerants do not damage the ozone layer and have much lower GWPs. A detailed overview of the use of hydrocarbon and natural refrigerants is presented in the EMAS technical report for the retail trade sector (EC, 2011), with respect to retail refrigeration systems.

Achieved environmental benefit

The main environmental benefit of heat pumps and groundwater cooling is a significant reduction in primary energy demand. The extent of this reduction is heavily dependent upon the reference system compared (Figure 7.24), and is determined by the system efficiency (e.g. heat pump COP) and by the primary energy factor of the energy carrier (e.g. 2.7 for electricity: Table 7.4 in section 7.1). The primary energy saving potential of heat pumps and groundwater cooling range from 0.2 to 2.0 kWh per kWh heating or cooling delivered. Despite the high COP of groundwater cooling, the primary energy savings are higher for heat-pump heating owing to the lower efficiency of conventional heating systems.

Primary energy savings for heat pumps and groundwater cooling are reduced owing to their dependence on electricity, which has a high primary energy factor. However, the primary energy factor of electricity varies considerably depending on generating sources, so that primary energy savings arising from heat pumps and groundwater cooling can be close to 100 % if renewable electricity is used to drive the systems.



NB: Assumes A-HP heating and cooling COP values of 2.5 and 3.5, respectively, W-HP heating COP of 4, GW-C and chiller cooling COP values of 8 and 2.5, respectively, gas conversion efficiency of 0.9, and gas and electricity primary energy ratios of 1.1 and 2.7, respectively.

Figure 7.24: Primary energy requirements for 1 kWh heating or cooling delivered by air- and water-source heat pumps (A-HP and W-HP) and groundwater cooling (GW-C), and savings compared with conventional heating and cooling sources

Application of groundwater heating and cooling, with COP and EER values of 4 and 8, respectively, is claimed to result in total final energy consumption of less than 43 kWh per m^2 per year for the Crowne Plaza Copenhagen Towers hotel (CP Copenhagen, 2012).

Appropriate environmental indicator

Currently, there remains a lack of standardisation with regard to measuring the overall system efficiency of heat pump applications at the building level. The project 'SEasonal PErformance factor and Monitoring for heat pump systems in the building sector (SEPEMO-Build)' is intended to develop a common methodology for field measurement of heat pump systems and calculation of SPF in the building sector. However, the efficiency of heat pump units can be measured with respect to energy inputs and outputs.

Heat pump energy efficiency

Heat pump efficiency is calculated as the ratio between the total heat output and the primary energy input. A standardised methodology to calculate heat pump efficiency is provided by EN14511: 2004. The most common way to express the heating efficiency of a heat pump is the COP:

$COP = Q_H/W$
Q_H is the delivered heating energy, expressed in kWh; W is the work energy used to drive the system (usually electricity), expressed in kWh, and including all circulating pumps

The same equation applies for calculating cooling EER, replacing Q_H with with Q_C.

Heat pumps and geothermal cooling usually rely on electricity, with high upstream energy consumption and loss. For comparison with alternative direct heating sources, such as on-site gas boilers, primary energy efficiency (PPE) is a useful indicator. Primary energy efficiency can be calculated accordingly.

$PEE = Q_H / Q_P$
Q_H is the delivered heating energy, kWh; Q_P is the primary energy consumption, in kWh, calculated by multiplying the final energy consumption by the primary energy factor for the relevant energy carrier (see Table 7.4).

COP and EER values may also be expressed as Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER), respectively, specifically representing operational performance averaged over a heating or cooling season.

System global warming potential

Refrigerant leakage makes a significant contribution to the environmental impact of heat pump systems owing to the high global warming potential (GWP) of traditional CHFC refrigerant gases (see Figure 8.27 in section 8.4). Leakage (top-up) rates of refrigerants can be multiplied by their GWP, and added to the carbon footprint of electricity consumed by the heat pump where these data are available, to calculate the annual carbon footprint of the cooling or heating system.

Building energy performance

Ultimately, the efficiency of the heating and cooling system is reflected in the indicators for building total energy consumption, and more specifically where available heating and cooling energy consumption (sections 7.2 and 7.3), expressed as kWh per m^2 heated and cooled area per year.

Benchmark of excellence

German DENA standards define a heat pump to be 'efficient' if it has a HSPF above 3.0 and 'very efficient' if it is above 3.5. A more detailed breakdown of reference performance COP, EER and PER values for different types of heat pumps is provided in the EU Ecolabel criteria for heat pumps (Table 7.18 and Table 7.19). These values are proposed as benchmarks of excellence for specific heat pump types under specified conditions, according to the methodology of EN14511: 2004.

In relation to an EER benchmark for geothermal cooling, in the absence of detailed information, a value of 8 is initially proposed.

In addition, best practice in this technique is to install water-source heat pumps and/or geothermal cooling systems wherever feasible, and to optimise their operation through an HVAC system design that minimises the heat differential between the heat/cool source and delivery temperature (see section 7.3).

BM: water-source heat pumps and/or geothermal heating/cooling is used in preference to conventional heating and cooling systems wherever feasible, and heat pumps comply with EU Ecolabel criteria.

Table 7.18: Minimum heating efficiency requirements for heat pumps according to the EU Ecolabel criteria under various operating conditions

Heat pump type	Min. COP (elec.)	Min. COP (gas)	Min. PER	Outdoor unit (temp., ºC)	Indoor unit (temp, ºC)
Air/air	2.9	1.27	1.16	Inlet DB: 2 Inlet WB: 1	Inlet DB: 20 Inlet WB: 15
Air/water	3.1	1.36	1.24	Inlet DB: 2 Inlet WB: 1	Inlet DB: 30 Inlet WB: 35
Brine/air	3.4	1.49	1.36	Inlet: 0 Outlet: –3	Inlet DB: 20 Inlet WB: 15
Brine/water	4.3	1.89	1.72	Inlet: 0 Outlet: –3	Inlet DB: 30 Inlet WB: 35
Water/water	5.1	2.24	2.04	Inlet: 10 Outlet: 7	Inlet DB: 30 Inlet WB: 35
Water/air	4.7	2.07	1.88	Inlet: 15 Outlet: 12	Inlet DB: 20 Inlet WB: 15

NB: Additional lower COP and PER values are indicated in EU Ecolabel criteria based on higher output temperatures.
DB = dry bulb thermometer, WB = wet bulb thermometer.

Source: EC (2007).

Table 7.19: Minimum cooling efficiency requirements for heat pumps according to the EU Ecolabel criteria under various operating conditions

Heat pump type	Min. EER (elec.)	Min. EER (gas)	Min. PER	Outdoor unit (temp., ºC)	Indoor unit (temp, ºC)
Air/air	3.2	1.4	1.3	Inlet DB: 35 Inlet WB: 24	Inlet DB: 27 Inlet WB: 19
Air/water	2.2	0.97	0.9	Inlet DB: 35 Inlet WB: 24	Inlet DB: 23 Inlet WB: 18
Brine/air	3.3	1.45	1.3	Inlet: 30 Outlet: 35	Inlet DB: 23 Inlet WB: 18
Brine/water	3	1.32	1.2	Inlet: 30 Outlet: 35	Inlet DB: 23 Inlet WB: 18
Water/water	3.2	1.41	1.3	Inlet: 30 Outlet: 35	Inlet DB: 23 Inlet WB: 18
Water/air	4.4	1.93	1.8	Inlet: 30 Outlet: 35	Inlet DB: 27 Inlet WB: 19

NB: Additional lower EER and PER values are indicated in EU Ecolabel criteria based on lower output temperatures.
DB = dry bulb thermometer, WB = wet bulb thermometer.

Source: EC (2007).

The benchmarks of excellence proposed for HVAC and total final energy consumption in sections 7.2 and 7.3 in relation to overall building energy performance for existing hotels are based on data for hotels that mostly do not use heat pumps for heating or cooling. Therefore, application of efficient heat pumps and geothermal cooling should enable enterprises to perform considerably better than those benchmarks.

Cross-media effects

Operation of heat pumps containing hydrofluorocarbon refrigerants contributes to global warming via refrigerant leakage which can somewhat offset GHG emission savings attributable to lower energy consumption. The EU Ecolabel for heat pumps requires use of refrigerants with a GWP of ≤2000, and allows a 15 % reduction in minimum COP, EER and PER values for heat pumps using refrigerants with a GWP of less than 150. Air-source heat pumps also generate some noise.

Operational data

Basic good practice in heat pump system design is provided in EU standard EN *15450 'Heating systems in buildings – Design of heat pump heating systems'*.

Efficient heat pump system design

The decision to install a heat pump, the selection of the preferred type of heat pump, and the specific application of the heat pump will depend largely on local factors and the alternative heating and cooling options available. As referred to under 'Applicability', climate is a critical factor when deciding whether to install air-source heat pumps, but can affect all types of heat pump through its influence on the heating and cooling demand. The key questions that follow are relevant.

- What are the heating and the cooling demands (see section 7.3)?
- What alternative heating and cooling options are available?
- What supply temperatures are required for the existing or planned distribution system (section 7.3)?
- What is the seasonal capacity and temperature of available heat sources/sinks?

Heating and cooling demand should be determined in accordance with relevant national standards, based on modelled data for new or newly renovated buildings or recent data for existing buildings. The concurrency between heating and cooling demands and heat source/sink is an important factor that should be ascertained by using an expert based on a site survey, considering yearly and daily variations that can have a large effect on the exploitability of a heat source/sink. Concurrency is important in relation to the selection of heat source and distribution system, and the installation of a buffer system. Buffer systems can be more easily integrated into water- and ground- source heat pumps operating with water-based distribution systems. Buffer systems enable loads to be balanced and the operating cycles length to be extended.

Calculation of theoretical and estimated actual (e.g. approximately half theoretical) efficiencies for different heat pump types using different heat sources or sinks locally available at specific temperature ranges (see below) can be used to indicate the relative energy and economic performance of different types of heat pump. When comparing alternative heating and cooling options, key aspects include energy consumption and costs as well as lifetime of the existing system (if an existing system is being replaced). The availability of alternative heating and cooling options is a critical and highly site-specific factor. For example, accommodation may be located in an area where district heating and/or district cooling is available, which could significantly reduce the energy and cost benefits of heat pump systems. Table 7.20 lists advantages and disadvantages associated with different types of heat pump.

A critical factor involved in ensuring that the heat pump systems are operating efficiently at high capacity is to install a centralised heat pump system, rather than a decentral system. The highest overall system efficiencies are achieved by installing a heat pump with a capacity slightly below the peak load, combined with a buffer system to regulate peaks and troughs in demand. This is easier to achieve with water-based, rather than air-based, distribution systems given the high heat capacity of water.

Table 7.20: Main advantages and disadvantages of different heat sources

Heat Source	Advantages	Disadvantages
Air	– Readily available and easy to establish – Decentralised systems – Relatively low establishment cost – An auxiliary heating system may function as a backup heating system	– May require auxiliary heating system in winter – High temperature variations and low temperatures in winter – Lower HSPF due to temperature conditions – May require defrosting of evaporation coils – Potential noise emissions (decentralised systems)
Water	– Stable and relatively high temperature – Relatively low temperature difference between source and sink over the year – Higher HSPF due to the temperature conditions	– For groundwater systems: risks of water quality issues, water table issues, risk of polluting or deteriorating the water source – Corrosion due to salts/saline sea water – Relatively high establishment costs – Freezing of evaporation coils (mainly for surface waters or low saline sea water) – Less accessible as heat source, especially in urban areas
Ground and	– Stable and relatively high temperature	– Large outdoor space requirements for horizontal systems + reestablishment

Heat Source	Advantages	Disadvantages
soil	– Relatively low temperature difference between source and sink over the year – Higher HSPF due to the temperature conditions	of outdoor areas, e.g. gardens – Relatively high establishment costs and high costs of vertical systems (but low as percentage of Life-Cycle Costs) – Unknown geological structures or soil thermal properties – Risk of leakage from evaporation coils and soil pollution – Lowering of soil temperature during heating season and prolonged lowering of temperature at the end of the heating season
Source: Dinçer and Kanoglu (2003).		

Temperature differential

The heat pump cycle follows a Carnot Cycle and the theoretical COP_{max} can therefore be calculated by using the temperature difference between the heat source (evaporator) and the heat output (condenser). Thus, the theoretical system efficiency can be calculated based on the input temperature and the output temperature, as presented below for a heating system.

$COP_{max} = T/\Delta T$
T is the temperature of the heat sink (condenser temperature) in degrees Kelvin; ΔT is the temperature difference between the warm and the cool side (evaporator and condenser) in degrees Kelvin .

From the formula it is clear that COP_{max} is inversely proportional to the temperature difference between the heat source/sink and the HVAC supply system operating temperature.

To illustrate the calculation of the COP_{max} we can take two examples where the heat source is groundwater at 10 °C (283 K), the heat distribution system is either a low temperature underfloor heating system requiring supply water at 35 °C (308 K) or a high temperature radiator system requiring supply water at 70 °C (343 K).

Table 7.21: Examples of theoretical COP_{max} values for a low and high temperature distribution system

Low temperature underfloor heating	High temperature radiators
$\Delta T = 308 - 283$ $= 25$ K	$\Delta T = 343 - 283$ $= 60$ K
$COP_{max} = 308\ K / 25\ K$ $= 12.3$	$COP_{max} = 343\ K / 60\ K$ $= 5.7$

The COP_{max} as calculated above is a theoretical value for an ideal process. In reality thermal, mechanical, and electrical losses will impact the COP. The achieved COP can, as a rule of thumb, be taken as half of the Carnot Efficiency.

For DHW heating in summer, the COP is likely to be lower than for HVAC heating in winter because of the higher temperatures required for hot water. Studies of selected heat pumps across

Germany showed average HSPFs of just above 3.0 for the summer and around 4.0 between October and March (EC, 2012).

Applicability

Building ownership

As with building envelope improvement and HVAC optimisation, the installation of heat pump and geothermal systems may not be under direct control of accommodation management owing to the ownership structure of accommodation buildings, in particular for hotel chains. In such cases, this technique may be more applicable to building owners and management companies who decide on heating system installations, although accommodation managers may use information here as a guide for selection of appropriate premises, and to encourage building owners to upgrade the heating and cooling systems.

Air-source heat pumps

Air-source heat pumps are applicable in most conditions, but the heating efficiency of such systems may be limited and require backup when outdoor air temperatures fall significantly below freezing. Thus, applicability may be limited in very cold and sub-arctic climate zones, as displayed in Figure 7.20 (section 7.3).

Ground- and water-source heat pumps

Ground-source heat pumps require either: (i) sufficient outdoor area where extensive digging is possible adjacent to the premises; (ii) appropriate geology below the premises to enable economic drilling of boreholes.

Geothermal cooling with groundwater depends on the presence of suitable hydrogeology (groundwater must be present at an accessible depth) and geology directly below the premises.

Ground cooling tubes

The applicability of ground cooling tubes is limited by a number of factors, including the availability of outdoor space and easy-to-excavate ground. The average daily ground temperature must also be at least a few degrees cooler than the average daily air temperature during summer months, and the system may not work well with very warm humid air that requires dehumidification.

Economics

Installation costs

The costs of installing heat pump systems vary significantly with the type of heat pump, the location, and the selected collection and distribution system, but are typically around twice those of installing conventional heating systems (Geosystems, 2012). Consulted HVAC specialists have provided approximate installation costs of EUR 150 – 300 per kW capacity for the heat pump, and EUR 200 per kW installed capacity for the collection and distribution system (GMCB, 2010).

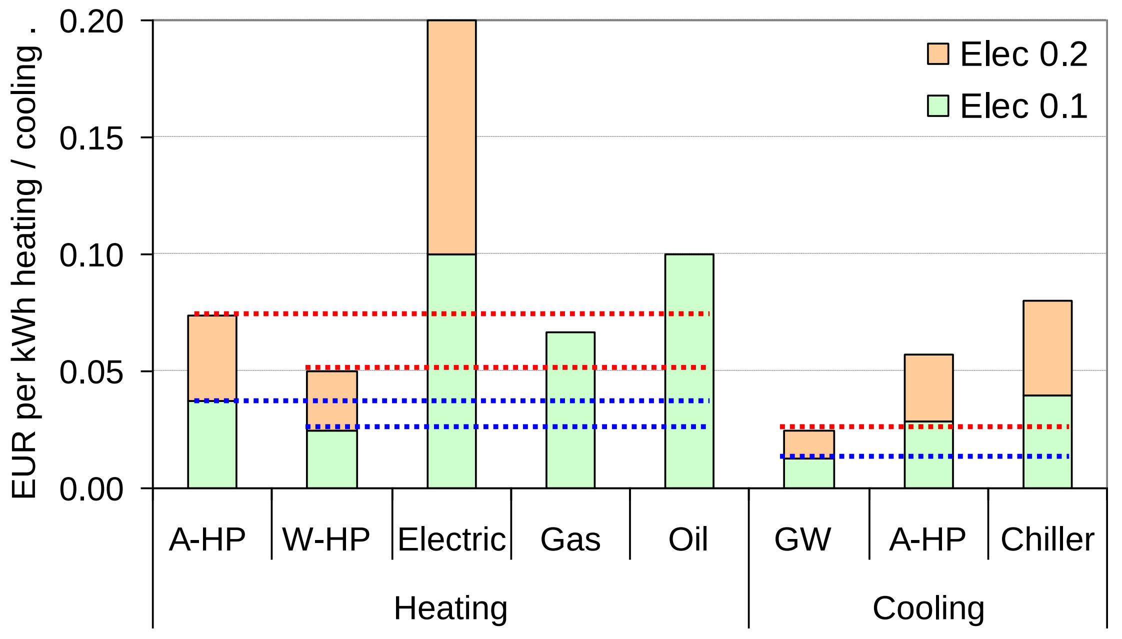
As an example, for a 5 300 m^2 100-room hotel, installing a heat-pump heating system may involve total costs of EUR 106 000, assuming a cost of EUR 400 per kW installed (including distribution system) and installation of 50 W per m^2 (Ochsner, 2008).

Even for more expensive heat pump applications, installation costs represent 10 – 20 % of lifecycle costs. For example, the comprehensive geothermal heating and cooling systems installed at the Crowne Plaza Copenhagen Towers (described below) are estimated to pay back within 6 years.

Government energy efficiency schemes may provide economic incentives for installing heat pumps. Equipment for which purchase costs may be offset against tax under the UK Enhanced Capital Allowance scheme includes heat pumps for space heating.

Operating cost savings

As for previous sections, country- and contract-specific energy prices determine the cost competitiveness and payback times for heat pump applications. Figure 7.25 shows energy costs per kWh of heating and cooling delivered for different systems, and shows the cost advantages of heat pump systems compared with conventional electric resistance, gas and oil heating systems (apart from air-source heat pumps compared with gas when the electricity price is EUR 0.20 per kWh).



NB: Based on efficiency assumptions applied in Figure 7.24, and energy costs of EUR 0.1 – 0.2 per kWh for electricity, EUR 0.06 per kWh for natural gas, and EUR 0.09 per kWh for oil.

Figure 7.25: Energy costs for every kWh of heating and cooling delivered by different systems

The relative differences in energy costs for one kWh of heating or cooling across the different systems are summarised in Table 7.22 and Table 7.23, respectively. Water-sourced heat pumps (i.e. using ground or groundwater) offer the lowest heating cost per kWh, and reduce heating energy costs by 63 % compared with gas and 75 % compared with electric resistance and oil heating (Table 7.22).

Table 7.22: Comparison of input energy costs per unit heat output for different heat sources

	A-HP	W-HP	Electric	Gas	Oil
A-HP	0 %	48 %	-63 %	-44 %	-63 %
W-HP	-33 %	0 %	-75 %	-63 %	-75 %
Electric	170 %	300 %	0 %	50 %	0 %
Gas	80 %	167 %	-33 %	0 %	-33 %
Oil	170 %	300 %	0 %	50 %	0 %

Groundwater cooling systems offer the lowest cooling costs per kWh, and save between 56 % compared with air-source heat pumps and 69 % compared with chiller systems (Table 7.23).

Table 7.23: Comparison of input energy costs per unit cooling output for different cooling sources

	GW	A-HP	Chiller
GW	0 %	-56 %	-69 %
A-HP	129 %	0 %	-29 %
Chiller	220 %	40 %	0 %

Payback times

Payback times are highly dependent on the type of system installed, contract energy prices, and the reference system compared, and should therefore be calculated for specific applications. To develop the example of a geothermal heat pump installed in a 5 300 m^2 100-room hotel described above, annual heating energy costs could be reduced by between EUR 16 563 and EUR 35 554 compared with gas heating, assuming average and best practice heating demand of 161 and 75 kWh/m^2yr, respectively. This compares with an investment cost of EUR 106 000 (see above), of which half may be additional for the geothermal system (Geosystems, 2012), indicating a simple payback period in the region of 1.5 to 3.2 years.

Meanwhile, the same sized hotel in a warm climate with a cooling demand of 75 kWh/m^2yr could reduce annual cooling energy costs by EUR 10 931 by installing a groundwater cooling system in place of a chiller. This would be associated with a simple payback of 4.8 years, assuming the geothermal system costs twice as much as the chiller system to install.

In fact, consideration of payback times can be complex for heat pumps, because they can provide both heating and cooling, and may in some cases be considered an upgrade of cooling system heat pumps that would be required anyway. In this context, the application of heat pumps for heating may be most cost effective in the 'mixed' and 'warm' climate zone of Figure 7.20 (section 7.3) where the heat pumps can also be used in reverse to provide summer cooling, thereby avoiding the costs associated with installing separate heating and cooling systems. In such cases, installation of an efficient air-source heat pump system may pay back immediately, and installation of the most efficient groundwater-based systems may pay back over a number of years before realising large annual energy cost savings.

Online calculation tool

The EU funded project ProHeatPump has developed a basic online calculation tool that can be used to evaluate and compare the following heating options in terms of capital and annual costs:

- ground-source heat pump
- oil boiler
- gas boiler
- direct electric
- electric boiler
- wood boiler
- pellet boiler
- district heat.

Based on information on investment costs, fuel costs, and efficiency the online tool calculates the primary energy demand, annual fuel quantities and costs, annualised capital cost (annuity factor of 0.096 and interest rate of 5 %), and total annual heating cost for the different options. The online tool is available at: http://proheatpump.syneriax.com/calculator.htm?lang=GB

Driving force for implementation

Potentially large reductions in annual energy costs, as described above, represent a major driving force for installing heat pump and geothermal cooling systems. Such systems can also significantly reduce the carbon footprint of accommodation, and facilitate 'carbon neutral' operations as claimed by some accommodation managers in sustainability reporting (e.g. Crowne Plaza, 2011).

With respect to use of low GWP refrigerants, the use of conventional refrigerants with high GWP must be phased out under current regulations.

Case studies

<u>NH Laguna Palace Hotel, Italy</u>

NH Laguna Palace Hotel comprises 384 hotel rooms and a convention centre, and has a total cooling capacity of 3 200 kW provided by decentralised water-to-water compact heat pump units and packaged water-to-air roof-top units (Curano, 2007). These units also provide heating for the hotel, and use river water extracted via a pre-existing underground duct as a stable heat source/sink. The installed system avoids the need for boiler heating of the HVAC system in winter and cooling tower cooling in summer.

High-efficiency water-source heat pumps use refrigeration circuits that include rotary/scroll compressors, 4-way valves, heat exchangers on the demand and source sides (finned coil and plate types), an expansion device (electronic thermostatic valves on larger models), variable flow pumps to reduce energy consumption, electronic controls and automatic safety devices.

A modular decentralised system was chosen because the different zones of the hotel have different needs, in particular the conference centre, rooms and large suites. For example, individual compact water-to-water heat pumps the size of a washing machine are used for each suite. Packaged water-to-air rooftop units supply conditioned air to high attendance zones including the restaurants, meeting rooms and conference centre. The system in this hotel also incorporates aspects of best practice for HVAC optimisation (see section 7.3).

<u>Crowne Plaza Copenhagen Towers, Denmark</u>

Crowne Plaza Copenhagen Towers was built in 2009, has a floor area of 58 000 m^2, and incorporates 366 rooms, a conference room section, kitchen, restaurant and ancillary office building. Geothermal heat pumps were installed based on the aquifer thermal energy storage (ATES) technique that utilise groundwater as a heat source and heat sink. Cold groundwater is pumped up during the summer and directed to the hotel's basement where it cools down the water in the internal HVAC system. The groundwater is then returned into the ground, where the water accumulates heat during the summer for use in the winter. During winter, the water which was heated during the summer is pumped up again and heat energy is sent through two heat pumps which raise the temperature to heat the hotel HVAC system. Table 7.24 summarises some technical characteristics of the system. Frequency converters regulate the speed of heat pumps and HVAC system circulation to optimise energy efficiency (Danfoss, 2010; CP Copenhagen, 2012).

Table 7.24: Key characteristics of the geothermal heating and cooling systems in the Crown Plaza Copenhagen Towers

Function	Heat pump capacity	Peak demand	COP	Supply temp.
Heating	1 183 kW	2 900	4.0	30 – 60 °C
Cooling	1 100 kW	4 100	8.3	12 – 18 °C

The technology realises energy savings of up to 90 % compared with mechanical cooling and up to 60 % compared with traditional heating, and enables the Crowne Plaza Copenhagen Towers to achieve the Danish Low Energy Class 2 standard, i.e. energy consumption <42.6 kWh per m^2 per year. The payback time for such systems is typically between 0 and 6 years.

The Zetter Hotel, Clerkenwell, London

The 59-room Zetter Hotel in Clerkenwell, London, installed seven heat recovery air conditioning units that use groundwater from a 130 m borehole sunk below the hotel. The selection of groundwater cooling not only maximised energy efficiency, but avoided losing valuable roof space to conventional air-source air conditioning units, thus enabling the provision of an additional penthouse suite. The main 5-story atrium provides natural ventilation, whilst each of the condensing units can supply simultaneous cooling and heating for up to 16 individual indoor units. Condensing units are interlinked via the building's water loop, enabling heat recovery from indoor units on the same refrigerant circuit in addition to transferring energy between circuits.

Others

Other examples of geothermal heating and cooling applied in accommodation buildings include:

- Brigittenau Youth Palace, Vienna
- Boutique-hotel Stadhalle, Vienna
- Decoy Country Cottages, Ireland
- Hotel A Quinta da Auga, Spain.

Other best practice examples of heat pump heating in accommodation buildings include:

- Kühlungsborn campsite, Germany (upgrades heat from waste water: section 9.2)
- Krägga Herrgard hotel in Sweden (ground-source heat pumps)
- Alle Ginestre Capri, Italy (air-water heat pump for hot water, and air-air heat pump for HVAC).

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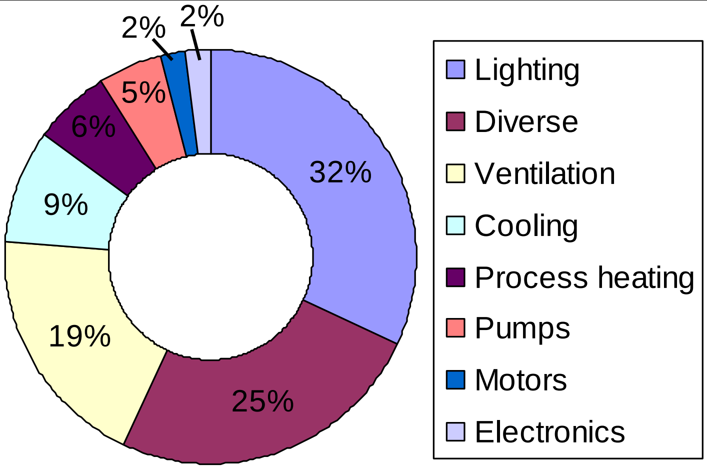
7.5 Efficient lighting and electrical equipment

Description

Lighting is the greatest single source of electricity consumption in accommodations, accounting for between 15 % and 45 % of hotel electricity consumption (Horesta, 2000; ITP, 2008; Leonardo Energy, 2008) (Figure 7.26). Typically, hotels can achieve substantial electricity and financial savings through the installation of modern lighting technology, good building design, and the implementation of intelligent lighting control. Inefficient lighting emits significant quantities of heat which can add significantly to building cooling demand in summer.



Source: Horesta (2000).

Figure 7.26: Electricity consumption in Danish hotels

Figure 7.27 presents modelled data for lighting electricity consumption across different areas of a 65-room luxury hotel using an inefficient traditional lighting system comprising incandescent, halogen and metal halide lamps and without intelligent lighting control. Electricity consumption for lighting in this case would equate to 831 216 kWh per year. Daily consumption is dominated by corridor lighting owing to 24-hour per day operation and high installed capacity of over 100 W/m^2 (representative of some luxury hotels). Permanent lighting in the small lobby area is the second largest draw of electricity, again owing to 24-hour operation and high installed capacity. Meanwhile, room space accounts for most of the heated and cooled areas in hotels, but are the third largest draw on electricity consumption for lighting owing to average use of approximately four hours per day in occupied rooms and an assumed occupancy rate of 80 %. Restaurant and outdoor areas account for significant portions of lighting demand. Outdoor lighting is described in more detail in section 9.2. Data for this hotel following installation of an optimised lighting system are presented in Figure 7.30 under 'Appropriate environmental indicators'.

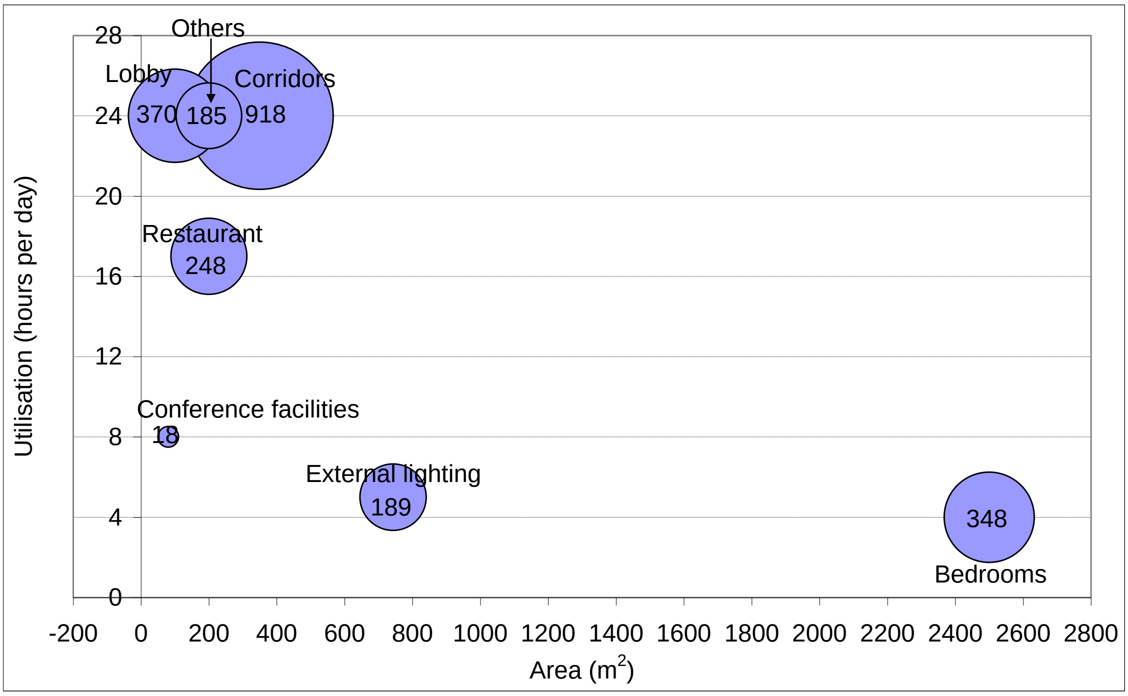


Figure 7.27: The total area, average utilisation rate (hours per day), and energy consumption in kWh per day (bubble size) for different areas in a 65 room hotel using traditional lighting

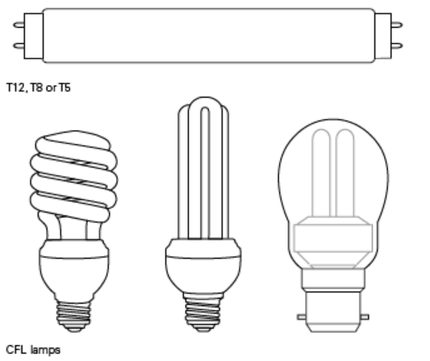
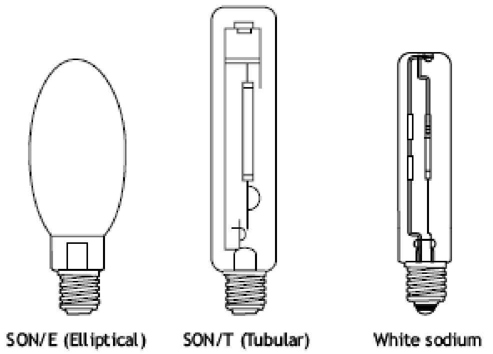
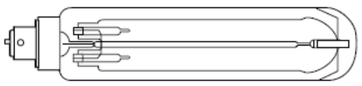
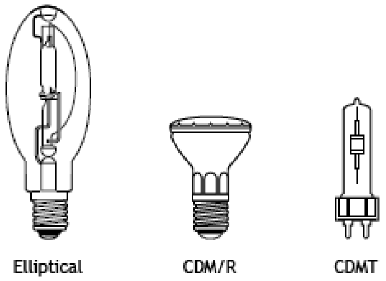
Lamp types

Incandescent lamps have a short lamp lifetime and poor energy efficiency owing to heat radiation in the infrared spectrum, and are consequently being phased out in the EU for most uses, to be replaced by more efficient lamps such as fluorescent lamps, high intensity discharge lamps and light-emitting diodes (LEDs). The main types of lamp suitable for replacing low efficiency incandescent lamps in accommodation are shown in Table 7.25 and Table 7.26, and are summarised below.

- **Gas discharge lamps** include a range of types, of which fluorescent tubes and compact fluorescent lamps (CFL) are the most common. CFLs can replace incandescent lamps directly. Fluorescent tubes that require specific luminaires containing the ballast and control gear. Advantages are that they are energy efficient, have a long lamp lifetime (approximately 8000 hours) and they are a mature technology. Disadvantages are that they make take a while to warm up and produce maximum light output, they are difficult to dim, they have a low Colour Rendering Index (CRI) (see Table 7.27) compared with incandescent lighting, comparatively high production costs, ultraviolet light emissions and they contain hazardous materials (e.g. mercury).

- **Light-emitting diodes (LEDs)** are semiconductor diodes which convert electricity into light. Modern LEDs use a coating which creates a wave shift that enables white light from a single diode, and can be produced relatively cheaply compared with older LEDs. Advantages of LEDs are that they are energy efficient with low heat radiation, have a very long lamp lifetime, start instantly, produce directional light, they can be dimmed, they are safe to dispose of, and they do not produce ultraviolet or infrared emissions. Disadvantages of LEDs are that production costs are high, the technology is still under development, the CRI is lower CRI than incandescent lamps, and the directional light they produce is not always appropriate for ambient lighting.

Table 7.25: Appearance of different types of lamps

Compact fluorescent lamps	High-pressure sodium lamps
	
Low pressure sodium lamp	**Metal halide lamps**
	
Source: Carbon Trust (2010).	

Fluorescent lamps have both significantly higher lighting efficiencies and significantly longer lifetimes compared with incandescent lamps. LED technology is developing rapidly, with high lighting efficiency, long lifetime and greater potential flexibility in colour temperatures. LEDs are already economical despite higher initial costs, and are expected to become the dominant lighting technology for buildings (EC, 2007).

Table 7.26: Specific properties of different types of lighting

Type	Optical spectrum	Nominal efficiency (lumen/W)	Lifetime (hours)	Colour temperature (Kelvin)	Colour	CRI
Incandescent	Continuous	12 – 17	1 000 – 2 500	2700	Warm white	100
Halogen	Continuous	16 – 23	3 000 – 6 000	3200	Warm white	100
Fluorescent	Mercury line + phosphor	52 – 100	8 000 – 20 000	2700 – 5000	White (tinge of green)	15 – 85
Metal halide	Quasi-continuous	50 – 115	6 000 – 20 000	3000 – 4500	Cold white	65 – 93
High-pressure sodium	Broadband	55 – 140	10 000 – 40 000	1800 – 2200	Pinkish orange	0 – 70
Low-pressure sodium	Narrow line	100 – 200	18 000 – 20 000	1800	Yellow, virtually no colour rendering	0
Sulphur	Continuous	80 – 110	15 000 – 20 000	6000	Pale green	79
LED (white)		40 – 100	>35 000 – >50 000	–	White, warm white	75 – 94
Source: Adapted from EC (2009).						

Building design
Optimised building design for lighting goes beyond the installation of energy efficient lamps. Glazed areas with appropriate shading devices may be used to minimise the need for artificial lighting during the daytime in rooms and many public areas. Sky lights may be installed where the climate is suitable, although care must be taken to ensure that energy consumed to compensate for additional heat loss does not exceed the electricity saved for lighting. Sky lights or similar horizontal glazing is not suitable for cold climates. See section 7.2 for more details on glazing within the building envelope. Careful positioning of indoor partitions can also optimise the penetration depth of natural light into the building.

The use of light materials and matt finishes in day-lit areas improves visual comfort, whilst the use of paints and finishes with high surface reflectance in all areas will maximise lighting effectiveness (ASRAE, 2009).

Intelligent lighting system
Design and implementation of an optimised lighting system incorporating intelligent control should include the following elements:

- identification of the specific lighting requirements according to the type of use for the particular space (i.e. zoning);
- selection of the most efficient lamps to deliver the lighting requirements for each zone;
- installation of lighting management control systems, including occupancy sensors, timers, photo sensors, to switch lighting off when not required;
- implementation of a maintenance programme that includes lamp cleaning and sensor testing to ensure optimum performance.

Efficient electrical equipment
The procurement of efficient electrical equipment, especially mini-bar refrigerated cabinets and television sets, can significantly reduce electricity demand. The highest 'A' rated appliances according to the EU Energy Label, or Energy Star labelled appliances, should be selected.

Anther important best practice measure with regard to lighting and room electrical equipment such as televisions is the installation of key-card controllers that cut off the electricity supply to all lighting and equipment when guests are not in the room.

Achieved environmental benefits
Reduced electricity consumption
Installation of low-energy lighting and efficient control systems can lead to considerable reductions in electricity consumption and associated upstream impacts associated with electricity generation – in particular air pollution, climate change and resource depletion. Typically, for every kWh of electricity saved, between 2 and 3 kWh of primary energy and over 0.5 kg CO_2 eq. is saved (DEFRA, 2011). Section 7.1 summarises the magnitiude of electricity savings achievable for a typical 100-room hotel.

Efficient lighting
The magnitude of electricity reductions from efficient lighting is demonstrated by three case studies.

One 65-room luxury hotel saves over 700 000 kWh per year through an efficient lighting system almost entirely comprised of LED and CFL lamps, compared with a reference scenario of traditional lighting (Figure 7.28).

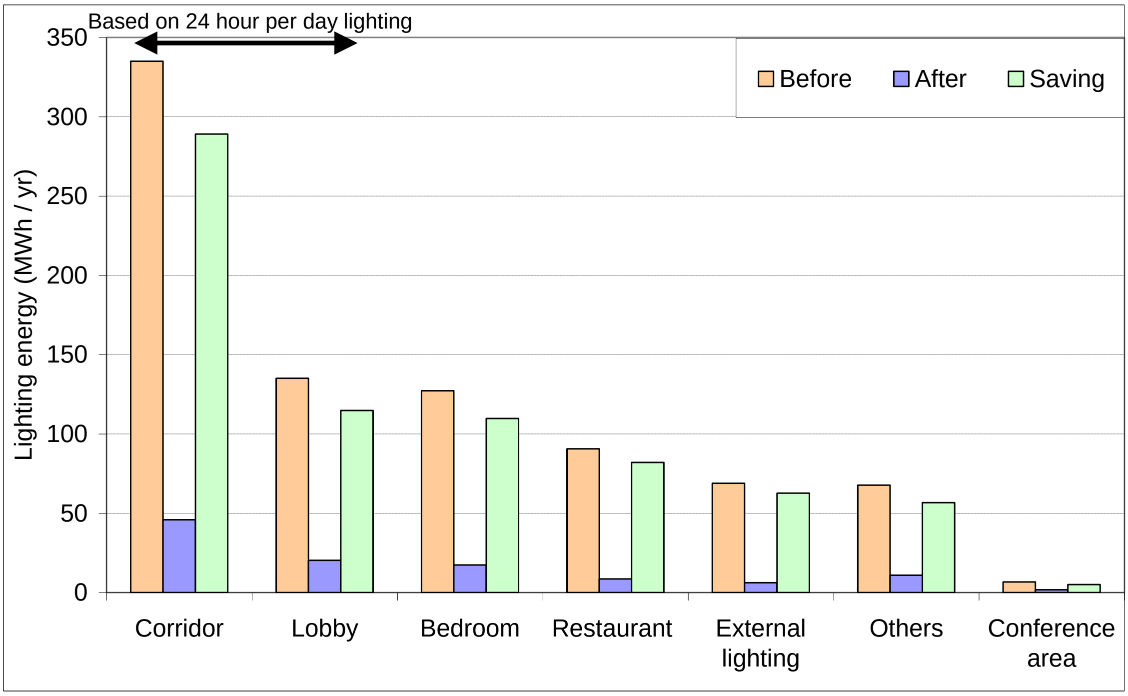
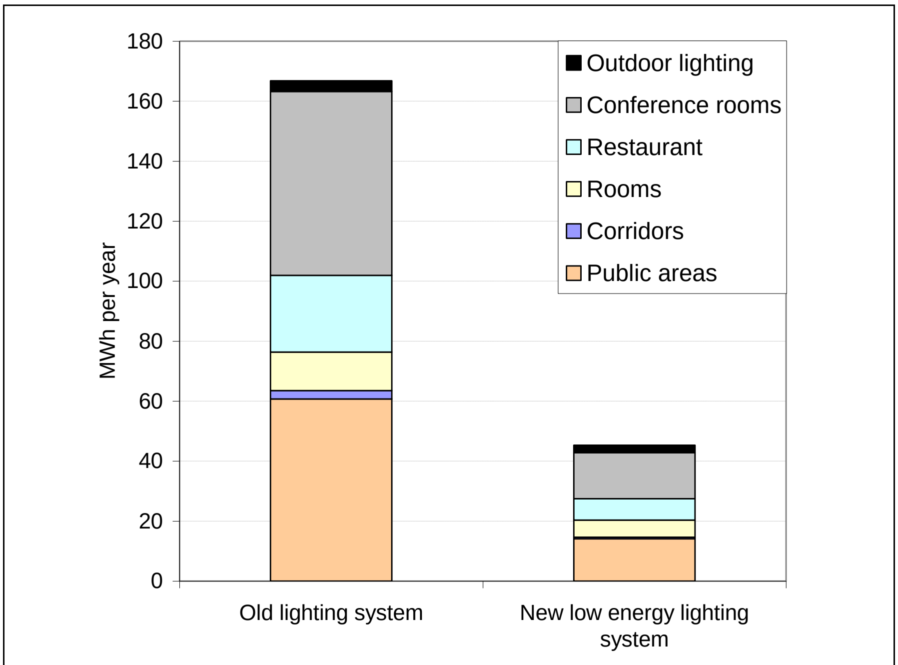


Figure 7.28: Electricity reductions achieved by installation of almost universal LED and CFL lighting in a 65-room hotel, compared with a reference scenario of incandescent, halogen and CFL lighting

Hotel Tomo is a three-star conference hotel in Riga, Latvia, with 170 rooms, 6 conference rooms, restaurant and bar services, with a serviced floor area of 6 911 m^2. A comprehensive light replacement programme reduced electricity use by 121 500 kWh per year, equivalent to 18 kWh/m^{2}yr. The greatest savings were made in the public areas, conference rooms, restaurant, and guest rooms (Figure 7.29).



Source: Based on data in Ekodoma (2007).

Figure 7.29: Estimated light energy use in different areas of the 170-room Tomo conference hotel in Riga, Latvia, before and after a comprehensive low-energy lighting retrofit

Extensive replacement of incandescent and halogen lamps with LED, CFL and E27 halogen lamps in the 293-room Prague Marriott Hotel resulted in an electricity saving of 404 MWh per year (58 % of lighting electricity), equivalent to approximately EUR 40 400 per year.

Intelligent control systems

Intelligent lighting control systems can considerably reduce lighting electricity demand. In the 65-room luxury hotel referred to above, corridor lighting still dominates lighting electricity demand after installation of low energy bulbs owing to 24-hour per day operation (Figure 7.28). Installation of sensor controls in corridors could reduce corridor lighting demand by 70 % and total lighting electricity demand by a further 33 %.

Installation of a key-card control system for room lighting in the Mövenpick Resort in Petra, Jordan, reduced total electricity consumption by 20 % (ITP, 2008).

Appropriate environmental indicators

Installed lighting type and capacity

For lighting, various technical performance indicators are relevant. For lamps, the appropriate indicator is lumens per watt energy input. To optimise installed lighting capacity and ensure that lighting is appropriate for the purpose, the illuminance measured in lux or lm/m^2 along with upper glare limit, UGR_L and the colour rendering index limit, R_a (Table 7.26) are relevant indicators.

Installed capacity, expressed in W/m^2, is an important indicator for design and the most easily measured indicator of potential lighting energy consumption. The lighting standard EN15193 provides reference values for a lower level of installed lighting capacity in hotels of 10 – 30 W/m^2.

Lighting control

Intelligent lighting control is reflected by the following indicators:

- percentage of public rooms with outdoor glazing with photo-sensor control of lighting
- percentage of guest rooms with occupation-controlled lighting (e.g. key-card control)
- installation of motion-sensor-activated, or timed push-button, lighting in corridors.

Best practice is for all rooms and corridor areas to have intelligent lighting control. For small enterprises where automatic lighting control in rooms may not be practical, the best practice is to install appropriately positioned signs reminding guests to switch off lights (as required in EU Ecolabel criteria for accommodation: EC, 2009).

Lighting electricity consumption

The ideal final indicator of efficient lighting is electricity use (kWh) for lighting, expressed per m^2 serviced area per year. In many cases it will not be possible to calculate this indicator because lighting electricity consumption is not sub-metered. The EN 15193 standard provides guidance for the calculation of annual energy consumption for lighting in individual zones based on installed capacity, average use frequency and time, and parasitic energy for standby lighting and lighting control systems. However, lighting energy efficiency will be reflected in total electricity consumption (below).

Figure 7.30 presents daily energy consumption across different hotel areas for a luxury 65-room hotel fitted with low energy LED and CFL lighting throughout. This translates into annual electricity consumption for lighting of 127 457 kWh per year, equivalent to 34 kWh/m^{2}yr throughout the hotel, and consistent with the proposed benchmark for total electricity consumption below. Installation of sensor-controlled lighting in the corridors could reduce lighting energy consumption further, to an average of 22 kWh/m^{2}yr. Assuming a gross floor area equivalent to 50 m^2 per room, lighting consumption in the Prague Marriott Hotel referred to above would be less than 20 kWh/m^{2}yr.

Figure 7.30: Installed capacity and daily consumption (kWh, bubble size) of lighting in different areas of a 65-room five-star hotel implementing good practice

<u>Benchmark of excellence</u>

The data above support the following benchmark of excellence where specific lighting electricity consumption data are available:

BM: installed lighting capacity <10 W per m^2 or lighting electricity consumption <25 kWh/m^{2}yr (heated and cooled floor area).

However, the most comprehensive and easily calculated benchmark for lighting and electrical device efficiency is total annual electricity consumption expressed per area. Figure 7.31 displays electricity consumption per m^2 across a well performing mid-range hotel chain. Based on the tenth percentile of best performing hotels within this group, the following benchmark of excellence for electricity consumption is proposed:

BM: total electricity consumption ≤80 kWh m^{2}yr (heated and cooled floor area).

This benchmark is widely applicable to accommodation of different types and sizes, and is consistent with achievable electrical demand for lighting in a luxury hotel, as described above. However, this benchmark may not be achievable by accommodation with a high electricity demand for heating and cooling. For example, accommodation located in warm climates with a high (electrical) cooling demand will not be able to achieve this benchmark without also having a high quality building envelope (section 7.2) and optimised HVAC system (section 7.3). For such hotels, the benchmark of final energy consumption applies (section 7.1).

Both the benchmarks above are expressed per m^2 indoor heated and cooled area, but include electricity consumption for all processes, including lighting, in outdoor areas.

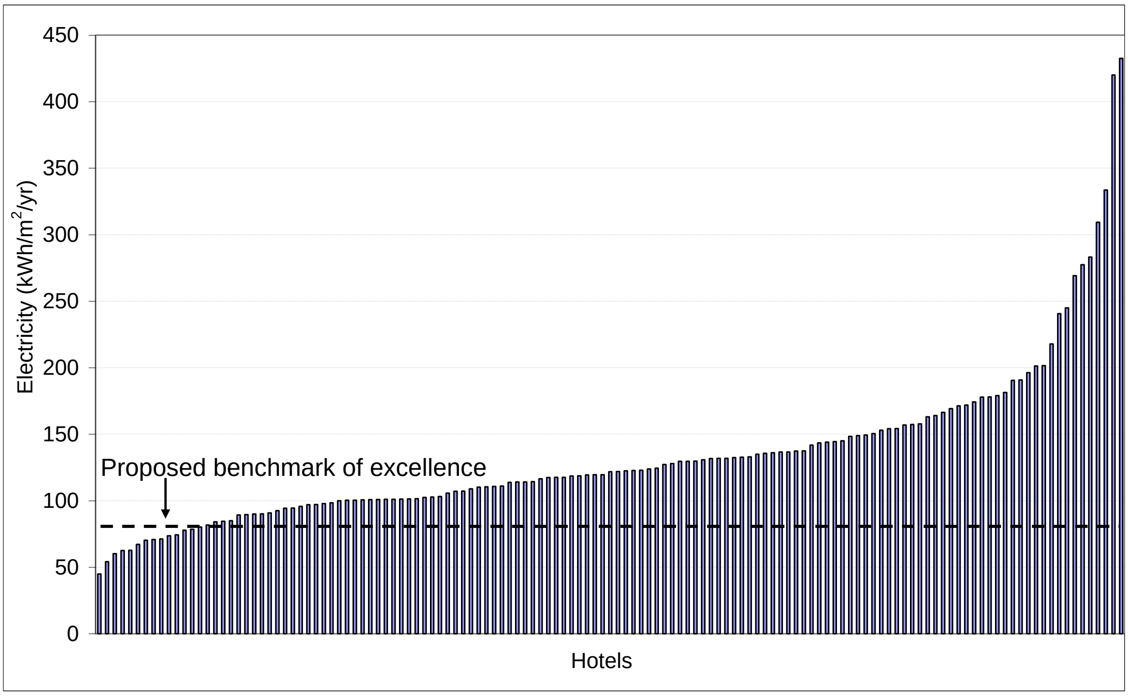


Figure 7.31: Electricity consumption per m^2 across a mid-range hotel chain, and proposed benchmark of excellence

Cross-media effects

Use of day-lighting should be considered carefully as it may have a significant impact on heating and cooling demand that can outweigh the benefits of reduced lighting energy. This must be considered at the design phase. Specifically, windows and skylights should be appropriately orientated and specified with low U-values and heat-reflective coatings (see section 7.2).

Efficient lighting generates less heat, which can increase the demand for heating in winter but reduce the demand for cooling in summer, and reduce the demand for cooling throughout the year for some rooms such as kitchens, storage rooms and busy conference rooms. Overall, energy savings from efficient lighting more than offset any additional winter heating requirements.

The major cross-media effect arising from the installation of low-energy lighting is the generation of hazardous waste arising from low-energy lamps, especially mercury-containing CFL lamps. Mercury content in fluorescent lamps can be reused, and the European Waste Electrical and Electronic Equipment (WEEE) Directive (EC, 2012) requires the collection and recycling of fluorescent lamps.

Lighting control systems that result in the frequent switching on and off of lamps may reduce lamp lifetime, especially for CFLs. For this reason, controlled halogen, and ideally LED, lamps may be better suited to areas such as corridors where lighting is required only intermittently.

Operational data

<u>Use of natural light</u>

Daylighting refers to the use of windows and skylights to bring sunlight into a building, reducing the need for artificial light, and depends on structural design features integrated during initial construction or during major renovation works. Glazing has a high heat-transfer coefficient (high U-values), and may result in excessive passive solar heating of indoor areas in sunny climates. Therefore, use of natural light should be considered carefully and integrated with optimisation of building envelope (section 7.2) and optimised HVAC systems (section 7.3). Further information on use of daylight is provided in the technical report for the building and construction sector (EC, 2012). Some main points are highlighted here.

The sizing and positioning of glazed areas should consider the cardinal directions, as referred to below.

- South-facing windows are advantageous for daylighting in cooler climates as they enable solar gain in winter, whilst solar gain in summer can be minimised through appropriate shading.
- North-facing windows provide relatively even, natural light, produce little glare, and almost no unwanted summer heat gain. They are therefore also advantageous for daylighting.
- East- and west-facing windows cause glare, admit a lot of heat during summer, and contribute little to solar heating during winter.

To realise the full advantage of natural light, it is important to account for natural lighting in system design and control. For example, lighting should be installed in separate circuits running parallel to natural light sources (e.g. windows), and these light circuits should be controlled separately according to natural lighting using photo-sensors and on-off or dimmer controls. The objective of the control is to minimise the utilisation of artificial lighting without dropping below the design levels or lighting requirements for the specific space.

<u>Lighting type and quantity</u>
Table 7.27 describes some important terminology and features of lighting. Some features of lighting, such as CRI and CT, have important implications for functionality and should be matched according to use. This may affect the choice of lighting technology. In accommodation buildings, such as hotels, lighting may be classified according to three primary purposes:

- ambient lighting provides general lighting for daily indoor activities and outdoors for safety and security;
- task lighting provides the lighting required for particular tasks that require more than ambient lighting, including in the kitchen, bed-side lamps, bathroom mirror lamps, etc.;
- accent lighting draws attention to specific features and enhances aesthetic qualities of an indoor or outdoor environment.

Table 7.27: Description of terms relating to important features of lighting

Term	Description
Colour Rendering Index (CRI)	The CRI refers to the colour rendering properties of the light in relation to sunlight (set to a value of 100). Lamps with a CRI above 80 are considered acceptable for most indoor applications. The CRI is particularly important where food is prepared and served.
Colour Temperature (CT)	The warmth (yellow-red) or coolness (blue-green) of a light source. Colour temperatures are measured in Kelvin, where higher Kelvin temperatures (3600 – 5500 K) are considered cool and lower colour temperatures (2700 – 3000 K) are considered warm. Cool light produces higher contrasts than warm light. Lamps with a high CT are preferred for visual tasks. Lamps with low CT are used in bathrooms.
Efficacy	The ratio of light produced to energy consumed measured in the lumens divided by the electrical consumption (lumens per watt).
Illuminance	The illuminance (E) indicates how much light – the luminous flux measured in lumens – from a light source falls on a given surface. It does not include reflectance and does therefore not give a precise measure of the brightness of the room.
Lumens	The luminosity provided by a light source.
Luminance	The brightness of a luminous or illuminated surface as perceived by the human eye measured in candelas per area.
Lux	The quantity of light incident on a surface, measured in lumens per square metre. Where 1lx = 1 lm/m^2
Maintained illuminance	The value below which the average illumination is not allowed to fall. Reduction in the luminous flux will occur due to dust particles and wear.
Reflectance	The reflectance indicates the percentage of luminous flux that is reflected by a surface.
Wattage	The wattage of a lamp indicates the number of electricity units in watts it burns per operating hour, e.g. a 100-watt bulb uses 100 watts per hour of operation.
Source: ITP (2008); Licht.de (2010); Winconsin University (2011).	

The zoning of the hotel according to lighting uses and the associated specific lighting requirements should be in compliance with relevant regulations. Lighting requirements for indoor and outdoor workplaces, including for restaurants and hotels, are specified in the EN 12464 standard (Table 7.28). The standard specifies lighting requirements according to task or activity in relation to: (i) maintained illuminance; (ii) upper limit for direct glare; (iii) lower limit for colour rendition index (CRI).

Table 7.28: Specific lighting requirements for indoor areas according to standard EN 12464

Zone or task	Maintained illuminance, E_m (lux)	Upper glare limit, UGR_L	Lower CRI limit, R_a	Recomm-ended lighting density (W/m^2)	Comments
Entrance halls	100	22	80	11.8	
Lounges	200	22	80	-	
Reception	300	22	80	11.8	
Kitchen	500	22	80		Transition zone between kitchen and restaurant required.
Restaurant, dining room	-	-	80	-	Lighting should be designed to create the appropriate ambiance.
Self-service restaurant	200	22	80		
Buffet	300	22	80		
Conference rooms	500	19	80	11.8	Lighting should be controllable.
Corridors	100	25	80	5.4	During night-time lower levels are acceptable.
Guest rooms				8.0	
Offices				9.7	
Source: EN 12464; ASHRAE (2009).					

Intelligent lighting control

Lighting can be controlled intelligently by people or using an automated control system. Some lamps, such as fluorescent lamps, are not suited to frequent switching on and off owing to long warm-up times and an adverse effect on lamp lifetime. Therefore, the choice of lighting must be carefully considered alongside control options. For example, it may be more efficient to install sensor-controlled halogen lighting, rather than permanently on CFL lighting, in corridors – but the ideal would be controlled LED lighting. The most common types of lighting controls and typical applications in accommodation are described below.

- Dimmers provide variable indoor lighting and reduce the wattage and output of lamps to save energy. They increase the lifetime of incandescent lamps, but reduce the efficiency. Dimming fluorescent lamps requires special dimming ballasts and lamp holders, but in contrast to incandescent lamps it does not influence the efficiency. Dimmers may be installed in public areas, such as restaurants, or in bedrooms.

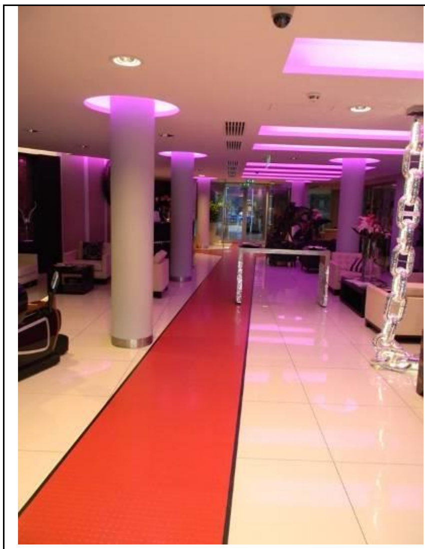
- Motion sensors automatically turn lighting on when motion is detected and turn them off after a preset time. They may be applied in corridors, public toilet and outdoor areas, but are not compatible with fluorescent lamps where the frequency of switching on and off is high. Occupancy sensors include key-card operated lighting, and are particularly useful to ensure bedroom lighting is switched off when the bedroom is unoccupied.

- Photo-sensors sense ambient (natural) lighting and can be used to switch artificial lighting on and off accordingly. They may be combined with dimmers in order to maximise the use of natural lighting. Photosensors are particularly useful in outdoor areas and indoor public spaces.

- Timers can be used to turn lighting on or off at a specified time each day, or in response to manual control. They may be combined with other forms of control, such as motion- or photo-sensors, or simply activated by a switch. They are particularly useful for outdoor areas where lighting may be required for e.g. a few hours after dusk.

Outdoor lighting

Low energy LED lighting is increasingly used for decorative indoor and outdoor lighting. LED technology is available in outdoor spotlights, and is well suited to colour applications often used in accommodation. A few visual examples are presented in Figure 7.32, below.



Source: Rafayel Hotel (2011).

Source: Chylighting (2012).

Figure 7.32: LED feature lighting in the reception of a luxury hotel, and on a building exterior

It is important that installation and control of outdoor lighting avoids light pollution, for example through ensuring appropriate capacity, direction and colour during installation, and appropriate timing control during operation. More information on avoidance of light pollution is provided in section 9.2.

Maintenance

Regular maintenance is important to maintain lighting efficiency. Illuminance levels decrease over time as a result of lamp aging and collection of dust on fixtures, lamps, and lenses. This can reduce the total illumination by 50 % or more while electricity draw remains the same. The following general advice on maintenance programmes will help to ensure that lighting systems operate at optimum efficiency:

– clean fixtures, lamps, and lenses periodically (e.g. every 6 months) especially in areas where grease, lint, dust, humidity, and insects can obscure the surface;

– replace lenses if they appear yellow;

– use light colours on walls, ceilings, window frames and lampshades, and clean and repaint periodically to maximise light reflectance.

Green procurement

Accor (2007) propose the following criteria for efficient mini-bars:

– glass doors, energy consumption less than 1 kWh per day

– solid doors, energy consumption less than 0.8 kWh per day.

The Accor criterion for mini-bars with solid doors corresponds with ASHRAE (2009) who propose all new mini-bars should have an average power draw of less than 33 W. Meanwhile, Scandic (2003) require television sets to have a maximum consumption of 5 W in standby mode.

Criteria for award of maximum points under the Nordic Swan ecolabel for hotels and hostels include:

- at least 90 % of the television sets have a passive standby setting of maximum 1 W, and if applicable, an active standby setting of maximum 9 W;
- At least 90 % of minibars consume no more than 0.8 kWh per day.

Applicability

These measures are relevant to all serviced accommodation, including luxury establishments. The installation of features to utilise natural lighting is possible during initial design and major refurbishment.

CFL lamps can be fitted in incandescent lamp fittings, and LED lamps can be fitted in halogen lamp fittings, at any time. In some cases, low-energy lamps, particularly LEDs, may require new light fittings in which case it may be more economic to replace them during planned renovations.

Economics

Building design

Use of natural lighting must be considered at the design phase for new-build and renovated premises. The investment cost and payback period is highly dependent on the specific design. Any additional investment costs (e.g. for windows or sky-lights) should be balanced against reduced lighting costs, and the considered alongside any effect on heating/cooling costs.

Low energy fittings

Higher purchase costs for low-energy lamps have a relatively short payback period through reduced electricity and replacement lamp costs. The net saving over the lifetime of low-energy lamps is seven to nine times their purchase price (Table 7.29).

Table 7.29: Lifecycle costs for low energy LED and CFL lamps, compared with conventional equivalents, calculated over the lifetimes of the low-energy lamps (40 000 and 8 000 hours, respectively)

	50 W halogen	7 W LED	75 W incan -descent	20 W CFL
Lamp lifetime (hours)	3 500	40 000	1 300	8 000
Lamp cost (EUR)	1.5	20	0.5	6
Energy consumption (kWh lamp lifetime)	2 000	280	600	160
Energy cost (at €0.10 / kWh)	200	28	60	16
Replacement lamps	11	0	6	0
Replacement lamp costs(*) (EUR)	16.5	0	5.5	0
Total cost over low-energy lamp lifetime	218	48	66	22
Net saving per lamp (EUR)		**170**		**44**
(*)Excludes labour costs *Source:* TUI (2011).				

Payback period and net financial savings are highly sensitive to electricity price (Figure 7.33). The payback period for a 7 W LED lamp costing EUR 20, versus a 50 W halogen lamp costing EUR 1.50, varies from 1 800 hours of operation at an electricity price of EUR 0.25 per kWh to 5 700 hours at EUR 0.07 per kWh (approximately 5 to 16 months if operating 12 hours per day). Financial savings over the LED lamp lifetime range from EUR 118 to 428.

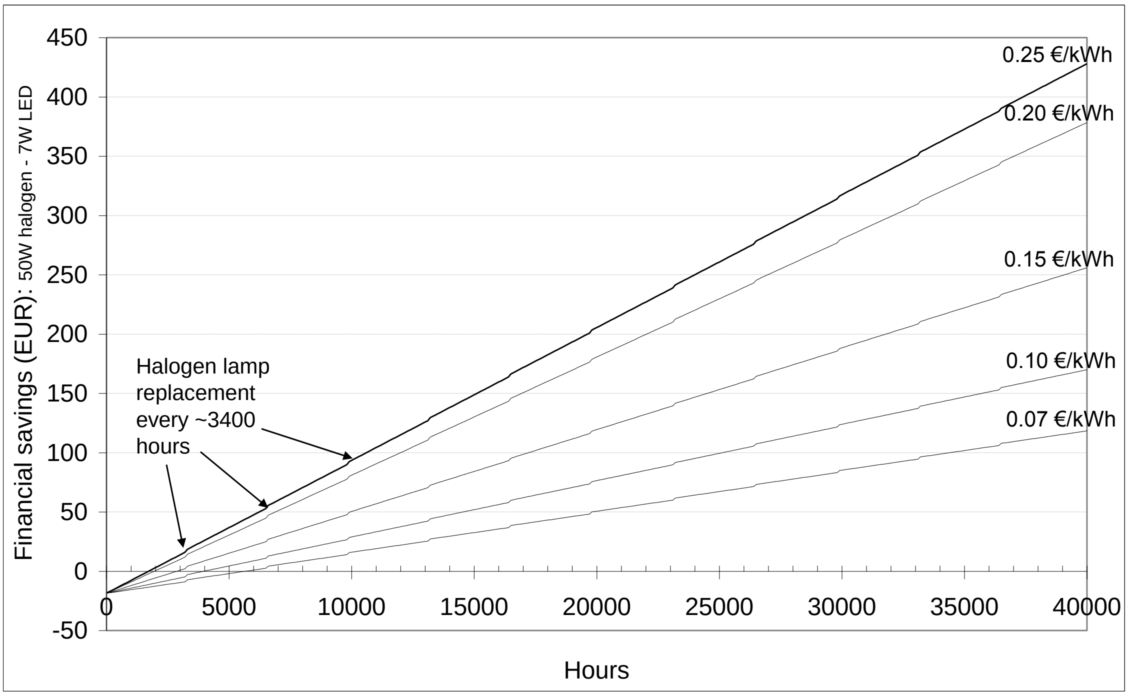


Figure 7.33: Financial cost savings over the 40 000-hour LED lamp lifetime, compared with 50 W halogen lamps, at different electricity prices

Intelligent control systems

Electricity and lighting control devices in rooms and corridors can achieve a similar magnitude of savings, and relatively short payback periods, by considerably reducing the hours of lamp operation. Two examples are illustrated below.

- Installation of sensor-control in the reference 65-room luxury hotel referred to above would result in an annual saving of EUR 4 240 in electricity alone, at an electricity price of EUR 0.10/kWh.
- Installation of a key-card control system in rooms at the Mövenpick Resort Petra cost EUR 13 200, but resulted in an annual saving of EUR 39 000 and a payback time of just four months (ITP, 2008).

Hotel energy and maintenance savings

Previously referred to examples indicate the magnitude of operational cost savings possible from the installation of low energy lighting throughout a hotel. The Tomo Hotel in Latvia achieved an estimated annual reduction of 73 % in lighting electricity, equivalent to over EUR 12 500 per year at an electricity price of EUR 0.10/kWh. The Prague Marriott Hotel reduced electricity use by 404 MWh/year, equivalent to approximately EUR 44 000 per year.

As indicated in Table 7.29, savings associated with less frequent lamp replacement are also significant, and can be larger than electricity savings. An energy audit of the reference luxury 65-room hotel estimated annual savings from reduced electricity consumption (at a price of EUR 0.10/kWh) and maintenance of EUR 50 000 and EUR 70 000, respectively, totalling over EUR 120 000 per year in savings (Figure 7.34).

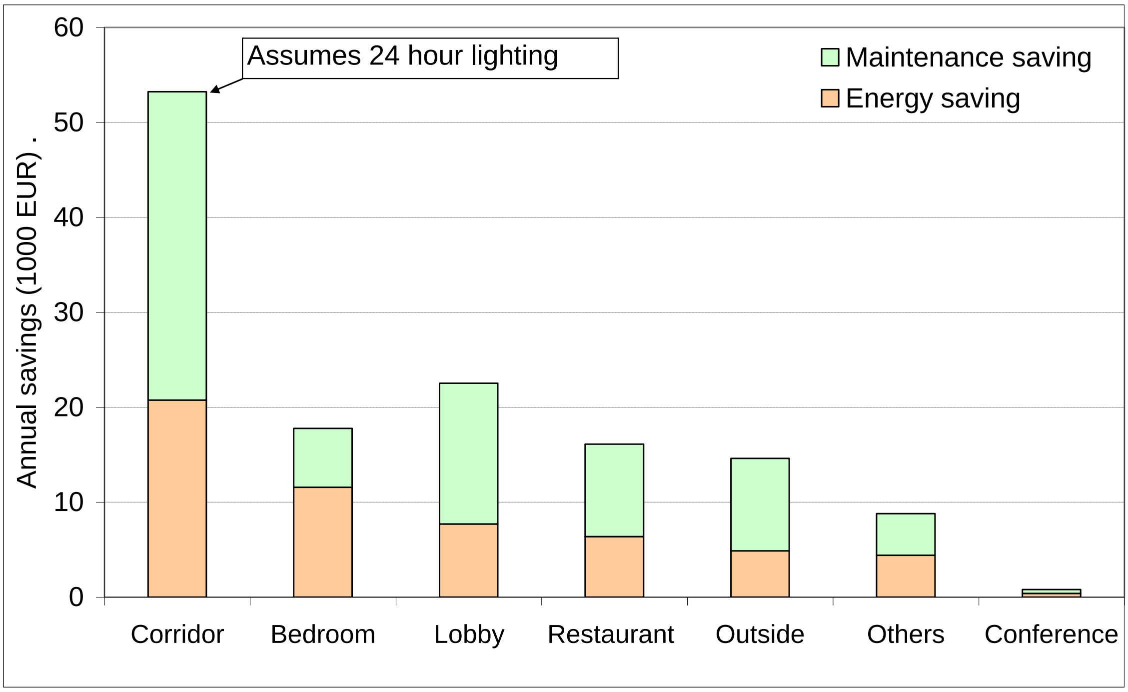


Figure 7.34: Annualised financial savings associated with reduced energy consumption and lower maintenance requirements arising from extensive installation of LED and CFL lighting in a 65-room hotel, compared with a reference scenario of incandescent, halogen and CFL lighting

Driving force for implementation

Installation of efficient lighting systems can improve the quality of lighting whilst reducing operating costs. It is also a visible example of efficient and environmentally-friendly hotel management. The main driving forces can be summarised as:

- reduced energy consumption and costs
- reduced maintenance costs by switching to lighting technology with longer lifetime
- wellbeing of guests and staff (improved lighting quality)
- environmental credentials and CSR (reduced CO_2 emissions)
- rapid development of new lighting technology, especially LEDs.

In addition, European legislation requiring the phase-out of incandescent lamps for most uses is a powerful driving force behind the change in lighting technology to more energy efficient types such as fluorescent and LED lighting technologies.

Reference organisations

Marriott Hotel Prague, Rafayel Hotel London, Scandic Hotel Berlin, Tomo Hotel, Latvia

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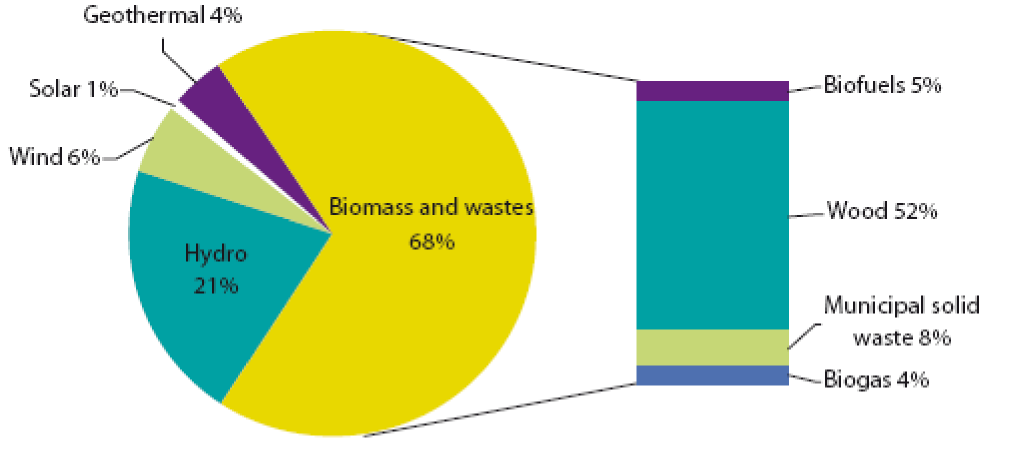
7.6 Renewable energy sources

Description

After implementation of measures to reduce energy demand, further reductions in primary energy consumption and associated environmental benefits can be achieved through measures to increase the supply of renewable energy (RE). Most currently exploited energy sources ultimately originate from solar energy. In the first instance, passive use of solar energy for heating through good building design (passive gain through south facing windows in cold climates) is the first important best practice measure (section 7.2). Active utilisation of RE sources exploits energy carriers that do not necessitate the depletion of finite reserves, and that do not release carbon sequestered in fossil resources to the atmosphere where it contributes to climate change.

The Renewables Directive (2009/28/EC) establishes mandatory national targets for RE shares consistent with at least a 20 % of energy from renewable sources across the EU in 2020. Member States must demonstrate implementation of national RE action plans. This target requires rapid expansion in RE generation from the 1 481 882 GWh produced in the EU-27 in 2006, representing 7 % of final consumption. Latest available data from Eurostat indicate that RE production rose to 1 643 726 GWh in 2010. Figure 7.35 displays the breakdown of EU-27 RE production in 2006. Biomass and wastes, specifically wood, dominate RE production, reflecting the compatibility of bioenergy with traditional energy conversion processes (i.e. supply and combustion of solid fuels).



Source: Eurostat (2009).

Figure 7.35: Contribution of specified sources to total primary RE production in the EU-27

Table 7.30 summarises the main best practice RE options for accommodation. Heat pumps and geothermal systems utilise renewable aerothermal, hydrothermal and geothermal energy but require significant amounts of conventional energy (typically electricity) to operate, and are described separately in section 7.4 as options to reduce energy demand. Less widely applicable and emerging options not referred to in Table 7.30 include heat and electricity generation from biogas, and hydro-power. On-site production of biogas is an emerging option for accommodation enterprises that generate large quantities of organic waste, but only represents best practice where the organic waste cannot be sent to centralised biogas plants (see section 8.2). Considering the limited availability of biogas as a sustainable transport fuel, use for decentralised building heating or electricity generation is not considered best practice. Generation of electricity from small hydro-plants situated on adjacent streams or rivers is a best practice option for a small number of appropriately sited accommodation enterprises. An overview of the main RE technologies is provided below.

Table 7.30: Descriptions and applicability of major best practice RE options for accommodation

RE technology	Best practice description	Applicability
Off-site RE	Where it is not efficient to exploit RE directly on site, the preferred best practice measure is for accommodation enterprises to invest in RE schemes to install a RE generating capacity equivalent to that which would be required to supply on-site demand. An alternative, less rigorous, best practice measure is for accommodations to purchase 'green' electricity that can be traced to a specific renewable source that is not accounted for in national average (emission) factors for grid-supplied electricity as per GHG accounting guidelines provided by BSI (2011).	All accommodation providers.
Biomass heating	The main source of biomass heating is wood or pellet boilers that may be used to heat water feeding DHW and HVAC systems. The use of gasifying boilers fed by logs also represents best practice, and is described in section 9.2 for campsites. Best practice operation of wood boilers involves continuous operation at partial load wherever possible, in order to minimise emissions to air.	Any accommodation, but best suited to non-urban areas with a local wood supply and where combustion emissions pose a lower health risk.
Solar thermal	Flat plate or evacuated tube solar collectors can be placed on accommodation building roofs or in adjacent areas to heat DHW. Solar thermal water heating is particularly well suited to accommodation premises where occupancy and peak DHW demand occurs in summer, coinciding with peak solar irradiance.	Any building with suitable exposure to the sun, including at mid- to high-latitudes and in cloudy climates. Potential contribution to DHW heating is limited for large urban buildings.
Solar photovoltaic	Solar photovoltaic cells can be installed on or integrated with the building envelope – in particular roofs, exterior walls and shading devices – to generate electricity. Generated electricity may be used for on-site processes or fed into the grid in order to avail of feed-in tariffs for solar electricity.	Any building with suitable exposure to the sun (i.e. not shaded). More effective at lower latitudes and in sunny climates, but most cost-effective where high solar feed-in tariffs are available (e.g. Germany).
Wind turbines	Building-mounted wind turbines with a capacity of 1 – 6 kW are an emerging technology with low electricity outputs and typically poor return on investment compared with alternative RE options. Therefore, best practice is to install on-site free-standing turbines of tens to hundreds of kW capacity where space and wind conditions allow, or to invest in offsite large wind turbines of MWs capacity.	Best practice installation of larger turbines is restricted to accommodations in open (e.g. rural or coastal) areas. However, wind turbines are a good option for green electricity investment by all accommodation enterprises (see above).

Biomass heat

The most relevant source of biomass heat for accommodations is wood, and the most efficient conversion pathway is through direct combustion of wood chips or wood pellets in boilers, or combustion of larger wood pieces in gasifying wood boilers (application of a gasifying wood boiler is described in section 9.3).

Pellet boilers are highly automated and are well suited to meeting variable load demands. They are typically rated from 8 – 500 kW (Carbon Trust, 2008) and achieve efficiencies of 85 – 90 %. Pollutant emissions are lower than for other types of wood boiler owing to precise control of feed rates and combustion air possible with automated systems and homogenous pellet composition, so that pellet boilers represent state-of-the-art for solid biomass combustion alongside gasifying boilers. The buffer capacity of DHW storage tanks facilitate continuous operation at maximum combustion efficiency with minimum emissions.

Wood chip boilers work on the same principle as pellet boilers, with automated control of chip feed supply. Whilst boiler operation is similar to pellet boilers, the average heating value and homogeneity of wood chips is lower than for pellets, resulting in more variable performance and slightly lower efficiency. Wood chip boilers usually incorporate a fuel stoking system whilst pellet boilers use a simpler pellet metering system, and are better suited to larger applications of 30 – 10 000 kW capacity (Carbon Trust, 2008). Wood chips are often available at lower cost than pellets, per MJ energy content, owing to lower processing requirements.

Solar thermal

Solar thermal collectors absorb energy from solar radiation and transfer it to heat water via heat exchangers. Solar collectors are well suited for installation on accommodation roofs with orientation from 90 º to 270 º from north (180 º – due south – is optimum), and peak output in summer months may coincide with peak occupancy and therefore DHW demand in many accommodation enterprises. There are two main types of solar collector:

- flat plate collectors that can be built into the roof, transferring 50 % received incident radiation into heat
- evacuated tube collectors that must be mounted on top of the roof, transferring 60 % of received incident radiation into heat.

Thus evacuated tube collectors produce approximately 20 % more heating energy than flat plate collectors per m^2 of aperture (light entry) area, but actual output is highly site specific. Accor (2007) suggest that solar collectors can easily cover 40 % of hotel hot water demand.

Solar photovoltaic

Solar photovoltaic (PV) cells are made from layers of semi-conducting materials that generate a direct current when exposed to light. Solar PV installation has been growing exponentially since the late 1990s, and reached 15.6 GWp installed capacity by 2008, 60 % of which was in Europe (EPIA, 2009). Currently, 90 % of PV cells are made by slicing or growing crystalline silicon, whilst the remaining 10 % are made using film technology that involves depositing thin layers of photosensitive materials onto backing materials such as glass, stainless steel or plastic. Solar PV cell performance is measured according to the percentage of solar energy striking its surface converted into electricity. A typical commercial solar cell has an efficiency of approximately 15 %, and the main barrier to increased PV uptake has been capital cost per kW output capacity. Emerging technologies include concentrated PV cells that use concentrating collectors to increase the output of the expensive semiconducting PV material, and flexible cells derived from film technology (EPIA, 2011).

Wind

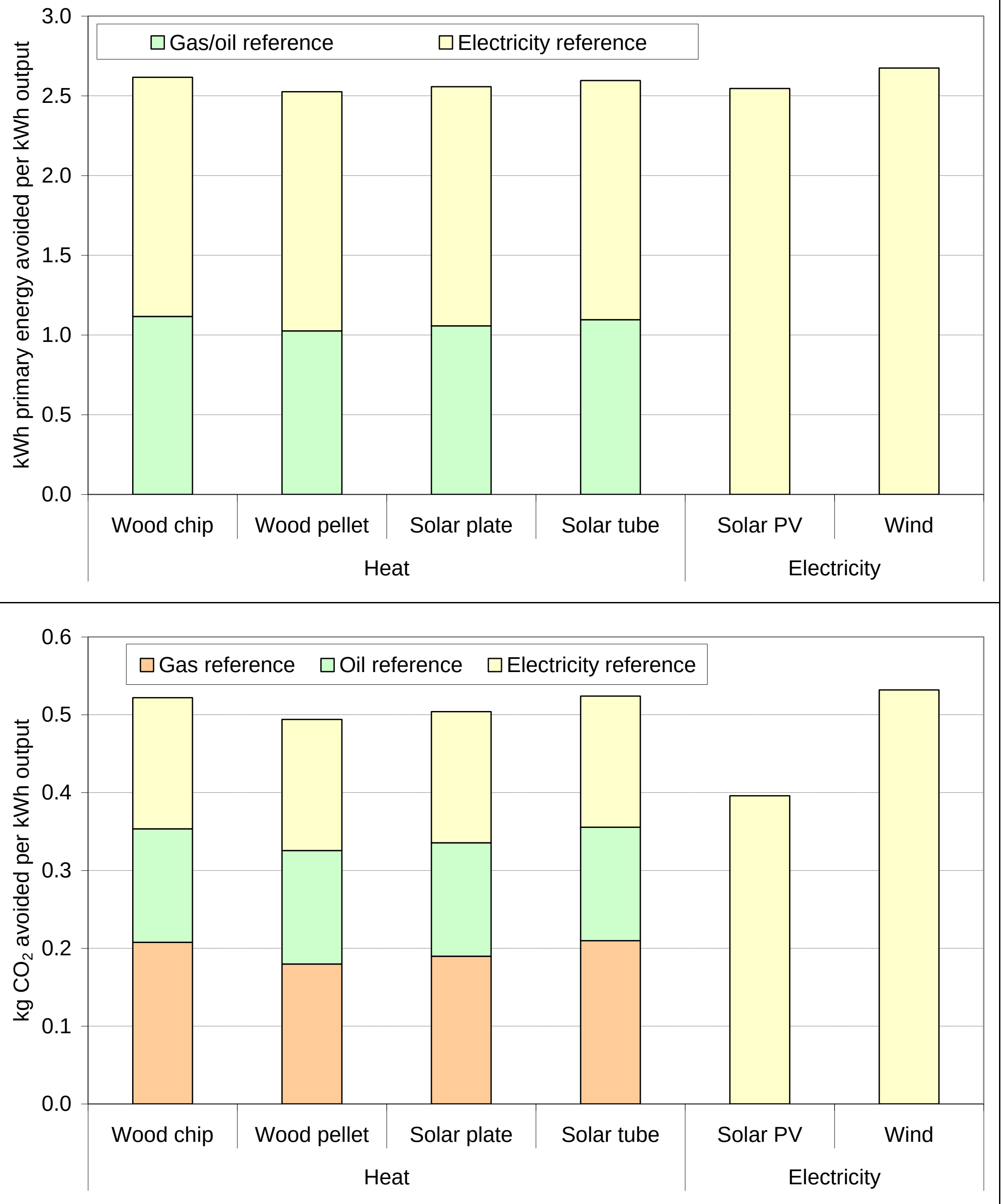
Wind turbines convert the linear motion of air in wind currents to rotary motion in order to drive electricity generators, usually via large rotors (impellors). Wind turbines range in capacity from small units with peak rated output of less than 1 kW to stand-alone units with a peak rated output of 7.5 MW and 130 m diameter rotors. The main limiting factors for larger wind turbines are the availability of sufficient space and sufficient wind speed. Turbines operate from wind speeds of around 4 m/s, but work best in locations with mean wind speeds of 7m/s or higher (Carbon Trust, 2008).

Achieved environmental benefit

Technology specific GHG avoidance

Figure 7.36 displays primary energy and GHG emission avoidance per kWh useful heat and electricity output for different RE options. Compared with conventional heating and electricity options, RE technologies reduce GHG emissions by between 76 % (solar PV) and 97 % (wind turbines). Thus, the type of energy displaced has a greater influence on primary energy and GHG emission avoidance than the type of RE option applied.

For example, displacing inefficient direct electric resistance heating with a wood-chip boiler results in a GHG saving of 0.52 kg CO_2 eq. compared with a saving of 0.21 kg CO_2 eq. When natural gas heating is the reference. Primary energy savings range from 1.03 kWh per kWh heat delivered for wood pellet heating replacing gas heating, to 2.67 kWh per kWh electricity delivered for wind turbines replacing grid electricity.

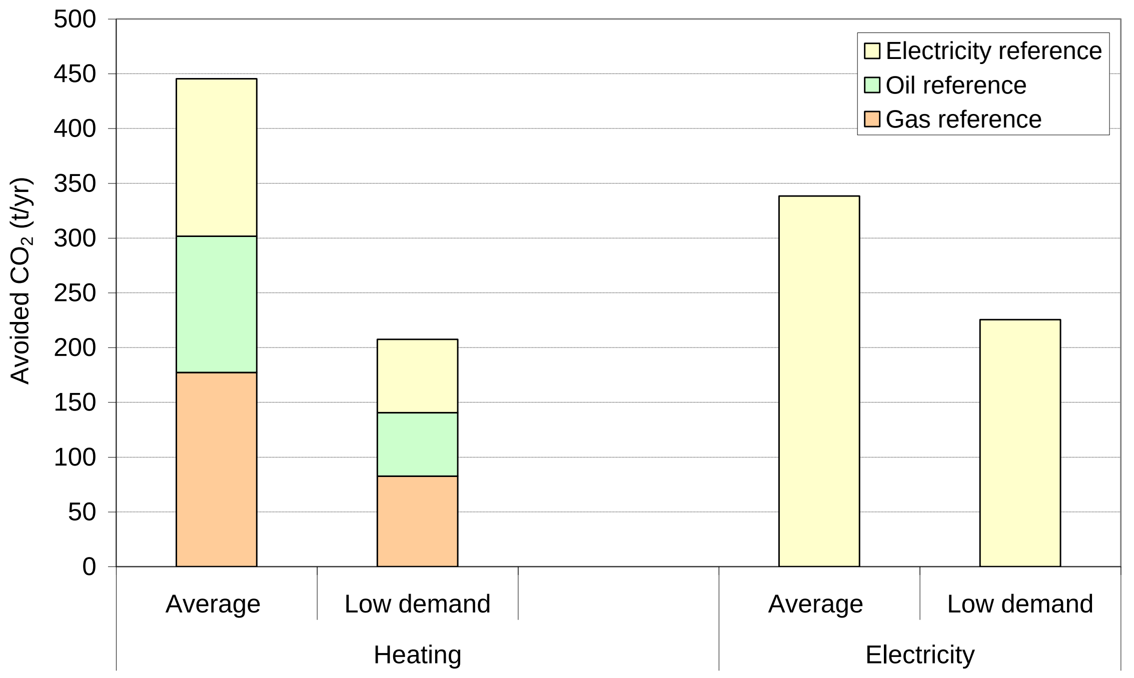


NB: Avoided primary energy and GHG emissions are calculated relative to gas heating, oil heating, electric resistance heating and average grid electricity supply. Assume 90 % boiler efficiency and 5 % additional emissions from boiler manufacture and maintenance.

Figure 7.36: Lifecycle avoided primary energy consumption (above) and GHG emissions (below) per kWh useful heat or electricity generated by different RE technologies, relative to conventional reference heating and electricity options

Accommodation GHG avoidance

Figure 7.37 provides an example of maximum GHG avoidance achievable through use of RE to provide 100 % of HVAC (wood chip boiler) and 100 % of electricity (wind turbine) demands for a 100-room hotel with average energy demand and best performance energy demand. Maximum GHG avoidance for a 100-room average hotel ranges from 516 to 784 t CO_2 per year, whilst maximum GHG avoidance for a low energy demand hotel implementing best practice ranges from 308 to 433 t CO_2 per year.



NB: Average and low HVAC demand of 161 and 75 kWh/m^{2}yr respectively; average and low electricity demand of 120 and 80 kWh/m^{2}yr respectively; 5 300 m^2 indoor floor area.

Figure 7.37: Maximum annual GHG avoidance possible for a 100-room hotel by substituting 100 % gas, oil or electric HVAC heating with wood heating, and 100 % grid electricity with wind electricity

Table 7.31 provides some less ambitious, and in the short term more realistic, examples of achievable GHG avoidance through implementation of different RE options for a 100-room hotel, again assuming average and low energy demand. Wood heating and (off site) wind electricity generation offer the largest realistic savings potentials, with smaller but significant savings achievable by installing solar collectors for DHW heating.

Table 7.31: Achievable annual GHG avoidance scenarios for RE installation in a 100-room hotel

Scenario	RE technology	Reference option	Avoidance (t CO_2/yr)	
			Low demand	Average demand
HVAC 50 %	Wood chip boiler	Gas boiler	41	89
HVAC 100 %		Oil boiler	141	302
Electricity 20 %	Solar PV (on site)	Grid electricity	34	50
Electricity 100 %	Wind (off site)		226	338
DHW 20 %	Solar evac. tube	Gas boiler	6	11
DHW 50 %		Electric heating	35	69

NB: Low and average HVAC demand of 75 and 161 kWh/m^{2}yr; low and average electricity demand of 80 and 120 kWh/m^{2}yr; low and average DHW demand of 25 and 50 kWh/m^{2}yr.

Appropriate environmental indicator

Off-site RE

The most direct and verifiable way to invest in off-site RE is to do so directly by contributing to RE schemes. The annual generating capacity of off-site renewable installations directly supported by the accommodation's investment may be considered equivalent to on-site renewable generation.

Attributing additionality to purchased 'renewable' electricity is a complex task for which a European methodology is being developed (EPED, 2012). According to the UK Publicly Available Specification (PAS) 2050 for the calculation of GHG emissions of goods and services (BSI, 2011), off-site RE generation can only be considered valid if the following conditions can be demonstrated:

- off-site energy generation is of the same form (e.g. heat or electricity) as that used on-site
- the generated RE has not been accounted for as RE consumption by another process or organisation and is excluded from the national average emission factor for electricity generation.

The PAS 2050 specification is primarily concerned with avoiding double accounting of RE consumption. However, the requirement for traceability and exclusive accounting of RE consumption provides a useful indication of additionality. Another potential indicator is that purchased RE should originate from new capacity, installed within the past e.g. two years.

Therefore, where accommodation enterprises can trace purchased RE to specific generation in accordance with the above conditions, such energy may be regarded as genuine purchased RE (see the second benchmark, below).

RE performance

The energy performance of RE technologies can be expressed as primary energy ratios (PERs), and compared with PERs for conventional energy sources (Table 7.4 in section 7.1) and for heat pump heating (Table 7.18 in section 7.4).

Lifecycle GHG emissions, expressed per kWh heat or electricity produced, is another environmental indicator of RE performance that is useful for sustainability reporting. Table 7.32 presents default PER and lifecycle CO_2 burdens for different RE technologies, taken from the GEMIS LCA database.

Table 7.32: Primary energy ratios and lifecycle GHG burdens per kWh_{th} or kWh_e delivered energy for different RE technologies from the GEMIS lifecycle assessment database

Technology / energy carrier	PER	CO_2eq./kWh
Wood chip boiler	0.08	0.028
Wood pellet boiler	0.18	0.056
Flat plate solar collector	0.14	0.046
Vacuum tube solar collector	0.10	0.026
Solar PV	0.48	0.154
Wind turbine	0.03	0.018
Source: GEMIS (2005).		

Energy content of wood fuel

In order to calculate on-site energy consumption, and to compare the price per unit energy of delivered fuel, information on the moisture content of wood fuel delivered for heating should be known as this is the primary factor affecting the net calorific value energy content of wood (dry value of 18 MJ/kg). This information can be provided by suppliers, and should be certified for relatively homogenous and standardised pellets. Table 7.33 provides indicative values for different wood fuel types.

Table 7.33: Typical moisture and energy contents of supplied wood fuel

	Dried logs	Dried wood chip	Wood pellet
Moisture content (% wet weight)	20 – 25	20 – 30	5 – 12
Energy content (kWh/kg)	3 – 4	2.5 – 3.5	4.8 – 5
Source: Carbon Trust (2008).			

Accounting for RE use by heat pumps

According to the Renewable Energy Directive (2009/28/EC), aerothermal, geothermal or hydrothermal energy captured by heat pumps can be considered renewable and calculated according to the following formula:

$$RE = Q_{final} \times (1 - 1/SPF)$$

Where Q_{final} is the final useful energy delivered by the heat pumps and SPF is the estimated average seasonal performance factor (HSPF for heating and SEER for cooling in section 7.4).

NB: Only heat pumps for which $SPF > 1.15 \times 1/\eta$ shall be taken into account, where η is the ratio between gross electricity generation and the primary energy consumption for electricity generation according to the EU average taken from Eurostat.

Renewable energy captured by heat pumps may be included in the share of RE used by accommodation, where total final energy consumption is recalculated to include the final energy delivered by the heat pump (Q_{final} above). Q_{final} may be estimated by multiplying energy consumed by the heat pump by the SPF calculated by the suppliers or installers. It is important to note that final energy consumption calculated in this way for accommodation premises using heat pumps will be considerably higher than final energy consumption calculated as the sum of on-site fuel and electricity consumption.

Benchmark of excellence

There are no extensive data on shares of RE across accommodation enterprises, but there are some examples of high shares, especially where geothermal systems are used. Renewable energy shares may be high where onsite energy consumption is minimised. Considering these factors, the following benchmark of excellence is proposed:

BM: the equivalent of 50 % of the accommodation's annual energy consumption is generated by on-site renewable sources, or by verifiably additional off-site RE sources.

An alternative benchmark of excellence where electricity flows can be accounted for at the necessary level of disaggregation is:

BM: 100 % of electricity is from traceable renewable electricity sources not already accounted for by another organisation or in the national electricity average generating mix, or that is less than two years old.

Cross-media effects

The main cross-media effects and options to mitigate them are summarised for each main RE technology in Table 7.34 below.

Table 7.34: Cross-media effects for different RE options

Technology	Cross-media effects	Mitigation options
Wood boilers	Wood burning emits CO, NO_x, hydrocarbons, particles and soot to air and produces bottom ash for disposal. These substances indicate incomplete combustion performance, and occur especially during start-up, shutdown and load variation. Wood chip boilers typically emit slightly more polluting gases than pellet boilers owing to lower fuel homogeneity, but emissions are low compared with other solid fuel boilers.	CO, hydrocarbons, soot and black carbon particles can be reduced by using continuously operating wood chip or wood pellet boilers.
Solar thermal	Production of solar thermal collectors requires energy and materials, and emits gases such as CO_2. The energy embodied in solar thermal cells is typically paid back within two to three years of operation depending on site-specific application, so that energy produced over the remaining ~20 years operating lifetime creates a large positive balance.	Maximise output through optimised siting and installation (e.g. south orientation), and ensuring long operational lifetime.
Solar PV	As with solar collectors, production of solar PV cells requires energy and materials and emits gases. Owing to lower conversion efficiencies and more complex production methods, energy payback times are estimated at three to four years by against 30-year operating lifetimes (US NREL, 2004). It is expected that energy payback times will be reduce to approximately one year with anticipated thin-film technology.	As above.
Wind turbines	Embodied energy in wind turbines typically represents less than one year's electricity output over typical operating lifetimes of 20 years.	Maximise output through appropriate siting (e.g. in areas of high and consistent wind speeds).

Operational data

Biomass heating

Wood fuel supplies can vary significantly from one location to another in terms of reliability and cost. Before installing a wood boiler, it is essential to ascertain the local availability, reliability and price of wood fuel. Owing to the lower energy density of wood fuel compared with oil, wood boilers require relatively large fuel storage areas for the chips or pellets, usually at ground or below ground level. Operational measures to reduce operating emissions from wood boilers are described below.

Combustion efficiency in wood boilers is optimised through air staging (splitting the combustion air into a primary air flow directly to the flame and a secondary air flow in direction of the combustion gases) to avoid excess oxygen in the combustion zone and ensure sufficient oxygen above the combustion zone. Secondary air injection increases the low-temperature outer-flame volume to ensure full oxidisation of hydrocarbons, black carbon and carbon monoxide following combustion.

Boilers connected to small hot water storage tanks operate under variable load conditions throughout the day, thereby producing relatively large quantities of partially oxidised compounds. Air and fuel feeding systems can ensure optimised combustion performance at loads of between 50 – 100 %. The installation of large hot water storage tanks can enable wood boilers to operate for longer periods at peak or close to peak load, and reduce the number of start-ups and shut downs during the day, thereby reducing emissions. Some important information related to wood boilers contained in the technical report for the buildings and construction sector (EC, 2012) is summarised below.

The EN-standard for automatic biomass boilers with nominal heat output of 50 to 150 kW (EN 303-5) establishes the emission limits shown in Table 7.35 for pellet boiler class types 1 (worst) to 3 (best).

Table 7.35: EN 303-5 test stand emission limit values for pellet boilers

	Class 1	**Class 3**
Energy efficiency (NCV)	67 + 6 log (Q_N)	47 + 6 log (Q_N)
CO emissions (mg/Nm³)	12,500	2,500
PM emissions (mg/Nm³)	200	150
Organic compounds emissions (mg/Nm³)	1,250	80
Source: EC (2009).		

Meanwhile, a preparatory study for solid fuel combustion under the Eco-design Directive (EC, 2009) proposes best performance emission parameters for wood pellet and wood chip boilers that may be used to guide selection of the most environmentally friendly boilers during procurement (Table 7.36).

Table 7.36: EcoDesign performance indicators for pellet boilers and combined pellet/wood-chip boilers

	Pellet	**Wood Chip**
Energy efficiency (NCV)	94 %	92 %
CO emissions (mg/Nm³)	30	30
PM emissions (mg/Nm³)	10	20
NO_x emissions (mg/Nm³)	90	90
Organic compounds emissions (mg/Nm³)	1.5	1.5
NB: reference O_2 content: 13 % vol.. *Source*: EC (2009).		

Studies have shown that optimising the combustion process can almost completely prevent large particle emission, but can leader to higher emissions of fine particles (diameter <0.1 µm). Secondary abatement techniques like electrostatic precipitators and fabric filters are therefore necessary to minimise emissions of fine particles, and can reduce total PM emission by 50 – 70 %. After-burning catalysts are available to reduce carbon monoxide and volatile hydrocarbon emissions.

Solar thermal

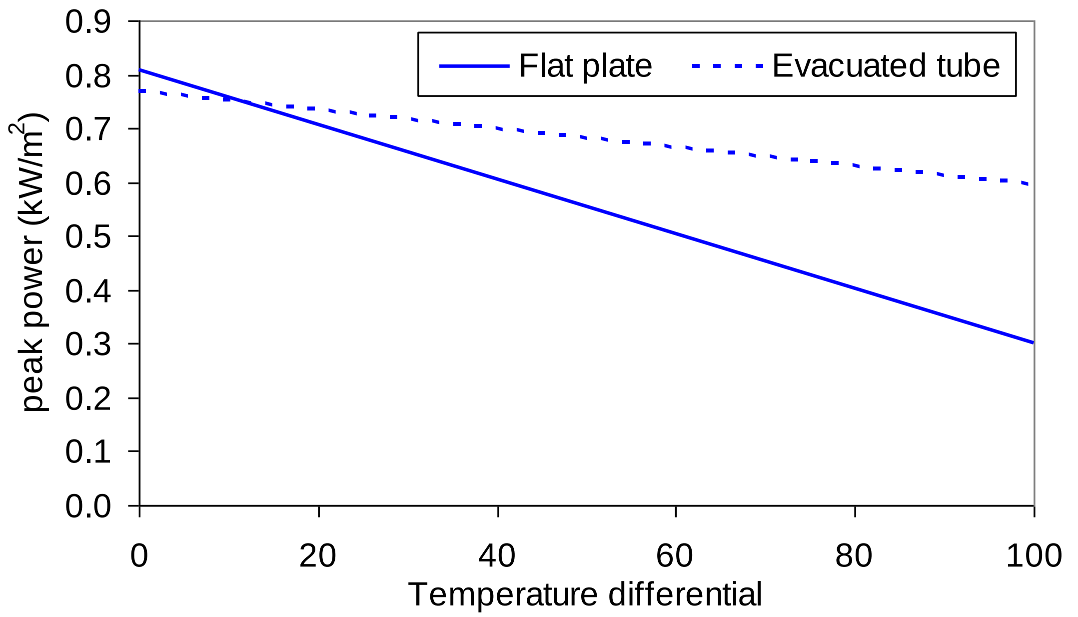
The heating output from solar collectors is highly dependent on the situation, especially:

- annual quantity incident solar radiation (function of latitude, cloud cover, shading)
- orientation
- tilt angle
- temperature difference between heated water and outside air.

Situation specific annual incident solar radiation and heat output can be calculated based on latitude and local climatic data, planned collector type and installation orientation and tilt. In Switzerland, south facing collectors can provide over 850 kWh/m^{2}yr of water heating (SPF, 2011). However, Ecocamping (2010) report that, on average, flat plate collectors installed in Germany can be expected to generate approximately 350 kWh/m^{2}yr water heating, and evacuated tube collectors approximately 450 kWh/m^{2}yr of water heating (Ecocamping, 2010). South-facing flat plate panels in Seehof campsite, northern Germany, provided an average of 600 kWh/m^{2}yr of water heating between 2010 and 2011 (see section 9.2).

The ideal situation for solar panels is on a south-facing roof with a tilt angle of 30º to 45º. However, in typical mid- to high- latitude (40º to 60º N) European situations, output is reduced by just 5 % when oriented SE or SW, and solar panels function adequately on E- and W-oriented roofs. When selecting solar collectors, the European Solar Keymark (ESTIF, 2012) provides assurance of compliance with European standards.

Climatic, seasonal and system design features also influence operating efficiency via the temperature differential between ambient outdoor air and maximum heated water temperature. This effect is greater for flat plate than for evacuated tube collectors (Figure 7.38). Solar collector output can be maximised by reducing the maximum water temperature required, for example by using solar thermal to provide water pre-heating. Reducing the maximum temperature differential (i.e. system maximum water temperature) by 20 ºC can increase peak heat output by 5 % and 13 % for flat plate and evacuated tube collectors, respectively.



Source: SPF (2008).

Figure 7.38: Variation in standard test peak power output from two solar collectors relative to temperature differential (maximum water temperature minus ambient temperature)

Calculated heat output in the specific situation can then be used to calculate optimum collector area – too large an area leads to redundant capacity in summer months, and is therefore uneconomic. It is usually economically attractive to cover up to 60 % of hot water demand with solar heating, and a general guide for campsites in Germany is to install 0.1 to 0.2 m^2 of flat-plate collector area per pitch (25 % less area required for evacuated tube collectors). Seasonal variations in water demand must also be considered.

Installed hot water storage capacity should be calculated according to the area of solar collectors, and be at a minimum:

- 100L per m^2 flat-plate collector
- 133 L per m^2 evacuated tube collector (Ecocamping, 2011).

Storage tanks and all pipework should be well insulated. A minimum of 50 mm insulation is recommended for storage tanks, preferably factory fitted, while pipe insulation should be of a thickness at least equivalent to the outer diameter of the pipes (SEIA, 2010).

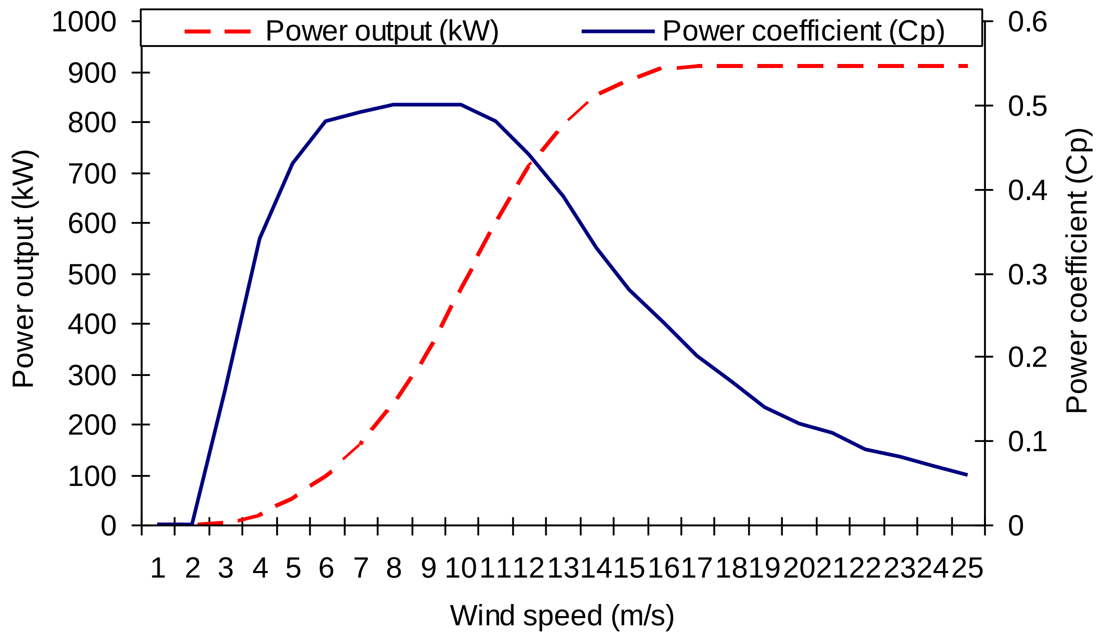
It is important to install an expansion vessel and pressure release valve to protect the solar heating loop from overheating and excessive pressure during periods of high solar gain. A control system is required with sensors on the solar collectors and in the water tanks to switch on circulating pumps when sufficient solar radiation is reaching the collectors and when water requires heating.

Solar PV

Factors affecting output from PV panels are similar to those described above for solar thermal panels. Aspect and tilt angle are important. In addition, more recent developments in PV cell technology make it feasible to apply solar PV cells onto vertical façades and shading devices. Cells must be cleaned at least once per year, more often where there are sources of deposition such as air pollution, sea spray, or a high concentration of birds, etc.

Wind

The main limiting factors for larger wind turbines are the availability of sufficient space and sufficient wind speed. Turbines operate from wind speeds of around 4 m/s, but work best in locations with mean wind speeds of 7 m/s or higher (Carbon Trust, 2008). Figure 7.39 shows the relationship between wind speed, power output and conversion efficiency (coefficient of performance, Cp) for a large 900 kW turbine (Enercon, 2011).



NB: Wind speed measured at hub height (45 m)
Source: Data from Enercon (2011).

Figure 7.39: Evolution of power output and conversion efficiency (Cp) with wind speed for a 900 kW turbine

In the first instance, indicative information on wind speeds can be obtained from meteorological data from the nearest weather station, or from national databases such as the BERR/NOABL Wind Speed Database in the UK (Renewable UK, 2012). However, local topography and buildings can significantly influence local wind speeds and generate turbulent flow patterns so that site surveys should be carried out before installation of wind turbines.

The economic viability of installing a wind turbine can be calculated by comparing total investment costs with annual electricity output and output value (electricity prices and any feed-in tariffs available), as described under 'Economics'. The annual electricity output from a wind turbine of a given capacity can be calculated based on the average annual wind speed according to product performance specifications such as those presented in Figure 7.39 according to the following equation:

$$E_a = C_{kw} \text{ x } T \text{ x } Cp$$

Where E_a is annual electricity output in kWh; C_{kw} is turbine capacity, in kW, T is time 'online' expressed as hours per year; Cp is the average coefficient of performance (based on average wind speed).

Assuming the 900 kW turbine for which output data are displayed in Figure 7.39 is online all year (8 760 hours) at a site with an average wind speed of 12 m/s (Cp = 0.44), the annual electricity output would equate to: 900 x 8760 x 0.44 = 36 468 960 kWh, or 36 960 MWh.

Installation of larger wind turbines may require an Environmental Impact Assessment to be carried out, and potential interference with aviation and telecommunications must be assessed. There are few maintenance requirements but a service check should be performed at least every two years (Carbon Trust, 2008).

Applicability

The potential to exploit particular RE resources on site depends on location- and site-specific factors such as climate, shading, available space, etc., as summarised in Table 7.30. These issues are not barriers to investment in off-site RE installations, although the opportunities for investment in off-site RE may depend somewhat on the national prevalence of RE schemes.

Economics

Subsidies

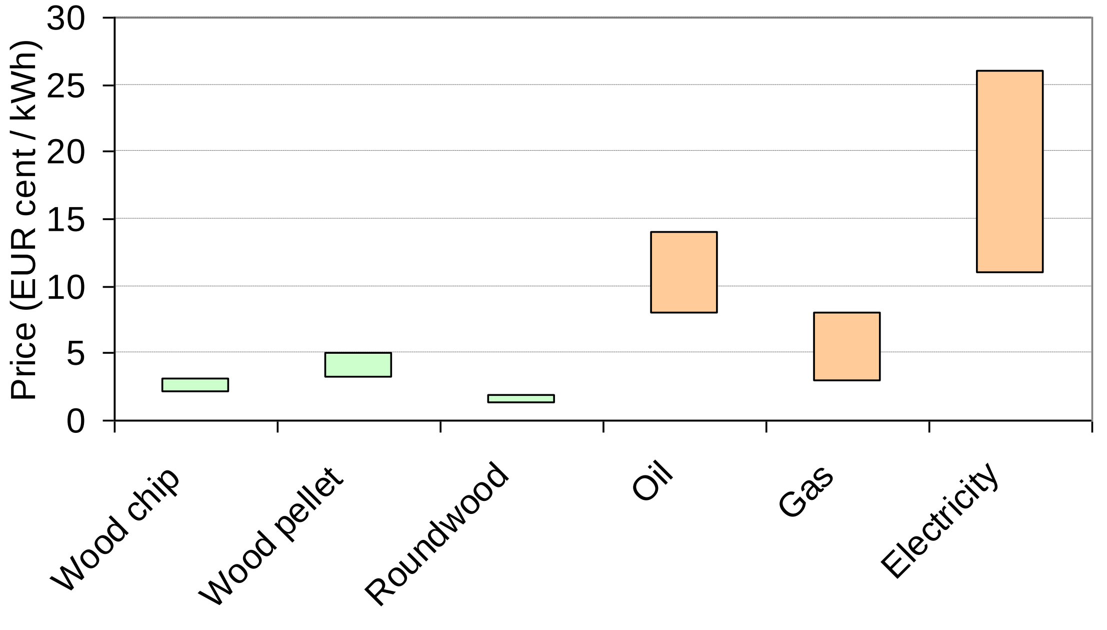
Subsidies may be available for the installation many RE technologies, reducing net installation costs and payback periods. Such schemes vary across countries. In the UK, the capital cost of many RE technologies can be offset against tax under the Enhanced Capital Allowance scheme. In some countries, RE electricity fed into the national grid is eligible for feed-in tariffs significantly above market electricity prices. These subsidies are referred to for specific RE technologies, below.

Biomass

Wood is a relatively cheap fuel although prices vary considerably depending on sources, transport distance, quantity purchased and preparation, from less than EUR 1.50 per MWh for delivered roundwood (logs) to over EUR 5 per MWh for delivered pellets (Figure 7.40).

Wood pellet boilers of 125 kW and 250 kW capacities are available for prices of EUR 30 000 to EUR 45 000 (excl. VAT), respectively. Installation of the complete heating system, including water storage tanks, approximately doubles the price, leading to total installation costs from approximately EUR 230 up to EUR 530 per kW installed capacity (Carbon Trust, 2008). Payback periods are estimated at five to 12 years.

Subsidies may be available for the installation of wood heating systems, reducing net installation costs and payback periods. For example, biomass boilers are covered by the Enhanced Capital Allowance scheme in the UK.



NB: Prices per delivered fuel, including taxes, and chipped/pelleted wood.
Source: Carbon Trust (2009); Energy.EU (2011).

Figure 7.40: Price range for wood fuel in UK, and price range for oil, gas and electricity across the EU, expressed per kWh energy content

Solar thermal

As with other RE options, installation costs vary considerably depending on situation-specific factors, especially the location of the collectors relative to the water storage tanks. In Germany, the retail price of flat plate solar collectors is approximately EUR 400 per m^2, although wholesale prices for large projects can be significantly lower (EUR 170 to EUR 250 per m^2). Total installation costs may be upwards of EUR 850 per m^2 of flat plate solar collectors, and upwards of EUR 1 000 per m^2 of evacuated tube collectors (Carbon Trust, 2008).

Figure 7.41 presents indicative payback times for a system costing EUR 850 m^2 to install, with outputs ranging from 200 to 800 kWh per m^2 per year, and at different energy prices. For installation costs to be paid back within the maximum collector operating lifetime of 25 years, energy prices need to be above EUR 0.04 per kWh for a high output system, and EUR 0.17 per kWh for a low output system. A typical payback time, for a system with an output of 400 kWh per m^2 per year and an energy price of EUR 0.10 per kWh (electricity), is approximately 20 years. In some circumstances, where systems achieve high output and displace expensive electric heating, payback times can be as low as five years. These payback times do not consider interest or discount rates.

In practice, payback times may be significantly reduced if government financial assistance is provided for solar thermal system installation. Solar thermal systems are covered by the Enhanced Capital Allowance scheme in the UK. In section 9.2, an example is provided of solar thermal installation in a German campsite with an estimated payback time of 10 years compared with gas heating owing to the availability of a government subsidy for installation.

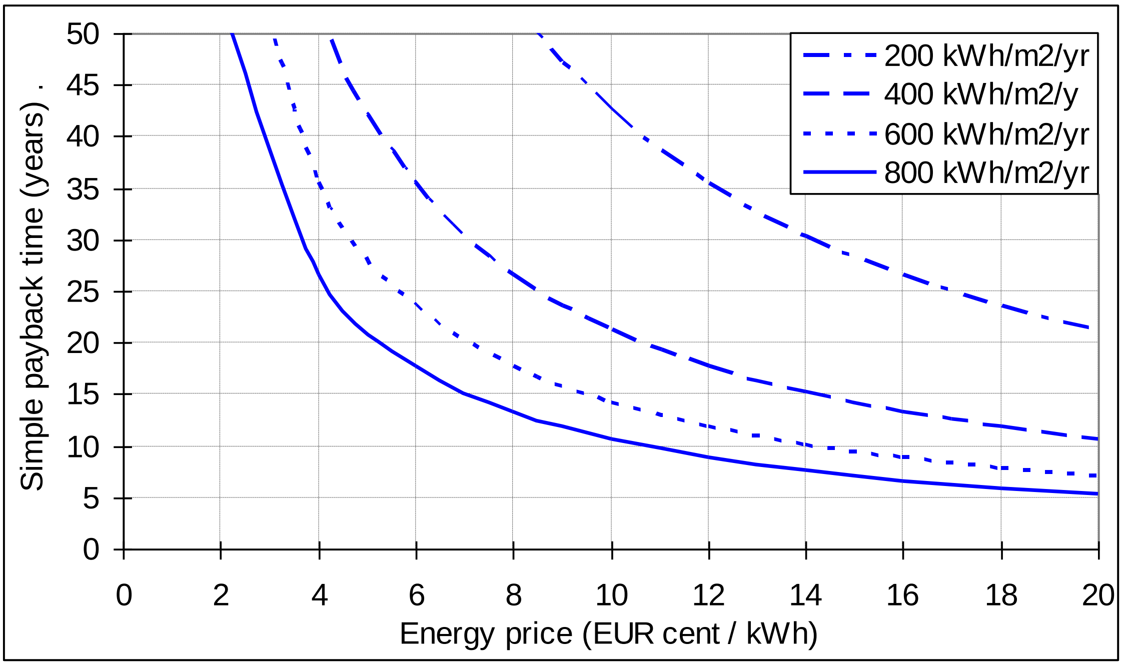


Figure 7.41: Simple payback time for solar thermal systems at different energy prices and annual thermal output, assuming an installation cost of EUR 850 per m^2

Solar PV

The price of solar PV cells has declined rapidly over recent years. The Carbon Trust (2008) quoted installation costs of approximately EUR 6 000 to EUR 9 500 per kW capacity, whilst a typical UK installer quotes installation costs ranging from EUR 2 100 to 3000 per kW installed capacity depending on system size (South-facing, 2012).

Many countries now implement a feed-in tariff for electricity generated by solar PV electricity. The value of this tariff in the UK varies depending on installed capacity, from EUR 0.10 to

EUR 0.255 per kWh (Table 7.37), is guaranteed for 25 years at an inflation-indexed rate, and can be claimed whether the electricity generated is used on site or is exported. Feed-in tariffs provide an additional return on investment over and above savings made through avoided purchasing of grid electricity.

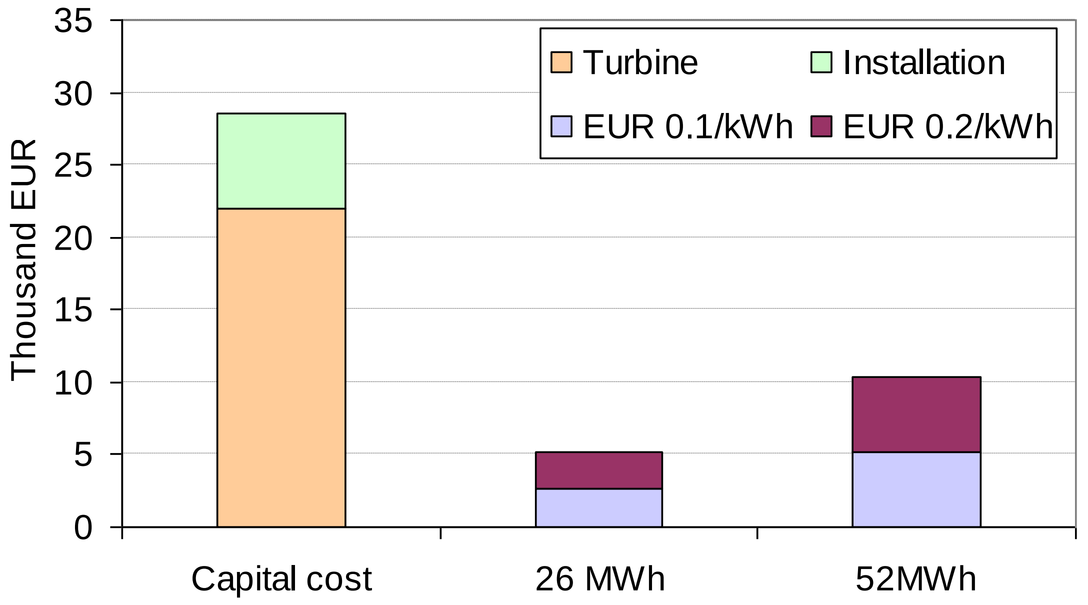
Based on the above information, assuming electricity output of 850 kWh per kW installed capacity in the UK, and an electricity price of EUR 0.1 to EUR 0.2 per kWh, payback times of eight to 11 years are achievable. Solar PV payback times will vary significantly depending on country-specific feed-in tariffs and electricity prices.

Table 7.37: Feed-in tariff rates for electricity generated by solar PV systems of different capacity in the UK

System size (kW)	0 – 4	4 – 10	10 – 50	50 – 250	250 – 5 000
FI tariff (EUR/kWh)	0.255	0.198	0.179	0.152	0.10

Wind

The lifetime of a wind turbine is approximately 25 years. The capital costs of small-scale turbines are up to approximately EUR 22 000 for a 20 kW model (Carbon Trust, 2008). Additional costs are associated with the site suitability survey, applying for planning permission and grid connection and metering. The return on investment for wind turbines involves a number of components, and is highly dependent on local and enterprise-specific aspects. Firstly, demand from the grid and associated electricity prices can be avoided. Secondly, electricity may be sold to the grid. Thirdly, produced electricity may be eligible for government support such as feed-in tariffs. Returns are therefore heavily dependent on the price of electricity and any government support schemes, but may be optimised by controlling the quantity and timing of generated electricity used on site and exported to the grid. For example, it may be worthwhile to invest in battery storage in order to store electricity generated overnight and sell electricity generated during the day at higher daytime electricity rates. Figure 7.42 provides an indication of capital costs and possible returns for a 20 kW wind turbine. The payback period ranges from 2.7 years (52 MWh annual output valued at EUR 0.2 per kWh) to 11 years (26 MWh annual output valued at EUR 0.1 per kWh).



NB: Assumes additional installation costs equivalent to 30 % of turbine cost; EUR/kWh reflects electricity price plus any subsidies.

Figure 7.42: Capital cost and potential annual returns for a 20 kW wind turbine at different annual outputs and output values

The payback period for large free-standing turbines of 0.5 to 5 MW capacity is typically between four and eight years on appropriate sites (Carbon Trust, 2008). Accommodation enterprises may avail of such returns directly by installing free-standing turbines in rural areas, or indirectly via investment in off-site wind farms.

Driving force for implementation

The main driving forces for installation of RE on accommodation premises are:

- government financial assistance for RE installation
- feed-in tariffs for generated RE
- GHG emission reduction
- corporate social responsibility
- to improve business image.

Reference companies

The HES publication 'best Practices Guide – successful RE technologies integration in SME hotels' (HES, 2011) provides a range of examples of RE applications in accommodation enterprises. Two additional examples are summarised below, for a large and small accommodation enterprise respectively.

Crowne Plaza Copenhagen Towers

In addition to the use of geothermal energy for heating and cooling (see section 7.4), the 360-room Crowne Plaza Copenhagen Towers hotel incorporates ultra-thin solar PV panels on all sunny exterior surfaces. These generate 200 000 kWh electricity per year, approximately 8 % of on-site electricity demand.

Huerta Cinco Lunas

Huerta Cinco Lunas is a traditional Andalucian farmhouse ('finca') providing bed and breakfast accommodation in three rooms. It was renovated using local materials in the traditional style, which includes small windows and thick walls made of stone and limestone plaster painted white. The high thermal mass of this design reduces summer daytime temperatures and avoids the need for air conditioning. All space and water heating is provided by renewable sources, avoiding the use of propane gas. During summer, energy for heating hot water is provided by 2 m^2 on-site solar panels. During winter (approximately 100 days per year), space and water heating is provided by a wood pellet boiler that consumes approximately 3 tonnes pellets per year (bought locally in 15 kg sacks at a total cost of EUR 730 per year). Installation costs were EUR 6 591 for the wood pellet boiler, and EUR 2 367 for the solar panels. Residual energy requirements for operation of pumps and appliances average 7 kWh per day, and are supplied by grid electricity (Huerta Cinco Lunas, 2011).

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