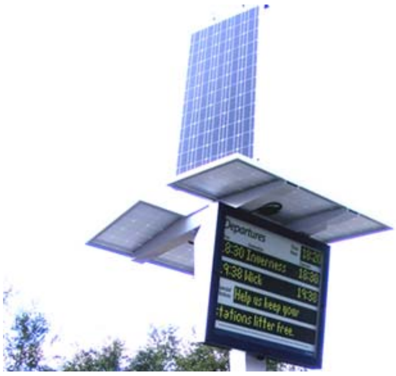
Guidance on Non-traction Energy Efficiency



RESEARCH AND DEVELOPMENT

Written by:

Ricardo Rail Ltd

Published:

April 2017

Guidance on Non-traction Energy Efficiency

1 Introduction

This document provides guidance on retrofit energy efficiency improvement measures that are suitable for non-traction aspects of the rail industry. It is intended for a diverse audience that includes:

- Energy, environment, and sustainability managers
- Station managers
- Procurement teams
- Facilities managers
- Budget holders

By improving energy efficiency, operators across the rail industry will be able to reduce their carbon emissions and achieve cost savings, allowing money to be directed back into improving customer experience and overall company performance.

The focus of this guidance is on **retrofit** energy efficiency measures (that is, those measures that can be applied to existing facilities). However, all aspects of the guidance are appropriate for consideration at the design specification stage.

This document deals with non-traction energy efficiency, which is defined as the buildings and infrastructure associated with the rail industry, such as station buildings, depots, and car parks. These areas are responsible for over 10 % of the energy used in the rail industry and represent a significant business improvement opportunity.

2 Planning your project

This section provides guidance on how to plan for effective energy management in your company or at your site. It looks at the steps required to develop and implement energy efficiency projects, and provides advice on how to create and get the most out of an energy efficiency strategy.

2.1 The role of energy management

Most businesses in the rail industry have considerable potential to save energy, reduce costs, cut greenhouse gas emissions, and improve resilience by implementing a structured and integrated approach to energy management. Doing this enables cost-effective energy efficiency improvement opportunities to be identified and implemented in a systematic way that best aligns with day-to-day business operations. Introducing an effective energy management strategy will lead to cost savings, allowing money to be directed back into improving the experience of customers travelling by train and using railway stations and, ultimately, the overall performance of your business. Having a well-planned energy management approach can also have additional benefits, such as enhancing staff morale and company image.

There are a number of energy management standards that can help businesses to approach energy management in a systematic way. Perhaps the most well-known are the European standard BS EN 16001 (Energy management systems)[1] and its international successor ISO 50001 (Energy management)[2]. It is not mandatory for a company to become accredited against one of these standards. However, it is good practice to adhere to the principles so that a robust set of energy management practices and procedures are created that can survive organisational changes, such as people leaving the company. Energy management can also be considered to be a subset of environmental management. Therefore, an energy management system can be part of a company's wider environmental management system.

1 www.bureauveritas.com/services+sheet/energy+management+systems+en+16001+certification

2 www.iso.org/iso/home/standards/management-standards/iso50001.htm

A typical model for an energy management system, as outlined in ISO 50001 and BS EN 16001, is illustrated in Figure 1. This shows the overall structure and process for the system – from developing a policy, through to planning and implementing it. It includes processes for monitoring, evaluation, and feedback for continuous improvement.

Figure 1 - Example of an energy management system model

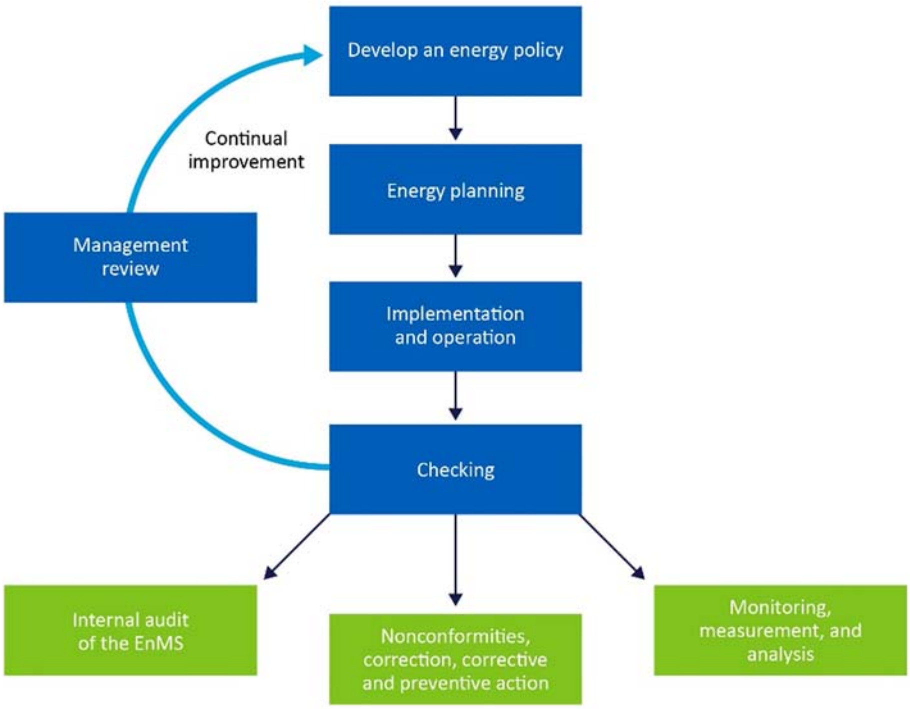
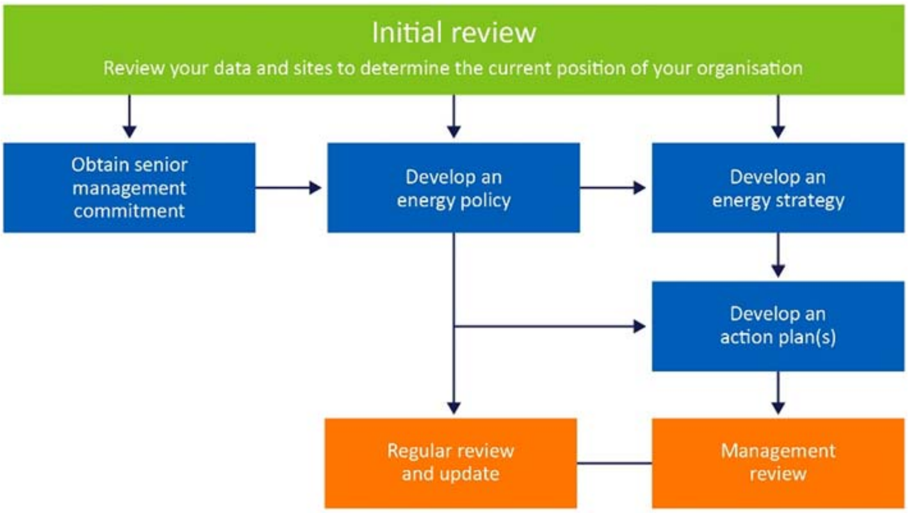


Figure 2 shows the steps that companies should follow when developing an energy management system. The first step should be to review data, sites, and any previous actions undertaken to determine the current status of energy management. This will form the baseline against which future progress can be measured. At this early stage, it is also important to obtain buy-in to the system from senior management. Evidence shows that, without management support, an energy management system is likely to falter or have focus diverted from it by other priorities.

Figure 2 - Developing an energy management system



Other key elements of Figure 2 are discussed in more detail in the following sections.

2.1.1 Develop an energy policy

Once you have established your baseline and obtained buy-in from senior management, the next step is to develop an energy policy.

An energy policy should provide a clear set of objectives for energy management. These should be formulated and discussed in collaboration with stakeholders at all levels (see Section 2.4 – Identifying and engaging stakeholders) to ensure they are practicable and fit with day-to-day business activity. This will help to ensure that energy management is accepted and embedded in routine company operations. The energy policy will provide the basis for a more detailed energy strategy and associated action plan(s). In line with the energy management systems standard BS EN 16001, an energy policy should:

1 **Define the scope and boundaries of the energy management system** – for example, which sites and facilities does it cover? Which energy supplies are included?

2 **Be appropriate to the nature and scale of the organisation's energy use** – a company with a large number of sites or a particularly large and complex station may require a more detailed policy.

3 **Include a commitment to continuous improvement in energy efficiency** – this sets out the company's aspirations for the future and in the case of the train operating companies, for at least the life of their franchise.

4 **Include a commitment to ensure the availability of information and of all necessary resources to achieve objectives and targets** – for example, this may include committing to assign energy management roles, responsibilities and budgets.

5 **Provide the framework for setting and reviewing energy objectives and target**s – the policy should set out how often the company intends to review progress.

6 **Include a commitment to comply with all applicable requirements relating to the organisation's energy supply and use** – this may include legal compliance requirements and voluntary actions.

7 **Be documented, implemented, maintained, and communicated to all people working for and on behalf of the organisation** – the policy should be provided to all personnel and be available via a central system.

8 **Be regularly reviewed and updated** – the policy should state the date it will next be reviewed.

9 **Ideally be made available to the public** – for example, on the organisation's website. This should also include actions to share best practice both within the rail industry and beyond.

An energy policy can form part of a wider corporate social responsibility (CSR) policy. It should be concise – a couple of pages at the most. The detail on how the objectives will be achieved should be contained in a separate energy strategy and energy action plan(s).

2.1.2 Develop an energy strategy and energy action plan(s)

An energy strategy sets out a company's approach to energy management and states how the objectives outlined in the energy policy will be achieved. It should provide uniform guidance for decision makers across a range of areas – from the people involved in delivering the targets to those holding the budgets required. When developing an energy strategy, you should aim to include the elements described in Table 1.

Table 1 - Elements of an energy strategy and action plan

Governance and resources	The strategy should clearly define all required energy management roles and responsibilities in detail. This will include confirming the responsible person for day-to-day delivery of the energy policy and implementation of the strategy (for example, the energy manager), and those individuals or departments with a supporting role. Accountability for energy consumption should be devolved to a level that encompasses all employees. The management team should be engaged in the development of the strategy and should ensure the availability of resources required to establish, implement, maintain, and improve the energy management system.
Compliance	The strategy should include details of any energy-related regulations that the business needs to comply with. For example, this might include the CRC Energy Efficiency Scheme and the Energy Savings Opportunity Scheme (ESOS). Important elements to cover include responsibilities and actions required for compliance, such as data collection and reporting requirements, and associated timelines. Some compliance activities may require specific budget allocations – this should be noted in the strategy – and senior management engaged as appropriate. Regulations change on a frequent basis and it is important that the strategy recognises this and includes a regular 'horizon-scanning' exercise to ensure that forthcoming changes can be noted and planned for.
Investment	Information on specific budgets that have been ring-fenced for energy projects should be described. Details on how potential energy efficiency projects will be assessed and the methods by which business cases will be developed should also be included. This will allow rational comparison of energy projects to other investment opportunities in the business.

Table 1 - Elements of an energy strategy and action plan

Procurement	There are two areas of procurement that should be considered in an energy strategy. The first is the procurement of energy itself. The second is the procurement of equipment, services, and buildings that will use the energy. The energy service provision arrangements should be in line with the objectives stated in the energy policy. However, the more important aspect of energy management is managing how energy is used. Therefore, the company procurement process should include energy efficiency criteria and references to appropriate standards (for example, ENERGY STAR® for office equipment[a]). This allows the inclusion of energy elements in key procurement contracts and actions, such as utility contracts, and specifications for new buildings; lighting; heating, ventilation and air-conditioning (HVAC); IT; and small power-consuming appliances. It may also be appropriate to describe the strategy that will be used to communicate energy efficiency objectives to contractors and tenants. For example, this may include setting specific energy efficiency or data management targets as part of third-party contracts.
Action plan(s)	The strategy should be supported by a company-level action plan, which should outline the specific actions that will be undertaken; and the responsible person, budget, and timeline for each action.
Monitoring and communication	It is important that the strategy includes a plan for monitoring and communicating processes, including how often this will occur, in what format, and who the intended audience will be. For businesses, it is important to use this information to determine where improvements could be made and for celebrating success.

a. https://www.energystar.gov/

As part of any energy management system, it is important that records and documents are controlled. All documents should be reviewed and revised periodically if necessary. The frequency and responsibility for reviews should be documented as part of the energy strategy. For example, the strategy itself could be reviewed annually by the energy manager (or equivalent), or the action plans may require review on a monthly or quarterly basis.

For an energy strategy to be successful, it is important that it is developed in discussion with the senior management team and is signed off by a senior member of staff with direct responsibility for energy.

2.2 The importance of data collection and analysis

Reliable, timely, and detailed data on energy consumption, and its use across the company and its sites, is important for effective energy management. Robust data can help you identify efficiency opportunities, allows you to measure the effectiveness of improvements and progress against targets, and can help anomalies to be identified and investigated.

Your energy strategy should identify the type and source of energy data to be collected, the person responsible, frequency of collection, format for recording it, and how it will be used.

2.2.1 The data collection process

Depending on your company and its site arrangements, sources of energy data might include half hourly meter (HHM) or automatic meter reading (AMR) data, manual meter or sub-meter readings, or invoice data from energy suppliers. The most accurate and comprehensive data is that from HHMs or AMRs, as the high frequency of its collection allows for detailed profiling of energy consumption. Data from invoices is often considered the least accurate as it may be based on estimates and is generally less frequently collected – invoices may be monthly or even quarterly.

Regardless of the choice of data source, the data should be recorded regularly and in a consistent format. It is best practice to record the information electronically on a centralised system and to retain the data for a minimum of 7 years.

Setting up a data collection process should be accompanied by identifying and reviewing energy supply and use by the organisation. The standard for energy management systems, BS EN 16001, suggests that this process should include:

1 A review of past and present energy consumption, and the factors that affect energy consumption, such as footfall levels at different times of day.
2 Details of areas of significant energy consumption – in particular, significant recent changes in energy use.
3 An estimation of energy consumption for the coming reporting period against which actual consumption can be measured to identify potential instances of energy waste.
4 Details of all the people working for and on behalf of the organisation whose actions may lead to significant changes in energy consumption. This should include specific projects that may temporarily drive up energy use, such as station refurbishment.
5 Details about how opportunities for improving energy efficiency will be identified, quantified, and prioritised.
6 A register of opportunities for saving energy. It is recommended that a log is kept of all identified opportunities, decisions on implementation, status, and data on savings achieved. It is important to capture information even if an implemented opportunity was not successful as this can inform future actions and decisions.

Assessing all of these factors will strengthen your ability to make the best use of your data, help you to better understand your energy consumption and to plan for the future.

2.2.2 Measuring performance and continuous improvement

Whatever source of data is used, it can be compared across similar sites or over specific time periods (for example, over a day, week, month, or year) to allow trends or changes in the consumption pattern to be identified. This will help to demonstrate the outcome of implementing a particular energy efficiency measure.

To drive improvement, energy efficiency targets should be clearly documented in the energy strategy. These should be consistent with the energy policy, and include a commitment to improve energy efficiency and to comply with relevant legal obligations. The targets should be set for controllable parameters that have a significant impact on energy efficiency and should be specific, measurable, attainable, realistic, and time-based (SMART).

It is important for the energy strategy to outline clearly how performance against targets should be measured. Key performance indicators (KPIs) should be set out as part of the strategy and, where possible, benchmarked against any published industry standards. Establishing KPIs and benchmarking will help to focus improvement effort. Effective KPIs should be:

- Clearly defined
- Related to a company's strategic objectives
- Flexible enough to take into account the dynamic nature of a company's operations
- Timely
- Relevant
- Measureable or quantifiable
- Objective rather than subjective
- Aligned with other KPIs

Some energy KPIs include issues around ensuring the completeness and/or quality of energy data, energy costs, energy usage, or greenhouse gas emissions.

Measuring performance allows for informed updates of the energy management system and drives continuous improvement. It also enables successes to be identified and celebrated.

More detailed information on the collection and use of energy data is provided in Section 3 – Understanding energy use.

2.3 Embedding energy management within a company

To embed energy management successfully within its culture, a company must first ensure senior management buy-in. Then that all employees, associates, tenants, and sub-contractors are aware of its energy policy and energy strategy. Disseminating the energy policy and energy strategy should be included in the staff induction processes and any updates clearly communicated. Internal communication on progress against targets should also be delivered regularly.

While an energy policy is designed for internal use, some companies chose to communicate information about energy policy externally to demonstrate their commitment to good energy management. This information is normally published on the company's website or in an annual report to demonstrate good environmental, cost and risk management and to boost public image.

2.4 Identifying and engaging stakeholders

Stakeholder engagement is the process by which a company involves those individuals who can influence the implementation of decisions or who may be affected by the decisions made.

Stakeholders are individuals, groups of individuals or other organisations that have an interest in your company and the efficiency with which you manage your energy consumption. They can be internal or external to your organisation and may have varied interests. Stakeholders might include:

- Internal stakeholders

  These are mainly employees. Senior management will be important stakeholders in all energy management decisions. Individual staff members who will be involved with or impacted by any energy management projects you implement (such as individual station managers) are also extremely important.

- External stakeholders

  External stakeholders might be shareholders, neighbours, customers, tenants, supply chain companies, energy suppliers, regulators, and unions. It will be important to engage with these in instances where your energy management strategy will have an impact on them or where you wish to promote your energy efficiency activities.

Stakeholder engagement is important, particularly with internal stakeholders, as implementing a successful energy policy and energy strategy requires support and commitment across the whole company. Some of the key benefits of effective stakeholder engagement include:

- Improving the quality, acceptance, and effectiveness of an energy policy and strategy, and any projects carried out.
- Helping to secure buy-in and long-term support for the energy policy and strategy from senior management and other key decision makers.
- The decision-making process is more robust and transparent.
- Decisions made are based on a broader knowledge base, which helps to mitigate any associated risk.
- New ideas can be presented and further opportunities revealed.
- External stakeholders will have a direct impact on your organisation's energy consumption and therefore a joint approach with them is needed if

targets are to be met. Knowledge sharing between stakeholders can create a more robust process and enhance energy strategy.

2.4.1 Barriers to effective engagement

Barriers to engaging with stakeholders effectively include:

- A lack of understanding of the topic that is being considered.
- Stakeholders not seeing the need for the change.
- Lack of resources.
- Geographical spread of employees or sites.
- Poor communication or management.
- Engagement or topic not aligned with company strategy, culture, or values.
- Cynical employees or lack of trust in management or engagement teams.
- Inappropriate engagement methods used.

Having a well-planned engagement strategy is important to overcome such barriers.

2.4.2 Planning an engagement strategy – tips for effective engagement

When beginning a stakeholder engagement process, it is important to consider the **why**, **who**, and **what** of stakeholder engagement.

- Why?

  Having a clear picture of the purpose of the engagement is important. What do you want to achieve and how will the stakeholder engagement support this? For example, the aim might be to:

  - Develop a new energy policy and strategy.
  - Update the existing policy and strategy.
  - Encourage behaviour change within the organisation.
  - Continue to raise awareness, and support an existing policy and strategy.
- Who?

  To identify the stakeholders who should be involved, ask yourself:

  - Who is directly responsible for decision making that is relevant to the aim?

    - Are there other influencers who may not be direct decision makers?
    - Who will be affected by the decisions made?
    - Are there individuals who can obstruct a decision if they are not involved?
    - Who was involved in previous consultations?
- What?

  You should set the scope of the engagement by determining elements such as the subject areas, any parts of the company or site you wish to target, and the timescales. It is important to consider the context and what engagement has been carried out before to determine the most appropriate scope.

Once you have identified the key stakeholders, you should consider factors such as their expectations, knowledge on the subject, existing relationships, level of influence, and any cultural context.

Tips for developing a stakeholder engagement strategy

- Gain senior manager buy-in by making a strong case for improving energy efficiency and developing the right mind-set at the top levels of the organisation.

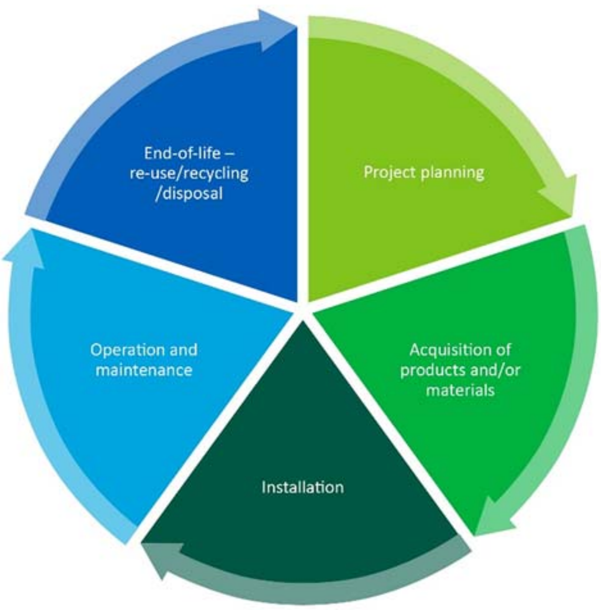
  When presenting business cases to obtain senior management buy-in, don't just focus on savings, but present income generation potential, whole lifecycle benefits, and alignment with company targets and objectives. Demonstration of previous successes can also help obtain buy-in at senior levels.
- Use the **why**, **who** and **what** principles to develop a clear strategy/vision that is linked to your organisational goals.
- Get to know your stakeholders and what their drivers are.
- Clearly communicate to stakeholders and employees what is expected of them.
- Provide relevant training or retraining where required.
- Use innovative methods to encourage stakeholders to act and to recognise good practice.
- Consider the use of working groups or energy champions if appropriate.
- Periodically review progress and amend the approach as required.

2.5 Risk assessment

When preparing to implement energy efficiency projects, the assessment and management of risks should play an important part in the planning process. A well-conducted risk assessment provides an objective assessment of a potential project, and proper accounting of the risks and uncertainties. This allows you to carry out contingency planning too, and can increase confidence in decisions and investments made. A risk assessment and proposed mitigation measures should always form part of the business case for any new project.

When assessing project risks, it is best to look at the whole lifecycle of the project. This means starting by identifying all products, processes, and activities from the planning stages through to a project's end of life. Figure 3 provides an example of the lifecycle of an energy project.

Figure 3 - Example lifecycle of an energy project



Once you have determined the products, processes, and activities throughout each stage of your project lifecycle, you should:

- Identify underlying sources of risk, starting with a complete chart of the proposed project (including major activities, timing, and resources). Risks around energy projects are likely to fall into one or more of the following categories:
  - **Political/regulatory risks** – for example, a change in public policy, such as policy around subsidies, may affect project income.
  - **Business/strategic risks** – these are risks that can impact on the reputation of an organisation, such as the risk of being associated with a specific technology or supplier.
  - **Installation/construction risks** – these may include risks during installation, construction, and testing new technologies; and those associated with third-party activities. The risk of any project to customers using rail facilities should always be considered.
  - **Environmental risks** – for example, damage to the environment during installation or operation.
  - **Financial risks** – any issues around access to capital or other financial uncertainties will impact on the business case and viability of a project.
  - **Market risks** – increases in the price of project inputs or fluctuations in the price of energy can have an impact on the business case for a project.
  - **Operational risks** – these risks can include a range of issues, such as unplanned breakdown, availability of resources, plant damage, or component failure.
- Determine how such risks might occur and if there are any triggers. When reviewing what situations may trigger risks, consider these internally (changes in the company) and externally (changes to energy policy).
- Establish the potential consequences of these risks under various scenarios. This should include consideration of median and worst-case scenarios.
- Outline mitigation measures to manage the risks identified. You should look at ways to avoid risks or reduce them to an acceptable level. The level of risk before and after the mitigation measure should be documented.
- Ongoing control of risks once projects have been initiated is important. Contractual and management systems should be set up in a way that allows for effective management of residual risks.

2.6 Listed buildings and conservation areas

Many rail facilities may include historic buildings (such as listed station buildings) or may be in a conservation area. In these situations, an appropriate balance needs to be achieved between building conservation and measures to improve energy efficiency. English Heritage has a number of published guides on energy efficiency and historic buildings[3] that may provide useful points of reference. These address the application of Part L of the Building Regulations to historic and traditionally constructed buildings. It is important to be aware of requirements when considering energy efficiency projects in historic buildings.

Part L (Section 6 in Scotland) of the Building Regulations covers the conservation of fuel and power. It is presented in four sections covering new dwellings (L1A), work to existing dwellings (L1B), new buildings that are not dwellings (L2A), and existing buildings that are not dwellings (L2B). Part L requirements are triggered in the following circumstances:

- When certain changes or renovations are made to thermal elements.
- When an extension or conservatory is to be added.
- When the building is to be subjected to a change of use or a change of energy status.
- When changes are to be made to controlled fittings or services.
- When consequential improvements are required.

Certain classes of historic building are expressly exempted from the need to comply with the energy efficiency requirements of the Building Regulations. This is where compliance would unacceptably alter a historic building's character and appearance.

- Listed buildings

  Listed Building Consent is required for any demolition, alteration or extension that would affect a building's character. Fixtures and curtilage buildings are treated as part of the listed building. The same controls apply whatever the grade of listing.

3 https://historicengland.org.uk/advice/technical-advice/energy-efficiency-and-historic-buildings/

- Buildings in conservation areas

  In a conservation area, the main emphasis is on external appearance. Surface materials (walls and roofs) and the details of windows, doors, and roof lights are all extremely important. Changes to these may need planning permission and consent is usually needed for demolition. Planning permission is not needed for internal alterations to unlisted buildings.

- Scheduled monuments

  Scheduled Monument Consent is required for any works that will affect a protected monument, whether above or below ground.

There are three further classes of historic and traditionally constructed buildings where special considerations apply when making provision for the conservation of fuel or power. These are:

- Locally listed buildings

  These buildings have no statutory protection unless they are within a conservation area. However, to retain their significance, it is often essential that original features and fabric are preserved in any alteration or extension.

- Buildings in national parks and other historic areas

  These may require special consideration if they help to create the townscape and landscape qualities that were among the original reasons for the designation of the area or site.

- Traditionally constructed buildings

  It is important that adaptations being considered to improve the energy efficiency of traditionally constructed buildings should take into account the technology and characteristic behaviour of the building fabric to avoid damage. This is because most traditional buildings rely on their ability to allow moisture to evaporate rapidly away (rather than on impermeable membranes or moisture barriers), and thus prevent the build-up of damp and resulting physical decay.

When considering any project on a historic building, you should review the relevant Historic England guidance documents as a first step. It is also advisable to consult your local planning authority to obtain advice[4] when planning a project in a historic area.

4 Find your local planning authority at: http://local.direct.gov.uk/LDGRedirect/index.jsp?LGSL=485

2.6.1 Planning an energy efficiency retrofit

When planning an energy efficiency retrofit, you should develop an energy efficiency retrofit plan. This is particularly important when considering retrofitting a historic building, although many of the principles can apply to any energy efficiency retrofit. The plan will allow you to weigh up the various energy efficiency measures, including their benefits, likely disruption, and any planning implications. Planning will help you to:

- Consider a wide range of factors that will influence whether a measure will be effective, appropriate, and acceptable in planning terms.
- Decide which of these measures you want to introduce and in what order.
- Develop a list of measures that are appropriate to install on your property.
- Select appropriate contractors to carry out the work.
- Identify any interdependencies between measures.

You should take the following steps[5] when planning your energy efficiency retrofit.

Step 1: Understand your building

- Assess and evaluate the condition of the building's fabric and services.
- Consider the building's heritage value and significance (such as age, architectural style, and features that contribute to its character).
- Assess the energy performance of the building envelope and its services (such as heating, lighting, and appliances).
- Think about the behaviour of the building fabric in response to heat and moisture. For example, do parts suffer from condensation, mould, or dampness?
- Consider the users' occupational requirements. For instance, how are different parts of the building used and at what times of the day?

Step 2: Identify opportunities and interdependencies with other planned works

- Is it possible to carry out energy efficiency measures at the same time as planned refurbishments, repairs, or extensions? This can help minimise

5 Based on the steps outlined in Camden's Energy efficiency planning guidance for conservation areas. https://www.camden.gov.uk/ccm/cms-service/download/asset?asset_id=3233015

disruption, and save time and money. Can work be carried out at times when customer numbers are low (such as at weekends or at night)?

Step 3: Evaluate effectiveness and risks

- You should review the cost-effectiveness of the measures being considered against the potential risks. This can help you decide which measures are best to install.

Step 4: Assess measures against heritage value and significance

- It will be necessary to balance the conservation of historic character with the introduction of the energy saving measures you select. The Camden guide provides advice on this so that you can assess those measures that are best suited to your historic building.

Step 5: Implementation

- Following step 4, you should be left with a set of appropriate energy efficiency measures that could be implemented.

2.7 Scaling opportunities across a portfolio

Many rail operators will have a large portfolio of sites and buildings. To maximise cost savings, it is important to assess whether any given opportunity may be suitable for roll-out across a wider portfolio. Collaboration between all stakeholders may achieve better economies of scale.

2.7.1 Portfolio assessment

If you wish to develop a strategic implementation plan to roll-out measures across your portfolio, you will need to consider how to assess and determine the best opportunities for scaling up. The portfolio assessment approach should contain the following stages:

Stage 1: A high-level portfolio assessment

- Benchmark and compare the types of buildings (or sites) in your portfolio with others and determine potential opportunities that may be relevant for specific building types.
- Divide buildings/sites in your portfolio into groups by type, size, and other distinguishing features relevant to energy efficiency measures, for example, group stations by category and group other buildings, such as offices, by function.

- Perform a high-level assessment of the general condition of the buildings in the group, compare across the group and, if possible, benchmark against typical/good practice.
- Determine possible energy saving opportunities and the scale of these.
- Sort group buildings into subsets according to their probable treatment to allow for the selection of sites for detailed assessment.

Stage 2: A more detailed investigation

This should include additional data collection and investigation of selected measures for sample sites from your benchmarked groups.

- Collect additional data on sites to confirm characteristics and condition, and finalise the selection of a sample of sites for more detailed investigation. Examples of data that could be collected include site type, age, building type(s), use, recent or planned refurbishment, fuels used, operational hours, and number of employees.
- It is advisable to select representative sites or buildings for audit to identify further relevant measures and to confirm the initial thinking from Stage 1.
- Perform more detailed investigations of feasibility of energy saving measures on selected sites and develop initial business cases. This will help you to determine the best potential solutions for each group.
- If possible, run trials of new projects at selected sites. This can help to verify impacts and develop the business case for wider roll-out.

Stage 3: Extrapolation and scaling of findings across portfolio

- Use findings from stages 1 and 2 to develop a suite of implementation options and detailed business cases for implementation. See Section 2.8 for more information on developing a business case.
- Apply the findings and implementation options across the subgroups in your portfolio. Develop a strategic implementation plan.

2.7.2 Benchmarking

Benchmarking is the practice of comparing the measured performance of a device, process, facility, or organisation to itself, its peers, or established norms. The goal is to inform and motivate performance improvement.

No specific benchmarks exist for the rail industry. However, it can be useful for rail companies to develop their own benchmarks to measure and compare performance across their portfolio. This can help to measure improvement and identify outliers in performance for further investigation. Suitable benchmarks may include:

- Energy use per square metre of platform (stations).
- Energy use per full time employee equivalent (offices).

The British Institute of Facilities Management (BIFM) provides 10 top tips for benchmarking facilities/properties[6], which have been adapted below:

1. **Understand your goal** for benchmarking. Do you only want to compare facilities or to improve them as well?
2. Be sure that **the way you undertake area measures** is the same as that used for other buildings or sites you have benchmarked. This will allow for direct comparison between buildings.
3. Understand the **difference between median and mean average**. The median of a set of numbers is that number where half the numbers are lower and half the numbers are higher. The **mean** of a set of numbers is the total of those numbers divided by the number of items in that set. Medians are more meaningful for benchmarking as they prevent outliers in the data (such as sites with extremely poor or good data that might be subject to issues in data collection) from skewing what a typical site looks like.
4. Identify **what outputs you want to obtain from your benchmarking** before carrying out the benchmarking itself. For example, are you looking for specific metrics for your sites or general trends?
5. **Identify the filters** you will need for comparison purposes. Examples of filters could be site age, size, type, or hours of operation.
6. Know **when** the benchmarking data was captured and **what error checks** have been carried out.
7. **Understand the data you are using for benchmarking**, its quality, and whether it is diverse enough to be representative.
8. Identify **instances where there is not enough benchmarking data** to generate meaningful conclusions.
9. Ensure **benchmarking methods are documented**, and are clear and easily replicable.
10. Ensure you have a **clear method for applying judgment and drawing conclusions** from the benchmarking data.

6 www.bifm.org.uk/bifm/news/6646

A number of guidance documents are available that present benchmark data for energy consumption, occupancy patterns, thermal comfort set points, and lighting levels. These are:

- BSRIA Rules of Thumb, Guidelines for buildings services
- CIBSE Guide A: Environmental design
- CIBSE TM46: Energy benchmarks
- CIBSE Guide F: Energy efficiency in buildings

2.8 Building a business case and preparing a project proposal

All energy efficiency projects that need funding will require a business case to be prepared. This document is for the stakeholders who will decide whether or not to allocate funds to the project. It is used to present the project, its financial case, any non-financial benefits, and to demonstrate that you have adequately assessed the risks and identified suitable mitigation measures.

2.8.1 Building a business case

The financial case for your proposal will depend on finding a balance between projected costs and savings. It is important to prepare a robust business case from reliable data and evidence, and ensure that this is subjected to rigorous evaluation. Decision makers will be assessing the project against other investment priorities in the organisation.

When developing a business case, you should:

- Understand what assets will be affected by the project, including their residual life (for example, if you are looking to replace a boiler, how long is that the boiler is likely to last before it would need to be replaced due to reaching the end of its life).
- Understand the other options that are available and carry out a high-level evaluation of each to help demonstrate why the selected option is the most appropriate.
- Evaluate the project costs including equipment and installation costs. Where possible, obtain quotes from suppliers. Costs for operation and maintenance should also be estimated.

- Calculate the cost, energy, and carbon savings from the project. If estimates have been obtained from suppliers, verify these (where possible) or find out the assumptions used so that due diligence can be carried out.
- Identify any available sources of funding.
- Calculate the internal rate of return and the net present value associated with the project.
- Determine the lifetime of the project and work out a project timetable.
- Ensure a robust risk assessment has been carried out. As a minimum, this should include consideration of technical, financial, operational, and market risks. Section 2.5 provides further details on carrying out a risk assessment.
- Consult with other interested parties (this might be other staff who will be affected by the project if it goes ahead or it could include tenants and unions).
- Include specific technology references or case studies for similar projects.
- Identify non-financial benefits. These might include lower maintenance requirements, better working conditions, lower failure rate/improved lifespan of equipment, improved safety or comfort for staff, reduced noise or enhanced reputation for the organisation.

2.8.2 Drafting and presenting your proposal

When drafting the proposal for your project, it is important that you consider what decision makers will be looking for. Your proposal will have a better chance of being accepted if it aligns with the objectives of the decision makers and is presented in a way they can easily understand. Some tips for making an effective presentation of your proposal to decision makers are:

- Understand your audience and their objectives. Where possible, address issues that are of relevance to decision makers and show how your proposal helps meet their objectives.
- Ensure that the problem is clearly articulated and demonstrate how the solution addresses this.
- Demonstrate that you have considered other options and clearly present the decision-making process for your final selection of project.
- Do not use jargon or ambiguous terms. Be clear and certain in your language.

- Show good consideration of the risks and your identified methods for dealing with these.
- Ensure you have used an appropriate financial appraisal method and present your business case in a manner appropriate for your audience.
- Outline your assumptions and evidence to support your solution and business case.
- Be clear and concise in your presentation, with well-defined recommendations for next steps. Use graphs and diagrams, as appropriate, to illustrate points. Remember to focus on the objective of the project.

If there are specific requirements for the presentation of business cases in your organisation, you should ensure these are followed. It may also be appropriate to consider how the timing of your proposal aligns with company budget allocation.

2.9 Project evaluation, monitoring, and reporting

Implemented projects should be regularly evaluated to determine how they are performing and to provide evidence to support the implementation of future energy efficiency projects.

It is important to have a clear method outlined for evaluating the success of projects that have been implemented. Your evaluation method should set out the evaluation criteria. These should include how performance will be assessed against the original objectives of the projects, the expected financial performance, and the original project timescales. The assessment of the project should cover:

- **Outputs** – the direct and immediate outputs resulting from the project.
- **Outcomes** – the short and medium-term effects of the project.
- **Impacts** – the long-term changes resulting from the project. These may be direct or indirect, positive or negative, intended or unintended.

From the assessment of the project, lessons learned should be captured – these can be positive or negative. This information should be used to inform decision making on future projects.

It is advisable to communicate the outcomes and impacts from an implemented project as part of continuous engagement on energy efficiency in the organisation. This can help with continuing to develop support and buy-in to your energy policy and energy strategy throughout the business.

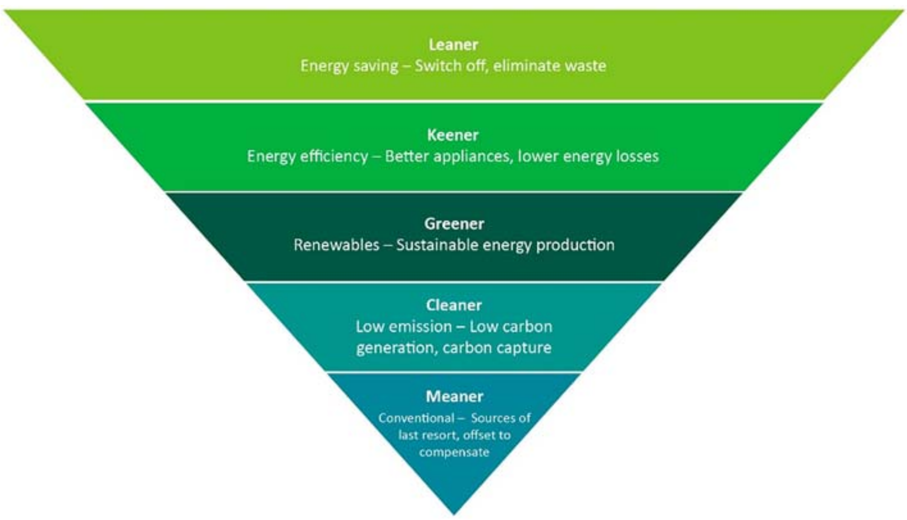
3 Understanding energy use

Understanding what is consuming energy across your company, site, or facility is an important first step in managing energy use. This section provides guidance on how to better understand your energy use and how to use the information to your advantage.

3.1 The energy hierarchy

The energy hierarchy (shown in Figure 4) provides a classification system for energy options, prioritised to assist progress towards more sustainable energy use. From top to bottom, the hierarchy flows through the order in which you should work to improve energy efficiency. By following the classification in this way, you will reach the most economical method of saving energy.

Figure 4 - The energy hierarchy



Leaner – the top priority under the energy hierarchy is energy conservation. This is the prevention of unnecessary energy use and should always be the first action taken when assessing opportunities to reduce energy use. It involves eliminating waste by turning off energy consuming devices when they are not needed, such as turning off lights when no one is on a platform or in a room.

Keener – once unnecessary sources of energy use have been eliminated, the next priority is to ensure that energy is produced and consumed efficiently. For example, this could include the use of more efficient boiler technology to convert fuel to heat energy. It can also refer to the use of a more efficient electricity generation system such as combined heat and power (CHP).

Greener – following reductions in energy use by being leaner and keener, the third priority is to incorporate renewable energy sources, such as biomass or solar, to provide on-site energy generation.

This guide focuses on these top three priorities.

3.2 Monitoring and targeting

Monitoring and targeting (M&T) is an energy management technique that enables you to understand your energy consumption, identify factors that impact this consumption, and set appropriate targets for improvement against which you can monitor performance. The objectives of this process are outlined in Table 2.

Table 2 - The objectives of monitoring and targeting

Objective	Description
Identify avoidable waste	This is waste that occurs at random because of poor control, unexpected equipment faults, or human error, and which can usually be put right quickly and cheaply.
Quantify savings from installed measures	These must take full account of variations in weather, levels of production activity, and other external factors. This is one of the most valuable results of M&T.
Identify fruitful lines of investigation for energy surveys	Rather than starting an energy survey with no clear agenda, you can go prepared with specific questions to ask, prompted by observed erratic or unexpected patterns of energy consumption.

Table 2 - The objectives of monitoring and targeting

Objective	Description
Provide feedback	Provide feedback to raise staff awareness, to improve budget setting, and to demonstrate the value of a particular investment to senior management.
Set performance targets	Your M&T system should provide the evidence base for the savings that are technically feasible, and should feed into any policy and strategic commitments made. Your M&T system should also allow you to set and monitor targets and performance parameters for individual areas.

The rail industry has a large and complex energy consumption profile and suitable time should be allowed to carefully plan an M&T system. A number of systems are already in place throughout the industry. These are based on manual or automated data collection, or a mixture of both. The routine operation of your M&T plan should not be time consuming or complex. If it is, your plan should be reviewed. The advantages and disadvantages of different data collection methods are shown in Table 3.

Table 3 - Methods of M&T data collection

Method	Advantages	Disadvantages
Manual	• People taking manual meter readings can also carry out other checks while they visit the site. These might be structural checks, water leakages, and security checks. • They can also check if the metering arrangement has been altered, such as adding new end uses to the meter.	• Human error when reading the meters. • People need to be sent to the site, which may be costly. • Higher chance that bills will be incorrect. • Can be impractical and unreliable. • Manual reading may not be at the correct interval due to unforeseen circumstances such as holidays, illness, and bad weather. • Safety risk due to location of meters such as lineside or difficult-to-access locations.
Automated	• Lower cost long term. • Real-time fault detection. • No human error. • Lower data-processing time. • Potential for automation. • Bills based on actual consumption.	• Reduces the number of opportunities to identify other issues such as a breach of security. • Reliant on IT communications. • IT security needs to be increased. • Records need to be backed up regularly as no paper copies exist. • Significantly more data, which increases data-handling requirements.

Table 3 - Methods of M&T data collection

Method	Advantages	Disadvantages
Mixture	• Personnel can carry out on-site surveys. • Can automate data collection for sites where this will be cost-effective. • Can be used as a method of validation.	• The two separate sources of information must be merged periodically.

At larger energy consuming sites with profile class ‘00’ meters (Code of Practice 5 or lower meters), suppliers are obliged to install HHMs. These are fiscal electricity meters, meaning that they are directly used by suppliers as a reference for billing. They record data at 30-minute intervals. You can install HHMs on smaller sites, but this may incur a cost. If HHMs are present on your sites, a regular copy of the data should be requested from the supplier or service provider. Some suppliers provide web tools to help in analysing the data. This high-quality data can be used to assess the energy performance of your sites and visualise demand patterns.

Rolling out an M&T plan will require several factors to be in place. Once the plan is up and running, routine maintenance is simple. The three key components necessary to operate an M&T plan effectively are:

- Consumption data
- Driving-factor data
- Methods of calculating expected consumption

Consumption data may come from meters, delivery invoices (such as heating fuel oil), or proxy measures such as hours-run counters or ammeters. The critical task is to ensure that the data is synchronised as closely as possible with the required assessment intervals. Repeatability of measurements is highly important.

Meters should be read by in-house staff. It is better not to rely on invoice data as this may be inaccurate. Suppliers do not read private sub-meters, which are an important source of data. In-house meter readings should be scheduled at appropriate intervals, such as daily or weekly. The appropriate timing will be dependent on factors such as ease of access to site, annual energy consumption, and tariff structure. The data from half-hourly metered supplies will be more reliable and you should make arrangements to get this data as near to real time as possible.

Automatic meter reading is beneficial when meters are inaccessible, too remote, or too numerous for manual reading to be an option. They also provide a higher quality of data that can be available in real time. Meters with pulse outputs or serial communications interfaces are needed, along with additional components such as:

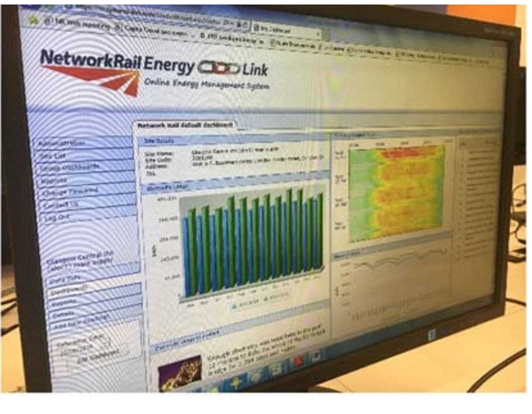
- Data loggers (when the meter has no recording capability of its own).
- Data concentrators (when data from several logging devices needs to be arranged).
- Gateways (for passing data between networks using different protocols or isolated by a firewall).
- Software to interrogate the devices and record results in a database.

Driving-factor data is data on the factors that directly influence energy use. It will often include degree-day statistics, footfall, hours of operation, hours of darkness, number of occupants, and size of building.

Driving-factor data needs to be synchronised with the assessment interval used for the consumption data. Finding appropriate driving-factor data can be challenging. Try a simple approach first and add more complexity as you progress.

Daily collection and review of data is favoured. This will highlight any metering or communication issues, thus minimising loss of data. Weekly or monthly to start off with is more manageable, but whatever your chosen assessment interval, the M&T process should be very easy and include:

- Collecting the data (consumption and driving factors).
- Creating an energy-spend league table.
- Checking the data behind any significant overspend.
- Asking for explanations.

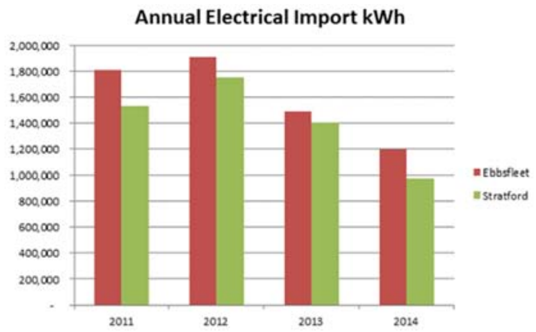


In many cases, excessive use of energy will be justifiable. In other cases, there will be some avoidable waste that can be easily remedied. By taking account of influencing factors – such as extreme weather, longer working hours, and special projects – it will be easier to understand reasons for excessive energy use and further analysis may be unnecessary. In other cases, an investigation and remedial work can be carried out if economical. If excessive consumption persists, this will be highlighted in future reports. Half-hourly data may prove invaluable for persistent excessive consumption as the level of detail allows the exact time of day that the energy is used to be pinpointed.

The lower end of the energy-spend league table should also be assessed occasionally. Persistent underspend can suggest extremely proactive staff or targets that are too lenient. Lessons should be learnt and shared.

3.2.1 Case study: Monitoring and targeting energy use

At Ebbsfleet and Stratford stations, new electrical sub-meters were installed between 2013 and 2014. These were connected to an automated data logging system, along with the existing mains electricity and gas meters.



Over time, the data from the new system were analysed to help identify opportunities for optimisation of station control systems, especially for heating and cooling. As a result, changes have been made to time schedules for air conditioning, and to the way the chillers are operated, to keep these systems switched off when the areas they serve are unoccupied.

Further details of the project are provided in Table 4.

Table 4 - ROI figures for Ebbsfleet and Stratford stations project

Capital cost of project	£59,917
Estimated annual savings (£)	£77,446
Estimated annual savings (kWh)	730,872 kWh
Project payback	0.8 years
Lessons learned	In future it will be possible to build exception reports and alarms into the process to sustain the savings achieved.

3.2.2 M&T software

There is an abundance of M&T software available. If you choose to use this type of software, ensure that your selected package is capable of performing some of the following:

- Showing all data and a subset of data easily.
- Displaying demand-profile charts in the form of scatter graphs, deviations, cumulative sum (CUSUM) control chart, heat mapping, and/or 3D graphing.
- Assessing physical performance of the systems (rather than energy accounting).
- Providing a means of setting up expected consumption calculations.
- Providing analytical and target setting functions.
- Generating league tables of energy overspend and underspend.

It is possible to build in-house software using spreadsheets, but this can be time consuming. If you choose this option, you should ensure that other members of staff understand the process of how these spreadsheets work to increase the potential for knowledge retention.

3.2.2.1 Case study: Network Rail – Energy monitoring and targeting system

In June 2016, Network Rail completed an upgrade to the system it uses to monitor asset energy consumption and invoices across the whole organisation.

Further details of the project are provided in Table 5.

Table 5 - ROI figures for the Network Rail energy monitoring and targeting system

Capital cost of project	£389,000
Estimated annual cost savings	£923,243
Estimated annual energy savings	10,429,814kWh
Project payback	Under 1 year

Table 5 - ROI figures for the Network Rail energy monitoring and targeting system

Non-financial benefits	• Availability of easy-to-understand, visually pleasing energy consumption data is making business engagement on energy efficiency much easier. • Assists the business in managing energy budgets and planning energy efficiency interventions. • Improved data integrity tools are helping to address gaps and inaccuracies in data. • Enhanced portfolio reporting tools allow quick identification of issues.
Lessons learned	• Migrating such a large database required careful planning and needs more resource to continue to cleanse data – so, ongoing data cleansing is slower than anticipated. • There is a requirement for ongoing system management and hosting costs, although these are less than before. • Intensive staff training is needed.

3.2.3 Sub-metering methods

Sub-metering enables a more detailed breakdown of energy data to be collected. For example, you might sub-meter different areas of a station. There are five methods of sub-metering energy use. In order of most accurate, reliable and expensive to least accurate, reliable and expensive, these are:

- Direct metering
- Hours-run, constant-load metering
- Indirect metering
- Difference metering
- Estimations

The preferred option should always be **direct metering**. This gives the most accurate data, but may not be the most cost-effective or practical approach. The cost of meters, and the resources necessary to run and monitor them, should be weighed against the value of the data (its potential to yield energy savings) and the equipment's energy consumption.

Hours-run or constant-load metering records the time the equipment is operating. This can then be multiplied by the equipment's known load and load factor to determine its energy consumption. The actual energy consumption of the equipment should be used and not that stated on its rating plate.

Indirect metering combines known scientific equations with direct meters to estimate the energy consumption. An example of this is when calculating domestic hot water energy consumption.

Through using **difference metering**, a third end use can be estimated from two direct meters. For example, boiler gas consumption can be estimated using data from a direct meter on the incoming gas main and a sub meter on the catering gas supply.

If no other metering method is available, you can **estimate** the energy consumption using rating plate information and estimated hours run. This is mainly used for office equipment assessments and is very inaccurate. You can also use benchmark data from published documents such as Butcher, K., 2008. *Energy Benchmarks*, Chartered Institution of Building Services Engineers (CIBSE) TM46: 2008.

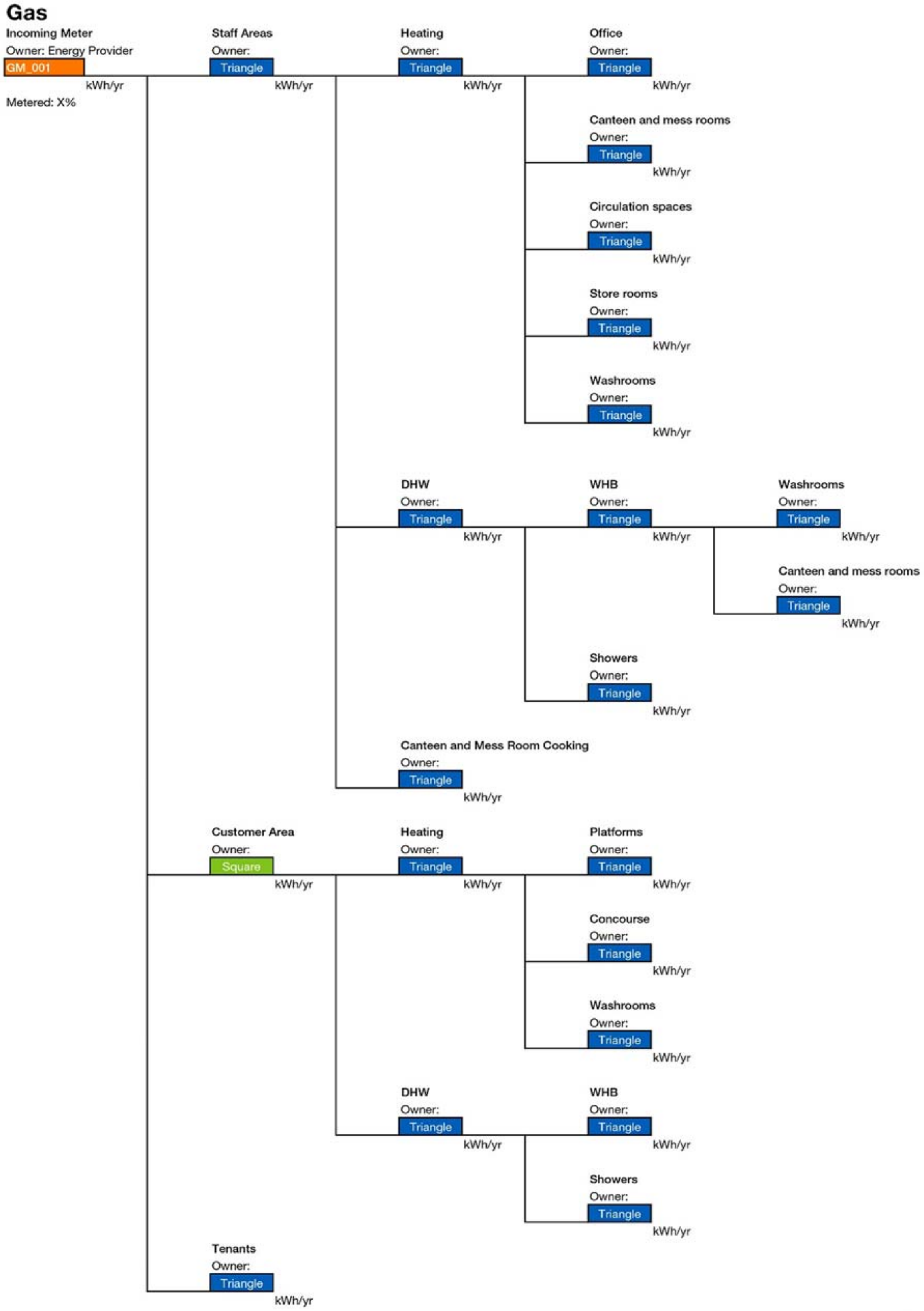
See Section 3.2.10 for details on the separation of shared supplies.

3.2.4 Metering schedules

It is important to have a clear understanding of which meters you have and exactly what consumption they are measuring. This will help you to manage your data collection efficiently and then to gain a complete understanding of the data you have before you attempt to analyse it. This process will also help you to identify where additional sub meters may be needed.

Once collected, meter data can then be used to communicate information about levels of consumption to relevant site or other staff in support of efforts to better understand energy consumption and reduce energy waste. Figure 5 provides an example of a metering schedule.

Figure 5 - Example of a metering schedule



3.2.5 Meter types

The Measuring Instruments Directive (MID) is a European Directive (2004/22/EC) that blends the requirements of 10 different measuring instrument types, including gas and active electrical energy meters. MID-approved instruments will have passed specific conformity assessment procedures and have MID markings. You should only use MID compliant meters. For Network Rail https://www.networkrail.co.uk/catalogue-of-network-rail-standards

Table 6 - Electricity meter types

Meter type	Description
Mechanical meters	These display electricity use from the movement of a mechanical dial. These meters lack data storage capacity and the ability to communicate electronically. They are accumulator meters, which means that the previous reading must be subtracted from the current reading to obtain the energy consumption for the period. These should be replaced with more modern meters if appropriate.
Electro-mechanical meters	These meters are mechanical meters with an electronic or pulse output. They are not designed for internal data storage or communication, but equipment can be added to them for such purposes.
Advanced (solid state/digital) meters	These meters have no moving parts. They measure and record data, and communicate this to another site. Capital cost of these meters is decreasing and they should be the preferred option if installing a new meter.

Other energy carriers, such as oil, natural gas, steam, and hot water, are not as easily metered. Energy content in these carriers is dependent on such variables as composition, mass or volume flow, temperature, and pressure. Any meter that you install should be able to measure and record the correct data with minimal assumptions, and to communicate this data to another site.

3.2.6 Remote meter reading

Transferring data from one site to another is commonplace and is especially useful for reading meters located at remote sites. Energy data can be transferred by such means as:

- General Packet Radio Service (GPRS) or Global System for Mobile Communications (GSM)
- Satellite
- Low-power radio technology
- Ethernet/internet

Each application has its own particular communication solution. This will depend on such factors as:

- Location of meters and site
- Size of site
- Type of fuel supply
- Number of meters and sub-meters
- Proximity to phone lines, mobile or radio network coverage, or communications cabling

You should anticipate the potential future needs of the site when installing a remote metering system. Some communication protocols may have limitations on the size of data packets they can send at any one time. Selecting a communications protocol is extremely important as communication problems can be the biggest issue in data collection.

3.2.7 Temporary metering

When permanent sub-metering is uneconomical, temporary metering can be used to gather half-hourly profile data. A lot of non-invasive portable and/or temporary metering devices are available on the market. These can measure the flow of electricity or gas without having to interrupt the supply. Portable meters are also available for oil, steam, and compressed air. These devices are beneficial for:

- Quick access to half-hourly data.
- Gathering data during initial assessments of site energy use.
- Assessing the site for the optimal locations for permanent metering.

These meters are temporary and will not replace the need for permanent meters, especially fiscal meters.

Criteria to consider when purchasing portable meters are cost, ease of use, accuracy of output, and flexibility.

The cost of such meters has decreased and there is a wide range of devices available. You should assess all potential uses for the portable meters, from energy assessments to troubleshooting, before deciding on a device.

Devices come in a range of accuracies, depending on what energy parameters the device measures. For example, power can be calculated using readings from a portable ammeter, providing the voltage and power factor are known and remain constant. But this is only power (kW) and not energy (kWh). To work out the energy, the time over which the measurement is taken needs to be known.

Any portable devices purchased should comply with the appropriate standards, such as MID approved.

3.2.8 How to develop a metering strategy

When managing several sites, metering planning is essential to ensure the metering, data management, and data analysis investments are made where they can offer the greatest impact. A successful metering programme will:

- Provide appropriate and accurate data in a timely manner.
- Complete data analysis in a timely manner.
- Provide data and analysis results to users in a format that leads to actions.
- Identify how the establishment and maintenance of an effective metering system will be funded.
- Operate continually and effectively on a daily basis.

A metering plan should contain detail on:

- What data will be collected.
- How the data will be collected.
- How frequently it will be collected.
- Quality control of the data.
- How to minimise and mitigate against data loss.
- Project tracking.
- Data security.

Developing a metering plan establishes a metering framework for building managers and site energy managers to follow. Metering plans should include:

- A plan for each major function.
- Prioritisation of metering efforts to ensure that resources are in place to meter the appropriate buildings.
- A way to measure consumption in buildings that are not expected to be metered in the planning cycle.
- Anticipated milestones and timelines for the planning cycle.
- Estimated funding and personnel requirements for implementation.
- A description of energy tracking systems that are or will be made available to facility managers.
- A description of how standard meter data will be incorporated into energy tracking and benchmarking systems.
- A description of how known IT and cyber security barriers are being addressed.
- A description of how known implementation barriers are being addressed.

The first step in developing a metering plan for a portfolio of buildings and sites is to identify which buildings and energy end users need to be metered. You will have already completed a metering schedule of installed meters. Some buildings are expected to use such a small amount of energy that metering may not offer any opportunities to reduce energy use. Every building is different, so setting a standard for metering will not address every conceivable situation.

The decision to meter is easier the more a building manager knows about the building operations. However, when in doubt, add it to the list of buildings to meter and prioritise when and where the investment can be made available.

Though the ultimate goal of a metering programme is to reduce energy consumption and/or costs, this will be achieved only when it is known how the metered data is to be used. Some typical uses include cost allocation to tenants, bill verification, demand-side management, and energy consumption diagnostics.

Starting with the end in mind is useful in metering planning, particularly when considering anticipated data needs. By considering desired outputs and actionable information at the outset of metering planning, the system development and planning will become more focused.

To achieve any value from metering systems, there needs to be well-defined commitments in the areas of data usage and system maintenance. Each of these entails a different skill set and resulting resource requirements – both necessitate a commitment of time and resources for the programme to be successful. Assessing the costs to perform data analysis and system maintenance is difficult and highly dependent on the specifics of the system. The number and type of meters used will impact maintenance requirements, and decisions on how to receive and process data will impact analysis costs.

CIBSE has produced a useful guide, *TM39 Building Energy Meterin*g, which takes you through how to decide what to meter, how to select an appropriate meter for each item, how to decide on the location of meters, and how to read the meters.

3.2.9 Data loss

Data loss can occur because of communications issues, meter malfunction, or data processing error. Data loss is inevitable in any reporting system – typical causes include data transfer interruption, data corruption, and data interception.

Data transfer interruption, the most likely reason for data loss, can be caused by loss of power to the building, meter, communications port, or data processing point. Data corruption is not as common as interruption and can be seen as no data, partial data, or irrational data. It can be caused by meter error, communications interference, or data receiving error.

Though data interception is not likely, you should adhere to best practice for data transfer. You should consult with your IT department to find out how to conform with your organisation's guidelines on data transfer.

You should set up alarms to identify lapses in data and out-of-range values to mitigate against data loss. These alarms should operate continuously and be forwarded or highlighted to relevant parties.

You must understand the magnitude of your data loss when it occurs and determine the best methods to correct the data set. The American Society of Heating, Refrigerating and Air Conditioning Engineers Guideline 14-2002 suggests that missing data should be substituted or omitted depending on its magnitude.

3.2.10 Separating shared supplies

The two main areas of shared supply are:

- Stations with concessions.
- Non-traction energy with traction energy.

Shared supplies also exist between train operating companies and Network Rail.

Supplies shared with concessions should be given their own fiscal meter or, if uneconomical to separate the main supply, they should be sub metered. By separating the supply, it simplifies the end-use calculations, removes the process of billing each concession, and the energy usage is no longer contained in the rail industry's carbon reporting. However, this does have drawbacks. It limits the potential of on-site generation and energy storage, and the subsequent revenue stream associated with selling energy to the concessions. It also reduces the potential of creating energy sharing networks within larger stations, which is also an additional revenue stream.

For shared supplies between traction and non-traction energy use, schematics of the shared supply should be created and sub-metering points selected. It may be uneconomical to sub meter all end users. An appropriate sub-metering method should be selected that fits the energy consumption of the end user. The same process should be followed for shared supplies between train operating companies and Network Rail, with the monthly man-hours associated with processing the data for billing purposes taken into account.

3.3 Energy analysis tools and techniques

It is very important to have a robust plan in place for managing collected meter-data prior to receiving it. As much of the process as possible should be automated to minimise costs and potential error. Data will accumulate extremely quickly once the system is operational. A site with 50 meters, reporting every 30 minutes, will result in over 875,000 data points per year.

Do not underestimate the resource commitments for data analysis. For example, take a site with 50 meters, measuring electricity and natural gas consumption data. The data will be collected, and output graphs and reports will be created automatically every day. These graphs are only useful if they are analysed for change. Typically, alarms will be set to highlight out-of-range values and these will be highlighted for interrogation. Reports of comparison between day of the week and month of the year should be interrogated, including any exception graphs.

3.3.1 Baseload analysis

Baseload is the minimum level of demand on a site or property. For an office, this would be when it is unoccupied. For a 24-hour site, this would be the minimum energy it consumes at any point in the day. Baseload demand consumes energy all year round. Although a baseload demand might be small in comparison to the normal demand, it consumes for a long period of time, so it can consume significant amounts of energy. A portion of this energy consumption can be due to devices that are left on when they are not required.

Baseload analysis of all sites should be carried out at the same time. Comparing sites that perform similar activities will help to identify potential energy waste.

To carry out a baseload analysis, you should:

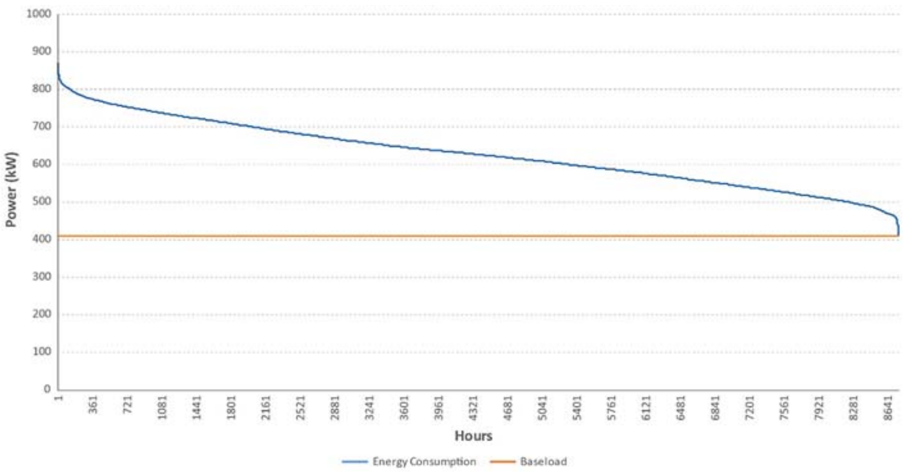
- Establish the energy consumption when a building is unoccupied.
- Understand contributing elements.
- Identify and separate the baseload.

Depending on the resource you have available, there are several ways in which the unoccupied or baseload energy consumption can be identified. If automatic meter reading is available, the half-hourly energy data during unoccupied hours can be identified. If only manual reading is available, a member of staff can take a manual reading at the end of a working day, and again at the start of the next working day. This can be repeated to gather a typical unoccupied profile. For sites that have intermittent occupancy, temporary metering might be the most cost-effective method.

Figure 6 shows the power used over time by a category A station. This is known as an electrical power duration curve. The baseload of this station is 410kW with its peak power rising to 875kW. The power duration curve can be used to calculate the baseload energy consumption over the time period shown. This is obtained by multiplying the baseload by the number of hours in the period. For this station, the baseload is 410kW and the number of hours in the period (a year) is 8,760. This leads to a baseload energy consumption of 3,591,600kWh. In this instance, this is 65% of the total energy consumption of the station.

To understand the cost of your baseload, you should apply your tariff structure to the energy consumption figures. A power duration curve will also aid in maximum demand (MD) analysis.

Figure 6 - Power duration curve



A site's asset register can be of great help when determining the elements contributing to a baseload because it helps you to understand what is on the site. Items that are more likely to be left on during unoccupied times are refrigeration units, vending machines, printers, personal electric heaters, and pumps. By using the asset register, the baseload can be calculated using information on the rating plates of the various assets, such as the power rating.

A baseload that is large compared with normal consumption, such as that shown in Figure 6, indicates that there is potential to save energy. A slow-rising baseload can reveal a fault with a device. An odd spike in consumption data can reveal incorrect timing controls. A number of time controls will not be able to recognise when the clocks change for British Summer Time, which will be highlighted in daily consumption graphs, and can then be amended if necessary.

3.3.2 Maximum demand analysis

The MD is the highest level of electrical demand measured during the period. To avoid penalty charges associated with your energy tariff, it is critically important that you do not exceed your MD. Therefore, you should check to see if it has been set at the right level. To do so, look at the power duration curve of the site against that of your MD allowance on your bill. If your MD allowance is too low, you may be getting penalised each month. If it is too high, you are paying too much each month for your allocation.

You should know when your MD typically occurs. Then, to maximise the potential of MD analysis, you can start switching off the non-critical loads on your site (that is, those loads that are not essential and will not affect your business drastically if they are turned off) as the demand approaches the limit you have set.

3.3.3 Visualisation techniques

Managers can use a range of data visualisation techniques to verify the energy savings being achieved by energy efficient technologies and to identify malfunctions in building equipment or problems with operating strategies.

Traditionally, building energy and environmental data has been in the form of point estimates, such as annual or monthly energy use. However, in recent years, the development of low-cost sensors means that more 'real-time' data collection is possible, enabling detailed building energy data to be collected and analysed in new ways. This offers various benefits, including:

- Improving data quality by identifying anomalous or suspect values (for example, from faulty sensors).
- Identifying when systems are malfunctioning.
- Identifying where systems are poorly commissioned leading to actual performance that is inferior to that anticipated at the design stage.
- Revealing where the correlation among several variables in control systems are incorrect. Examples are where control systems allow simultaneous heating and cooling within a building.
- Allowing users to select the most effective graphical display and time step (minute-by-minute, hourly, daily, weekly, or monthly) to meet their specific needs.

There are a number of graphing techniques to aid with M&T. The primary graphs being:

- Pie charts
- Column charts
- Line charts
- Heat mapping
- Load profiles
- Box plots

- Regression analysis
- CUSUM charts
- Sankey diagrams

A simple explanation of each of these types is provided in the following sections.

3.3.3.1 Pie charts

Pie charts are good for snapshot information. They provide information about energy mix and where energy is consumed in one time period. A pie chart is a circular statistical graphic, which is divided into slices to illustrate numerical proportion. In a pie chart, the arc length of each slice, is proportional to the quantity it represents. While it is named for its resemblance to a pie which has been sliced, there are variations on the way it can be presented.

Figure 7 - Pie chart – seasonal energy breakdown for a category A station

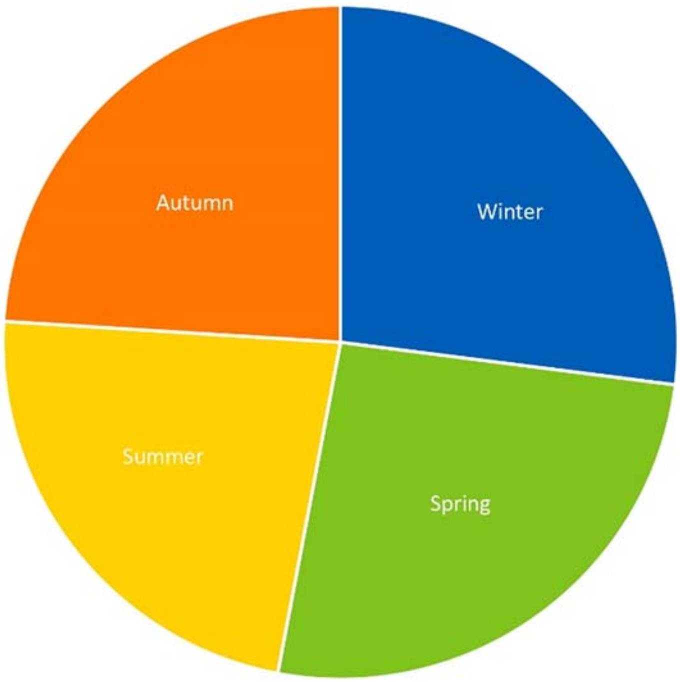
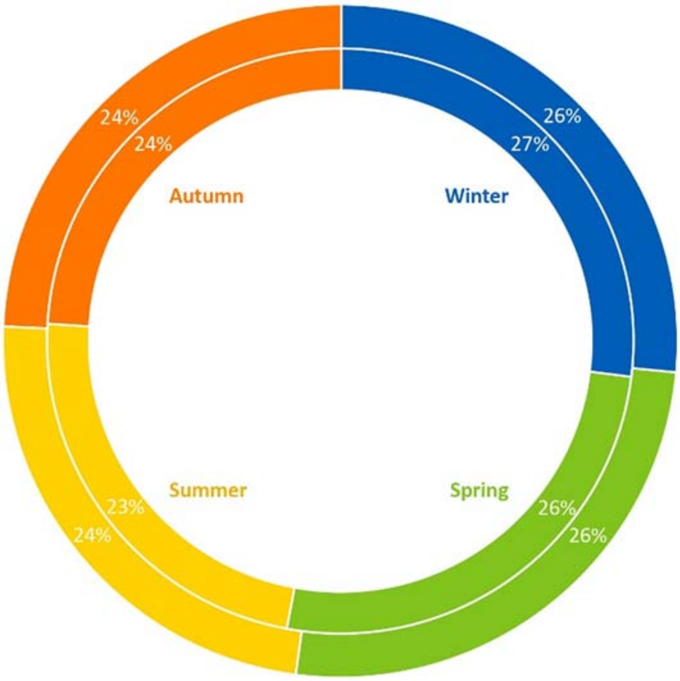
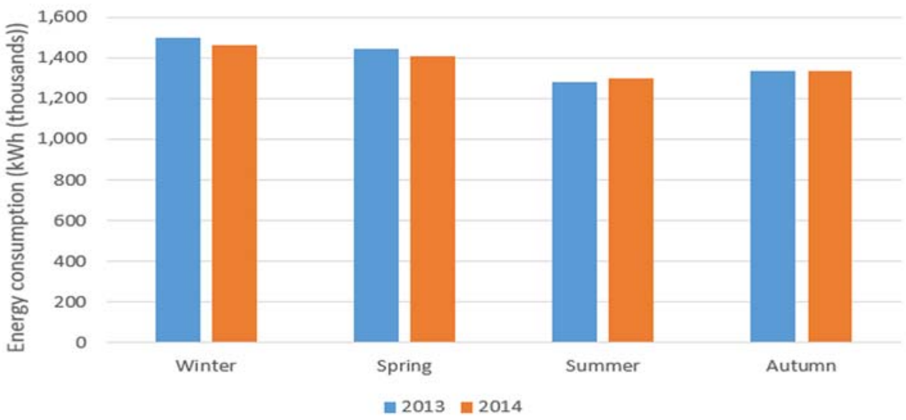


Figure 8 - Dual pie chart – two years of seasonal energy breakdown



Though pie charts can be useful to show data at a moment in time, such as percentage of people responding in a particular way to a customer survey, they do have their downfalls. It can be very difficult to compare two slices of the pie and even more so for one pie chart to another. Studies have shown that people determine differences in height significantly easier than differences in angles (which is what a pie slices uses). As seen in Figure 7 and Figure 8, slices that have similar angles are difficult to differentiate without the actual numbers. This means that people are really just looking at the numbers, which could have been displayed in a table or in a clustered column chart (Figure 9). When the differences between slices are large, pie charts are very useful as the difference is easily identifiable at a quick glance.

Figure 9 - Clustered column chart – seasonal breakdown of energy consumption at a category A station

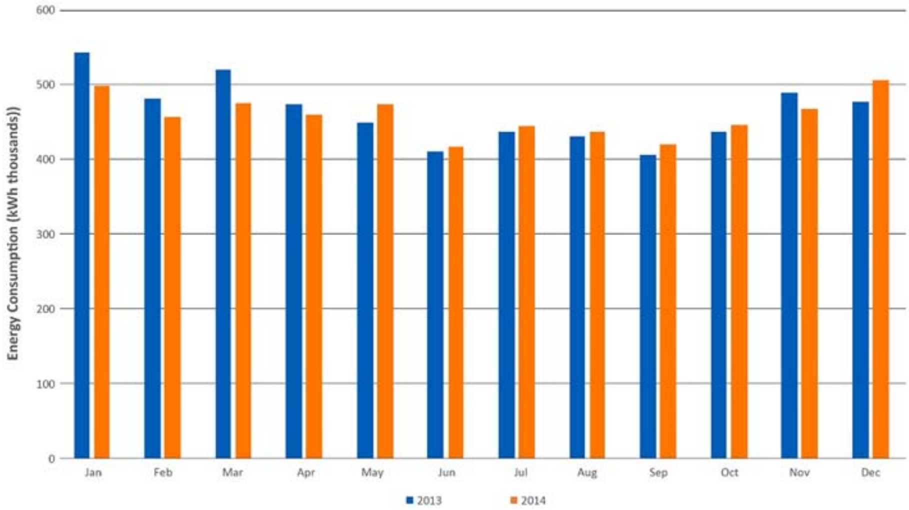


3.3.3.2 Column charts

A column chart or graph presents grouped data using rectangular columns with heights proportional to the values that they represent.

A clustered column chart consists of vertical columns (bars) that are arranged in groups, or clusters. Each bar represents quantitative data. The columns of each data series are always in the same position in each cluster throughout the chart. This means it is easy to compare one series to another, such as energy consumption per month in year 2013 and 2014 as shown in Figure 10.

Figure 10 - Clustered column chart – monthly values



A stacked column chart is used to break down and compare parts of a whole. This might be a breakdown of energy consumption per month or year to identify those months with large energy consumption over several years (Figure 11), or breakdown by fuel source (Figure 12).

Figure 11 - Stacked bar chart – station

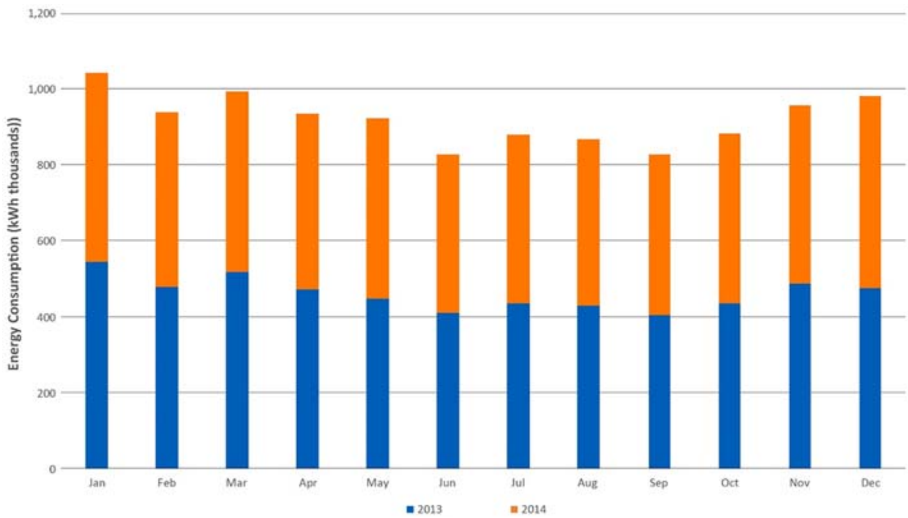
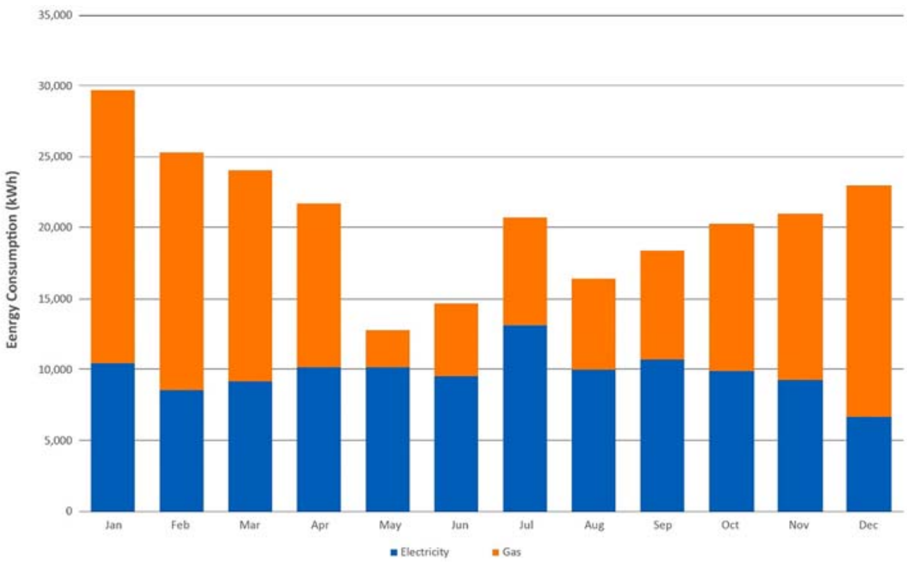


Figure 12 - Stacked bar chart – depot

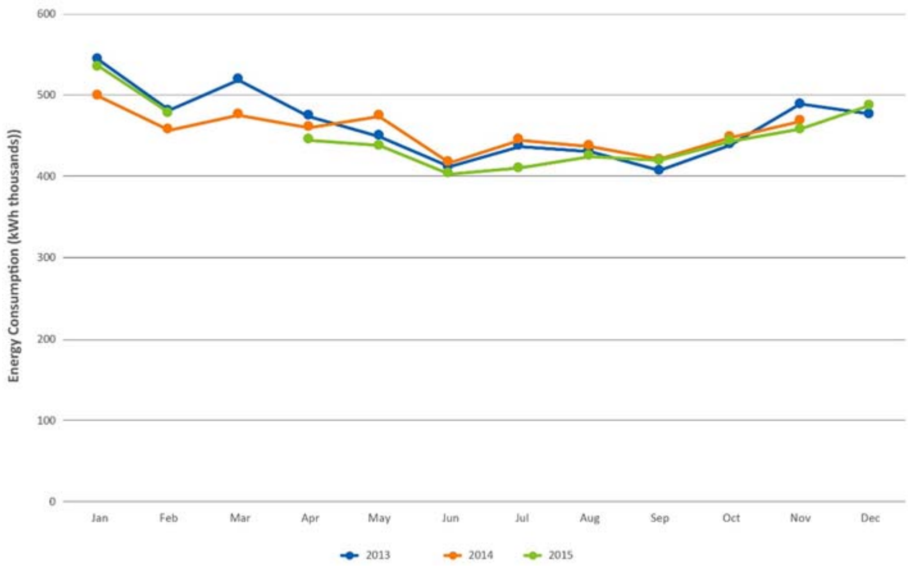


3.3.3.3 Line charts

A line chart or line graph is a type of chart that displays information as a series of data points called 'markers'. It is similar to a scatter plot (see below), except that the measurement points are ordered and joined with straight line segments.

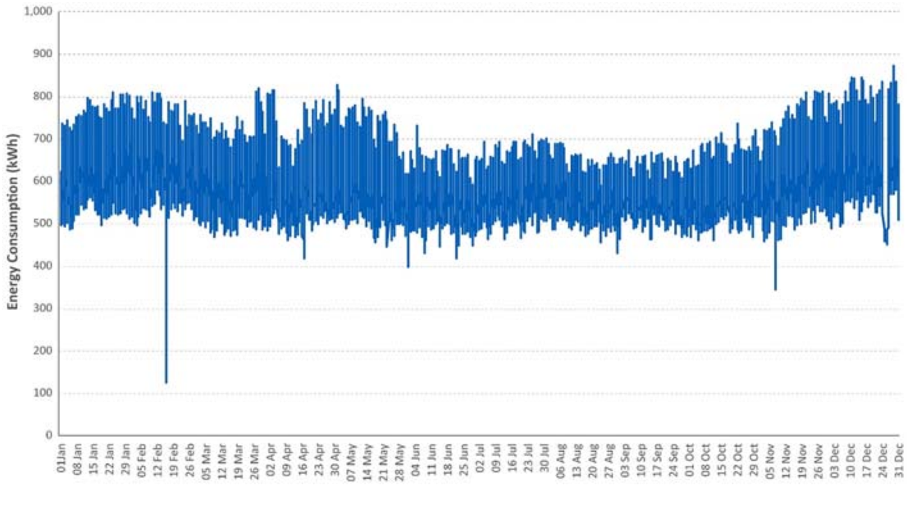
Typically, line charts have the option to view marker points. This can be useful to visualise where missing data has occurred. Figure 13 shows that data for December 2014 through to March 2015 is missing.

Figure 13 - Line chart with marker points visible



The yearly energy consumption of a site is typically shown on line charts. However, due to the amount of data points, it can be difficult to understand how energy is really being used.

Figure 14 - Line chart without marker points



3.3.3.4 Heat mapping

A heat map is a graphical representation of data where the individual values contained in a matrix are represented as colours. Fractal maps and tree maps often use a similar system of colour coding to represent the values taken by a variable in a hierarchy.

Heat maps are an easier way to visualise the energy consumption for a year. It can be significantly easier to view patterns in energy consumption using a heat map.

Figure 15 - Heat map of site energy consumption

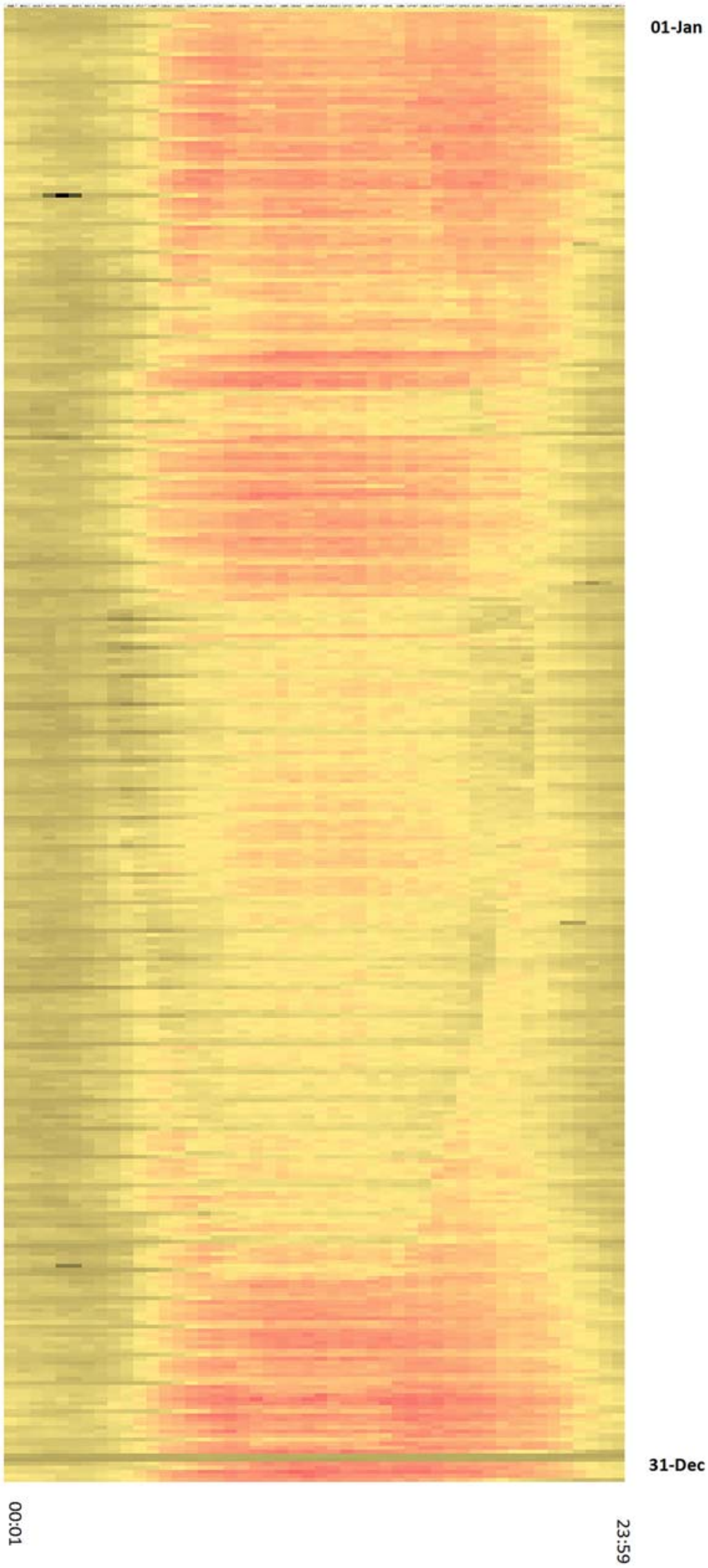
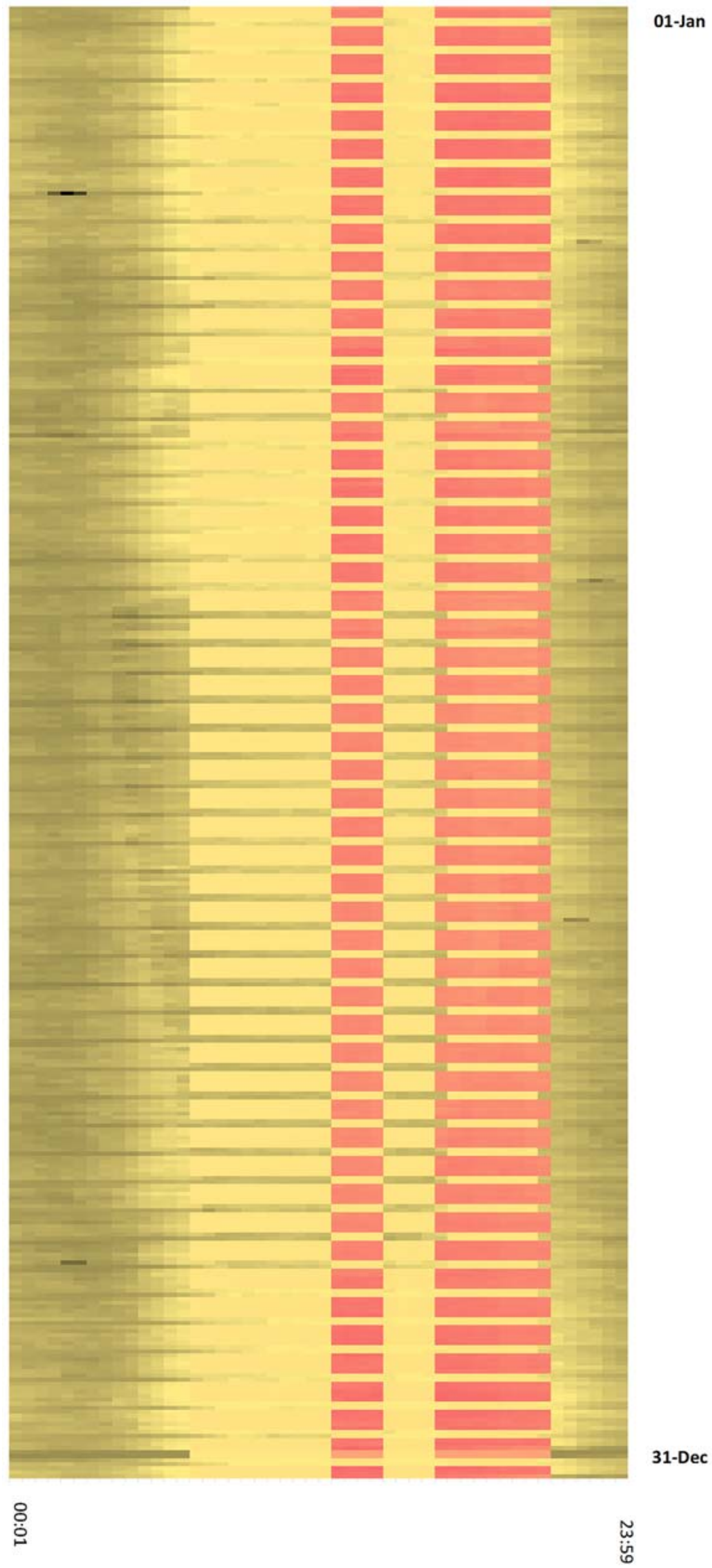


Figure 16 - Heat map of site energy cost

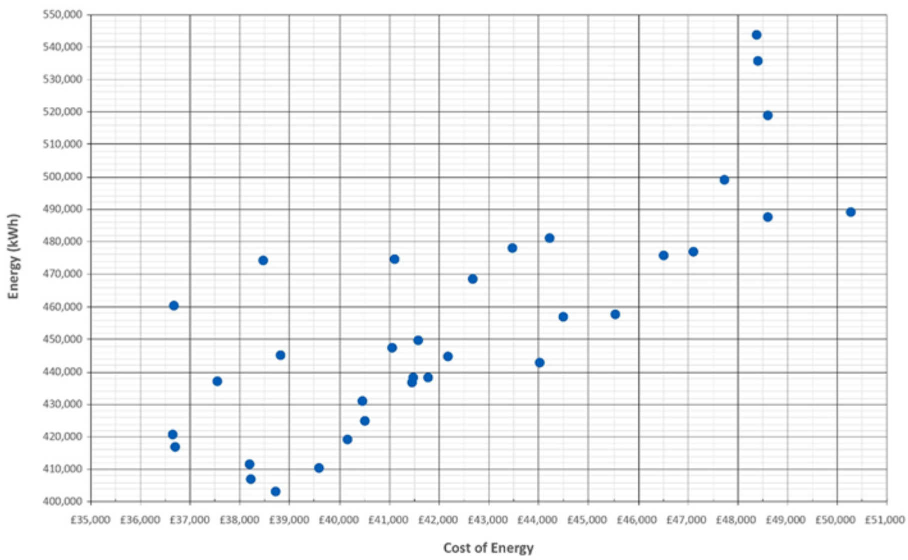


3.3.3.5 Scatter charts

The XY scatter chart is probably one of the most commonly used graphical techniques. It involves plotting the location of each separate data point relative to two variables, for example time and magnitude of measured consumption. Where the plotted data points form a line this indicates that they are correlated in some way.

Figure 17 shows monthly energy consumption versus monthly energy cost for a year. This indicates that there is a large amount of variability, which would tend to imply that the current supply arrangements need investigating to ensure that they are suited to the measured pattern of demand.

Figure 17 - Yearly energy consumption profile of a category A station

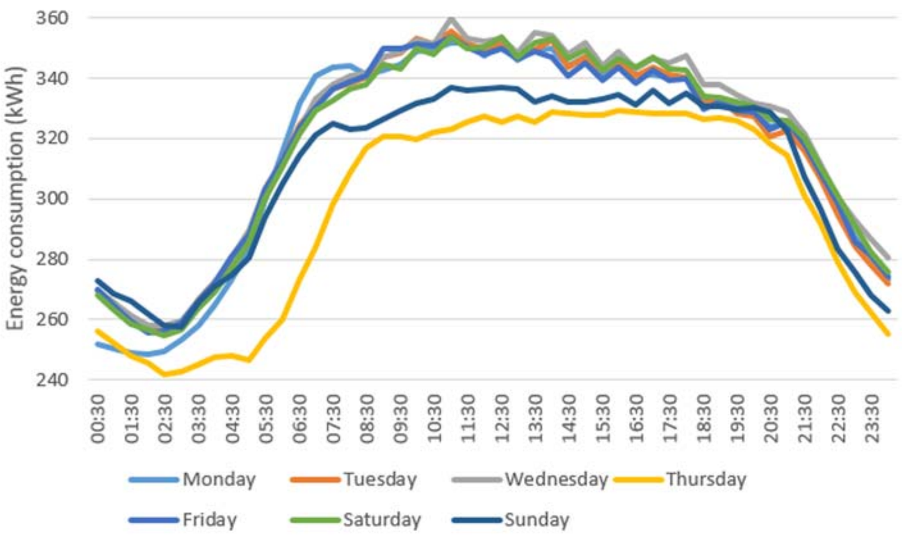


3.3.3.6 Load profiles

A load profile is a graph of the variation in the electrical load versus time. A load profile will vary according to customer type (typical examples include residential, commercial, and industrial), temperature, and holiday seasons. Power producers use this information to plan how much electricity they will need to make available at any given time.

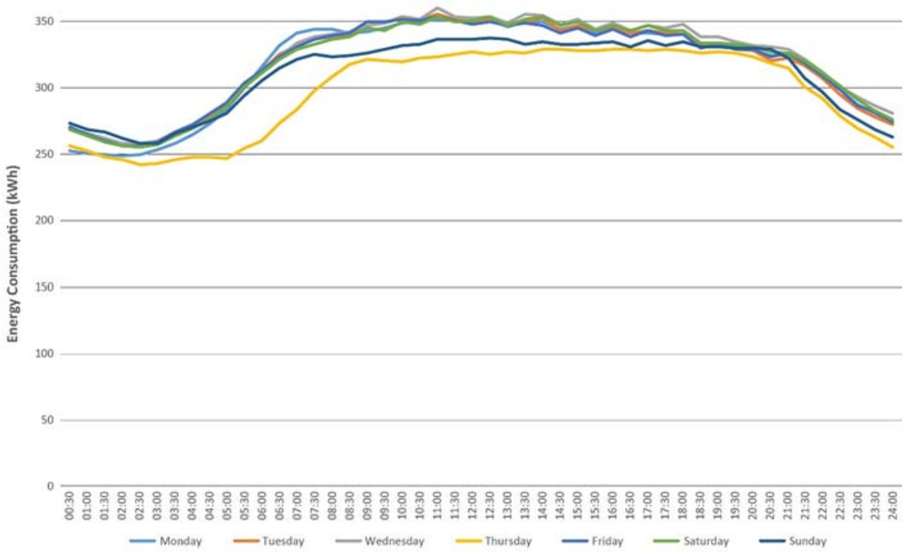
Figure 18 shows the average load profiles of a Category A station

Figure 18 - Load profiles at a category A station



Deciding on the base level is also important. Figure 19 shows the same information as Figure 18, but with the base level set to zero. This shows the baseload of the station and also provides a different representation of the data.

Figure 19 - Load Profiles – base set to zero

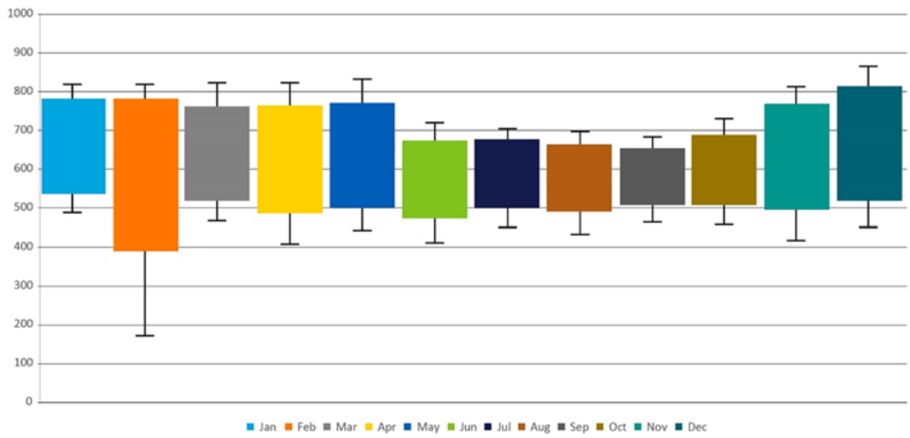


3.3.3.7 Box-plot load profiles

A useful way to depict groups of numerical data such as quartiles graphically is the box plot. By adding vertical and horizontal lines extending out from the box or within the box as appropriate, these plots can also show additional information. Examples are the median, the extent of the range of values being considered and the variability of the data. Plots with these additional lines added are often called box and whisker plots.

An example of box plot is shown below. Here, the coloured boxes show where 50 % of the load is typical and the minimum and maximum loads are shown using whisker lines.

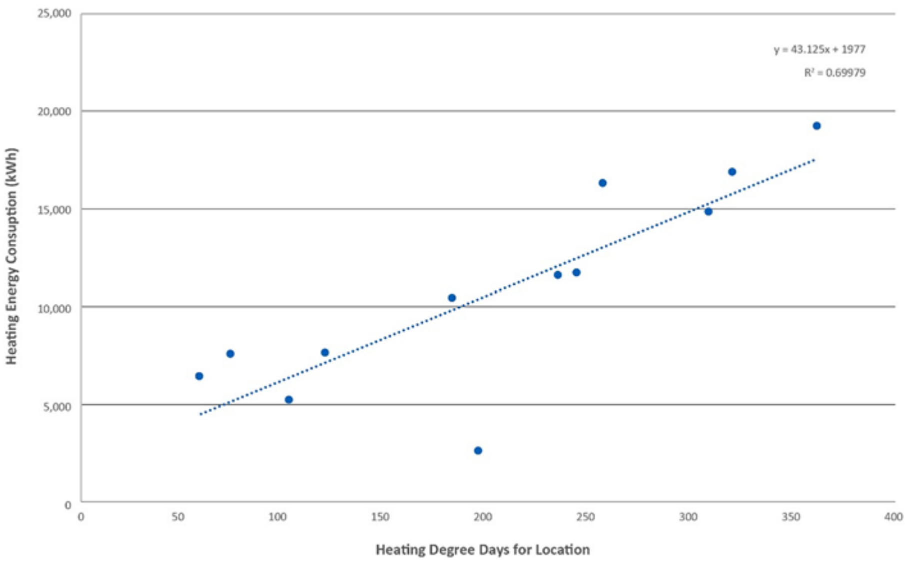
Figure 20 - Box plot



3.3.3.8 Regression analysis charts

Regression analysis is used to identify relationships among variables. This helps to understand how the typical value of something changes when any one of the independent variables contributing to it is altered. In energy management, the most common application of regression analysis is in degree day analysis. This is used to identify where more energy is being used for heating than would be expected for a day with a given average temperature.

Figure 21 - Regression analysis chart

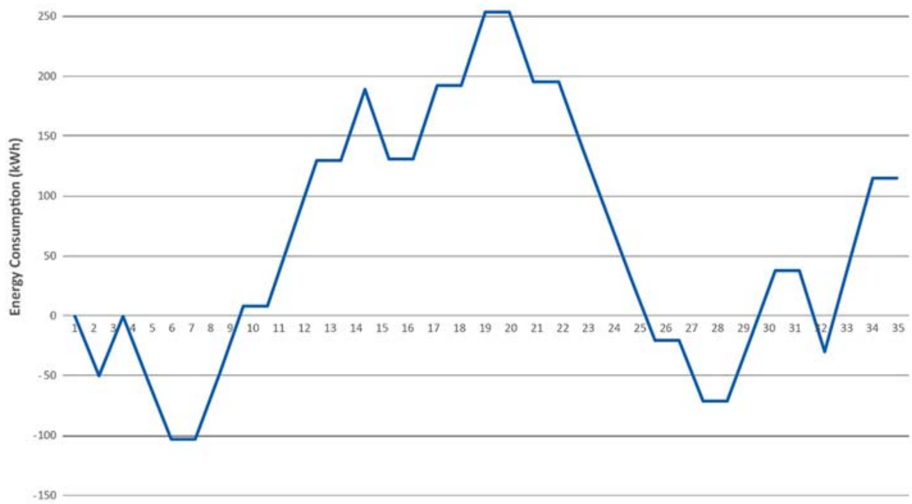


3.3.3.9 CUSUM charts

CUSUM charts plot cumulative deviations between a measured value and a reference value. This allows processes that should be in equilibrium to be measured. For instance, the flow of water in and out of a tank to maintain a specific water level, or the flow of electricity into and out of a battery to maintain a specific level of charge.

As the plot is cumulative even minor deviations will become apparent over time and it is therefore useful for measuring change.

Figure 22 - CUSUM

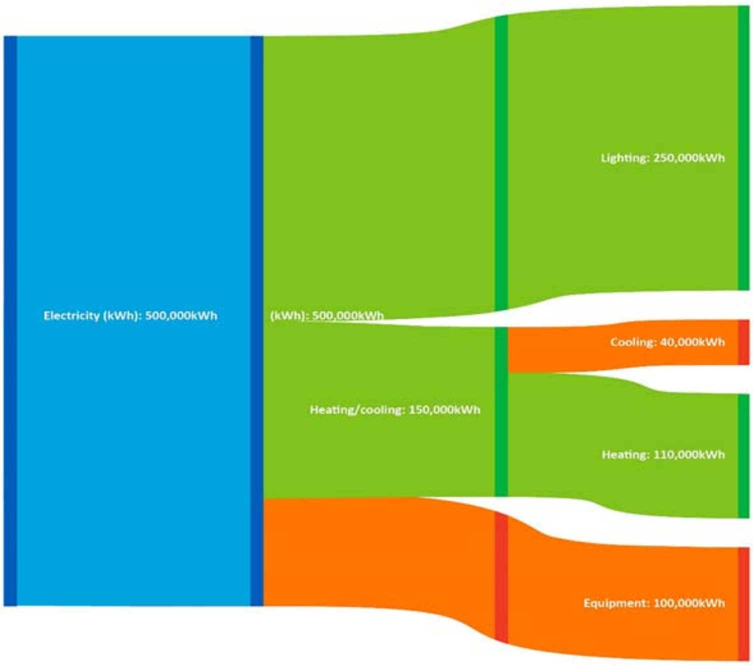


3.3.3.10 Sankey diagrams

A Sankey diagram is a good way to visualise how energy is consumed within a business, site or process. In a Sankey diagram, an initial bar on the left of the plot the size of which is proportional to total energy consumption splits as the plot moves to the right to show where this energy is consumed, with the separated bars in proportion to the consumption being reported.

This provides a simple and convenient way to communicate messages about where energy is being used and will identify the dominant contributions to consumption.

Figure 23 - Sankey diagram



3.3.3.11 Determine irregularities

Visualisation tools can be helpful in identifying errors or discrepancies in collected data. These tools can identify irregularities as changes to normal patterns of energy consumption, often as unexpected spikes or troughs.

While visualisation can identify where there may be a data error, by itself it will not identify the cause. This might be due to a number of things including:

- Faulty data collection equipment

- Data losses
- Changes to the use of equipment
- Operator error
- Data becoming out of sequence

In many instances, the visualised data will help to narrow down possible causes. For instance, a spike indicates a short-term issue, while data out of range may point to faulty equipment or incorrect calibration.

4 Retrofit opportunities

This section provides guidance on the different energy efficiency opportunities in existing buildings and other infrastructure that may be applicable to the rail industry. It includes consideration of behaviours that can contribute to energy savings, building structure and the energy efficient technologies that can be used in buildings.

4.1 Behaviour change

Behaviour change has long been recognised as a low-cost method of reducing energy waste and cost. In general, savings come from two main areas. The first is from encouraging staff to do such things as identify where energy can be saved by switching off equipment that is not in use or reduce demand where it is not needed. The second comes from engaging staff to identify more efficient energy practices such as optimising when in the day equipment is switched on and how it is used.

There is no one-size-fits-all solution to change people's behaviour. What works on one site may not work on another. However, there are a few design principles that underpin all successful behaviour change programmes.

To create an effective behaviour change campaign, you should understand how your site operates and how people use the site. A particular area to focus on is ownership of local decisions. For instance, energy consuming equipment is often left on when it is not needed because staff do not feel that they are empowered to switch it off. This is not a simple task as different activities can be carried out in different areas of the site, site function may change, and site occupancy can frequently change. This can become even more complex when dealing with several sites and many contractors.

Many behaviour change campaigns fail because they do not take into account behavioural psychology. Understanding people's barriers to change, values, and motivations is important in creating a campaign that has lasting impact.

A simple way to start this process is with empowerment. Encouraging staff to seek out energy waste and giving them the tools to do this will do much to engender behaviour change. What is needed here is simple signs that identify equipment that must remain switched on and a list of other equipment to monitor for opportunities to switch it off or turn down to reduce energy consumption. This will encourage and empower local staff to seek out and reduce energy waste.

This local activity is important as employees have no direct link between their actions and energy expenditure. However, people generally like to follow the social norms of their surrounding environment. If the majority of people turn off the lights at the end of the day, it is likely the rest will follow suit. This is why local leadership is important.

There is usually at least one staff member in a given area with an interest in reducing energy consumption who can take the role of a local ‘champion’. Giving these local champions support will also give a focus for behaviour change. This not only creates ownership for reducing energy demand at the site level, but provides the means to share best practice and to push ideas for energy savings up to senior management.

To support this positive behaviour, it is also important to reinforce it with regular communications and (where local metering will support this) providing consumption data to show the impact of local actions.

It is important to remember that while behaviour change can deliver energy savings at zero cost, human factors also mean that without constant refreshing of the energy saving messages, people can revert back to their old habits.

Table 7 - Potential energy savings due to measures targeting behaviour[a]

Intervention	Range of energy savings
Feedback	5 % – 15 %
Direct feedback (including smart meters)	5 % – 15 %
Indirect feedback (such as enhanced billing)	2 % – 10 %
Feedback and target setting	5 % – 15 %
Energy audits	5 % – 20 %
Community-based initiatives	5 % – 20 %
Combination interventions (of more than one)	5 % – 20 %

a. Barbu, A., Griffiths, N. and Morton, G., 2013. Achieving energy efficiency through behaviour change: what does it take. European Environment Agency-Copenhagen: Publications Office of the European Union. Retrieved from http://dx.publications.europa.eu/10.2800/4994.

4.2 Building fabric

Unlike behaviour, building fabric is less easily changed. The amount of energy required to heat and cool a building is dependent on the thermal performance of the fabric used to create the key components of the building's external walls, floors, roofs, windows, and doors. Energy loss or thermal gain is dependent on several factors such as weather, location, building shape, orientation, construction techniques, and occupant behaviour. The comfort and productivity of a building's occupants are affected by its design and construction. In addition to a building's general potential to be hot or cold, other problems can include:

- Draughts from windows.
- Glare from unshaded windows.
- Overheating from excessive solar gain.
- Differences in internal conditions across the building.

All of these can result in poor working conditions and high energy bills.

The following sections look at ways to improve the energy efficiency of building fabric. However, it should be remembered that decreasing the heat loss in winter can also increase heat retention in summer. You need to balance the effect of winter heating energy against that of summer cooling energy.

4.2.1 Insulation

There are many types of insulating material and certain types are better suited to specific applications. The U-value of a building element specifies its thermal performance and is measured in watts per metre squared kelvin (W/m2K). This measures the rate of heat flow through the element. Lower U-values are better. Glazing has a much higher U-value than a highly insulated wall, meaning that there will be a higher heat loss through windows.

Table 8 - General insulation thermal conductivity

Insulation type	Thermal conductivity (W/m2K)
Vacuum insulated panel	0.01
Aerogel	0.014
Polyurethane boards and spray	0.024 to 0.034
Extruded polystyrene	0.026 to 0.038
Expanded polystyrene	0.03 to 0.045
Glass fibre	0.03 to 0.043
Stone fibre	0.037 to 0.04
Cellulose	0.037 to 0.046
Wood fibre	0.04 to 0.05

Each of the above has a different cost and many have different physical forms. This means that it is important to select the insulation material that gives the correct mix of ease of installation, cost and performance.

4.2.1.1 Ceiling and roof insulation

There are many different types of insulating materials and installation methods that are suitable for a roof. Your choice depends on:

- Type of roof.
- Available space for insulation.
- Ease of access.

Insulation options include rolled insulation that sits between and above the rafters and material that is fitted directly under the roofing material itself.

To assess your options, you will need to undertake an assessment of the roof void. In addition to assessing the physical suitability of the space for the different insulation options, you will need to pay particular attention to the working height, the means of access, and the physical conditions in the roof void. Together, these will dictate the feasibility of applying roof insulation and will identify the means of insulation to use.

Where access to the roof is difficult, or it is flat or otherwise not suitable for a retrofit insulation option, ceiling insulation may be a more sensible and a safer option.

Good ceiling insulation can decrease heat loss during winter, but it can also reduce heat gain in summer. This is because it prevents the sun's heat from penetrating the roof into the spaces below. However, it is also important to note that winter sun may offer beneficial heating to some buildings. This is why it is important to undertake an investigation into the optimum level of insulation for individual buildings relative to their orientation and use.

For further information on roof insulation, please see Carbon Trust publication CTL178 – *How to implement roof insulation* (https://www.carbontrust.com/media/19469/ctl178-how-to-roof-insulation.pdf).

4.2.1.2 Wall insulation

Heat loss through walls can be significant and this differs with construction type. Pre 1920, most walls were solid. To insulate solid walls requires insulation to be applied to the inner or outer wall surface. If applied internally then everything fitted to or within the wall will have to be modified to accept the thickness of the insulating material. Examples are power points and switches, radiators, skirting, architraves, fitted shelves, and cupboards. The insulated rooms become smaller because of the thickness of the insulation.

For these reasons, solid wall insulation is usually applied externally and then covered with waterproof render. The Energy Savings Trust provides more information about solid wall insulation (see www.energysavingtrust.org.uk/home-insulation/solid-wall)

A building that has a double-walled or double-skinned construction can be retrofitted with cavity wall insulation. This is where insulation is injected into the gap between the internal and external skins, the cavity, of the building. This should be installed prior to upgrading any heating system as it could lead to a smaller heating system being required. The cavity should be at least 50mm wide and brickwork should be in good condition for the insulation to be effective. Older properties with smaller cavities may have to use external insulation to achieve the desired improvements in thermal performance.

Three commonly used types of cavity wall insulation are described in Table 9.

Table 9 - Cavity wall insulation types

Type	Name	Thermal conductivity (W/m^2K)
Fibre	Cellulose	0.04
	Mineral wool	0.04
Foam	Polyurethane	0.022 to 0.028
	Urea formaldehyde	0.04
Bead	Perlite	0.045
	Expanded polystyrene	0.032 to 0.038

Retrofitting all forms of wall insulation requires specialist installers. However, site owners can undertake thermal imaging of all walls. This should be done before and after the insulation has been installed as it will highlight any problem areas and the effectiveness of the insulation.

4.2.2 Air tightness

Air tightness is measured in air changes per hour (ACH) and is a measure of how 'leaky' a building is. To reduce heat loss though escaping heated air, a building should be sealed tightly. This usually involves replacing old, worn, or missing seals around windows and doors, or installing draught proofing systems to older doors and windows where no sealing strips are present. Fitting door closers can also improve airtightness. Draught proofing is a cheap and effective way of saving small to moderate amounts of energy.

Improving air tightness will have an impact on air quality, which can lead to odours persisting, condensation, and other issues. For this reason, a balance between air quality and air tightness should be struck. This may vary from area to area and with building use.

In high occupancy/high energy cost buildings, investment in controlled mechanical ventilation may be appropriate and should be considered where installation is feasible. Retrofit options usually require distribution ducting to be installed. This can be unsightly, costly, and might be disruptive during the installation process. However, mechanical ventilation does provide a means to recover heat from the air before it leaves the building, while maintaining a fresh air supply to eliminate odours and condensation.

Managers of older buildings with low air tightness should consider incorporating air locks and/or air curtains. This would be valuable for relay room space heating, depot or warehouse space heating, and concourse heating. Air locks can also help to improve security. Guidance on energy efficient heating of large halls is provided by the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) Guidebook 15: *Energy efficient heating and ventilation of large halls* (Kabele et al, 2011).

4.3 Adapting buildings to use

The rail industry has a vast number of different building types. The way that each building is used can have a significant impact on its energy efficiency. Adapting the building to the specific use that has been chosen for it can help to optimise its efficiency, as can housing particular activities in buildings best suited to them.

4.3.1 Building classification

A building's classification can be directly related to its energy consumption. Building classification should be considered when planning building services, and the way in which the space will be used.

4.3.1.1 Lightweight and heavyweight buildings

Lightweight, highly insulated and airtight buildings are very suitable for intermittent occupancy periods and should have a heating system that has a fast response time. This gives an excellent space where people can sit for short periods of time intermittently, such as a depot canteen. They can turn on the heating as soon as they arrive, the space heats up very quickly, and it turns off when they leave. People would be more inclined to leave the heating system on all the time if the building did not heat up quickly.

Heavyweight buildings are more suited for longer occupancy periods such as 24-hour occupancy. They have a longer heat-up time but, once heated, they hold their temperature for longer. Typically, heavyweight buildings have a more stable temperature profile than lightweight buildings and are suited to locations that have more extreme weather patterns. For example, on very hot days, the internal temperature will be lower than outside as the hot weather will not penetrate as quickly. They will also hold their temperature through a short cold snap. Heavyweight buildings typically require less maintenance and are more durable than lightweight buildings.

4.3.1.2 Transient spaces versus occupied spaces

Transient spaces are not intended to be occupied for a long period of time, such as corridors. Typically, occupants of these spaces have a higher level of activity than those in occupied spaces – walking instead of sitting. This higher level of activity means that the heating set point can be lower than that of the occupied spaces. In some cases, these spaces can be completely unheated. Occupied spaces need a higher heating set point due to the lower level of activity of the occupants. Occupants of transient spaces, such as a station concourse, often wear more clothes than people in occupied spaces. Wearing more clothes means that people are better insulated from the cold, so transient spaces may not need a heating system. Guides such as CIBSE *Guide B: Heating, Ventilating, Air Conditioning and Refrigeration* provide advice on the appropriate set points for different types of spaces.

4.3.1.3 Sparsely occupied versus densely occupied

For the rail industry, an open-plan office can be considered densely occupied with a high number of occupants per square metre. A depot can be considered sparsely occupied having a low number of occupants per square metre. The different spaces should have different heating systems. The entire volume of a densely occupied space may need to be heated, while it may be significantly more energy efficient to use a radiant heating system combined with passive infrared (PIR) sensors for a sparsely occupied space. This will depend on:

- The volume of the space – primarily the height of the ceilings.
- The spread of the occupants, in a single area of the space or distributed evenly throughout the space.
- The air tightness of the space.
- The frequency of their movements to other areas of the space.

Spaces with very high ceilings can benefit from radiant heating systems as these do not heat the volume of air.

Spaces with low air tightness can also benefit from radiant systems. Radiant systems come in different forms, ranging from underfloor water-based systems to ceiling mounted electrical systems. Electrical systems can provide almost instant radiant heat making them suitable for intermittent heating needs, while hydronic (water based) systems are best suited to buildings with longer and more predictable heating requirements.

This means that you should ensure that you understand the occupancy density and usage patterns of your buildings and match the heating system to it. An example might be in a large, centrally heated building now with sparse occupancy where it might be more cost-effective to have electrical radiant heating and not to run the central heating system.

4.3.2 Energy sharing

In a given location, it is usual to use energy to create heat while also using energy to remove heat. This is often the case in multi-use locations such as stations and in locations of high energy use such as data centres. Here, removing heat from one area and supplying it to another can reduce the overall energy requirement of a building.

Sharing heat can be done through a number of different methods. It can be as simple as placing a vent between the area being cooled and the area that needs to be heated, or through the use of heat exchangers and heat pumps. The issue here will be to understand the volumes of heat to be moved and the match between the supply and demand profiles.

An example of the successful application of heat sharing is in supermarkets where the heat from chillers and freezers is ducted to those areas of the store needing heat. While this requires some planning, this approach may have applications on a station concourse and is worthy of investigation.

As part of this investigation, the capacity to split the heat capture and heat delivery elements of a cooling circuit or refrigeration system should be considered. In this way, when heat is removed from a space or cabinet requiring cooling, it can be supplied to an area needing heating such as a waiting room, office area, or retail outlet.

In addition to investigating the technical feasibility of energy sharing, there is a need to both determine the cost of implementing it and to estimate the value of the energy benefits that will result. These energy benefits will include increased efficiency of the cooling process from better heat removal and the value of the heat being delivered. This information can then support discussions with the potential beneficiaries as to how the cost of the installation of a split cooling/heating system will be met.

4.3.3 Workspace layouts

Optimising the layout of a workspace can have a beneficial effect on its energy consumption. Microclimates exist throughout a single room. Where possible matching a person to a microclimate that suits their preference will reduce the need for services to condition the space in which they work. For instance, ensuring that the person who likes to be warm is located beside a radiator can reduce the need to potentially overheat the entire room to achieve the required comfort level for that person. The opposite will also be true.

It is also well understood that many people feel better working beside windows. Locating workstations near windows and locating meeting rooms in the centre of an office will aid worker productivity and reduce the need for artificial lighting.

To achieve these benefits, you will need to understand the preferences of those working in the room to ensure that the best possible locations can be achieved to reduce energy consumption.

4.4 Energy efficient technology

Having considered behaviour, building fabric and how the building is used to achieve energy savings, the next area to look at is the technology that is available to improve energy efficiency.

4.4.1 The Energy Technology List

When considering buying new energy using equipment, this should be selected from the Energy Technology List (ETL). The ETL is managed by the government and is a list of energy efficient products that must meet specific energy saving or energy efficient criteria. It is part of the Enhanced Capital Allowance (ECA) tax scheme for businesses (see https://www.gov.uk/guidance/energy-technology-list#enhanced-capital-allowance-eca-scheme).

Therefore, products included on the ETL are what is considered by independent experts to be among the most energy efficient on the market. Categories include:

- Air-to-air energy recovery
- Automatic monitoring and targeting (AMT) equipment
- Boiler equipment

- CHP plant
- Compressed air equipment
- Heat pumps
- HVAC equipment
- High-speed hand air dryers
- Lighting
- Motors and drives
- Pipework insulation
- Refrigeration equipment
- Solar thermal systems
- Uninterruptible power supplies
- Warm air and radiant heaters
- Waste heat to electricity conversion equipment

For more details about eligible product types, see the technology factsheets https://www.gov.uk/government/collections/energy-technology-list-technology-information-leaflets

The following sections look at specific areas where energy efficient technology can have a significant impact in reducing energy consumption and saving money.

4.5 Lighting

Lighting offers great energy savings potential. Typically, 50 % of an office's electricity spend can be due to lighting. Often, much of this is needless and can be reduced without affecting light quality or safety. This can be done by:

- Labelling lighting banks so people know which switch operates which light(s).
- Installing lighting controls and sensors:
  - Photocells to reduce artificial lighting when adequate daylighting exists.
  - Presence detection to ensure lights are on only when needed.
- Removing obstacles to daylight and maximising the natural light coming in to a room.
- Cleaning windows and roof lights regularly.

- Installing sun pipes to increase daylighting.
- Reducing lighting levels in non-critical areas.
- Cleaning fittings annually.

The three key factors that impact on lighting energy consumption are:

- The quantity of light.
- How it is used.
- Associated equipment.

It is important that the level of light in a given area is appropriate for the activity being undertaken (for example, offices need more light than a corridor). Excessive lighting will not only increase energy consumption, but can also create other issues such as reduced occupant comfort. The energy used by some types of lamp produces light and a significant amount of heat (for example, incandescent lamps). This can make an area uncomfortably warm and increase the need for ventilation and cooling.

4.5.1 Lighting terms

Luminous efficacy is the efficiency at which a lamp converts electricity into light and is measured in lumens/watt (lm/W).

Illuminance is the amount of light falling on a surface and is measured in lux. The activities being carried out in a space will determine its lux level. Lux levels for different activities can be found in European Standard BS EN 12464-11 or CIBSE's Guide A: Environmental Design. If the space has mixed activities, the background level can be set to the lowest lux level (normally around 200 lux) and the higher lux level provided for by task lighting on desks (normally between 300 lux and 500 lux for open-plan offices).

Lamp manufacturers can provide more accurate data on the performance of their products.

4.5.2 Technology

There are a number of different lamp technologies. While some of these have been developed for specific purposes, there has been a move in recent years towards developing lamps that are highly efficient, such as light emitting diodes (LED) lamps. In general, LED technology can now replace almost all traditional lamp types and offers significant reductions in energy use.

When considering lamp replacement, there are a number of factors to take into account, including:

- What the expected lifetime of the lamp is. A tungsten filament lamp has a life expectancy of about 1,000 hours, a compact fluorescent lamp has a life expectancy of about 8,000 hours, and an LED lamp is expected to last for over 50,000 hours. Using LED technology significantly reduces replacement costs, especially in a railway situation.
- If a higher efficiency lamp can directly replace an inefficient lamp or if a new luminaire is required. There is some question as to whether a replacement lamp in a luminaire designed for another lamp type will deliver the quoted operational life of the replacement lamp due to the potential for localised heat build-up in the luminaire.
- If the required light temperature and colour can be achieved.

Lamp manufacturers now offer comprehensive assessment services to support major lamp replacement programmes. They can also supply lamps and luminaires to meet any need, and can address all of the factors listed above.

The following sections summarise the main types of lamps and luminaires.

4.5.2.1 Light emitting diodes

After many years of development, LEDs are now available for almost every application. The high efficiency and falling cost of LEDs is making them the preferred choice not only when new lighting systems are being installed, but also for routine bulb replacement. In addition to the benefit of low energy consumption, LEDs also emit less heat than other bulbs and have long operational lives, which can lead to significant reduction in maintenance costs.

4.5.3 Case study: Lighting upgrade

In 2015, Network Rail carried out a lighting upgrade of its Shipdham regional office complex in Norfolk. The existing lighting system was replaced by 80 19W LED tubes, which were retrofitted throughout the building.

Further details of the project are provided in Table 10.

Table 10 - ROI figures for Network Rail Shipdham office lighting upgrade

Capital cost of project	£3,000
Estimated annual cost savings (£)	£2,500
Estimated annual energy savings (kWh)	20,000kWh
Project payback	1.2 years
Non-financial benefits	• The new lighting system provides a better quality of light for employees to work in. • The brand image presented to building visitors is enhanced.
Lessons learned	LED lighting is sensitive to even very small changes in the voltage of a building's power supply, and this can cause flickering. Before a retrofit is carried out, the voltage should be carefully checked at the point at which the electricity supply enters the building.

4.5.3.1 Tubular fluorescent lamps

Traditionally, these have been one of the most common lamp types used. They require control gear, which may include a starter, capacitor and ballast. Lamps are available in a range of lengths and diameters. The larger the diameter, the less energy efficient the lamp is. T12 lamps are 38mm in diameter, T8 lamps are 25mm in diameter, and T5 lamps are just under 16mm in diameter. In some cases, an LED direct replacement lamp may be available, in other cases a new luminaire will be required.

4.5.3.2 High intensity discharge (HID) lamps

Mercury vapour, metal halide, low-pressure sodium, and high-pressure sodium lamps are all HID lamps. They require control gear, can have long warm-up times, and only achieving full light output after several minutes. This does not make them suitable for applications where they are required to be switched on and off such as in security or PIR controlled lighting.

4.5.3.3 Luminaires

Luminaires, or lighting cases, physically support the lamp. Some are poorly designed and are not as energy efficient as others. Luminaires should have reflectors and refractors, and have efficient lamp control gear. They also need to be kept clean and well maintained to optimise output.

A luminaire's efficiency can be measured by the light output ratio (LOR). The LOR is the luminaire's light output to the bare lamp's light output. A LOR of no less than 50 % should be used.

High-bay luminaires have HID lamps up to 1,000W. They are suitable for high ceiling industrial and commercial buildings. They are generally made from plastic, glass or aluminium reflectors.

Batten luminaires are generally used with tubular fluorescent lamps and are low cost. If the lamp is bare, no control of glare is possible. If not, there may be reflectors and/or diffusers.

Recessed luminaires sit flush in ceilings. They are generally sized to fit in suspended ceiling grids. Some air-conditioning system use recessed luminaires as return air grilles.

Luminaires also provide directional control. The light should be directed to where it is needed. This should also reduce glare. Excessively bright, unshielded light sources cause glare and discomfort to building occupants.

External luminaires may need to be of a durable quality depending on their location. For example, luminaires fitted to bridges may have to deal with sea air and water, sun exposure, and bird faeces.

This means that when reviewing lighting with a view to improving energy efficiency, it is important to consider the whole luminaire to get the optimum system.

4.5.4 Controls

Lighting controls can be manual or automatic, or a combination of automatic with a manual override. Lighting controls not only save energy used for lighting, but also energy used for cooling because when lights are switched on for shorter periods, they emit less heat.

Effective behaviour training should ensure that local staff switch off lights when they are not needed. Where this cannot be guaranteed (such as those areas occupied by the public), then PIR sensors may be of value. In addition, you should consider if a daylight sensor is required to prevent lights coming on when light levels are high.

4.5.4.1 Manual switching

Manual switches should be located in the room that they control or, if outside the area, they should be clearly labelled. They should be no more than 8m away from the lights they control. Manual switching can be one or two-way. Two-way lighting may be used in corridors where a switch at either end of the corridor can switch the lights on or off. Localised manual switching allows for greater flexibility in providing the appropriate light. The occupant of the space can decide how many lights to turn on and leave off.

Lights should be banked in zones and clearly labelled. Out-of-hours use for cleaning and security should also be considered.

While the above might all sound obvious, there are instances where this basic level of control is not applied. This is usually the result of building alterations or the installation or removal of internal walls. This can lead to instances where manual light control as described above is not possible. In these circumstances, rewiring lighting circuits should be undertaken to restore acceptable levels of manual lighting control.

4.5.4.2 Time switching

Time switching is a simple and cost-effective control strategy. It switches lights on and off at certain times and can vary lighting levels throughout the day. Time switching can be 24 hours a day, 7 days a week. However, a drawback with simple time switching is that day and night lengths vary throughout the year and so applications where lighting is replacing daylighting may be an issue on timer-based systems and some energy wastage may result. Other issues are that clocks need to be reset after power outages and when the clocks change from British Summer Time to Greenwich Mean Time and vice versa. Over Bank Holidays and other periods, simple timer systems may also lead to energy wastage.

4.5.4.3 Occupancy sensing

PIR sensors are the most common motion-detection sensor. They detect infrared radiation heat given off by people. There are different PIR sensors for different applications. For corridors, a long, narrow field of view is needed; with open-plan offices, several beam sensors with a wide field of view would be more appropriate.

Sensors that radiate microwaves and monitor the signals' disturbance are known as active motion sensors. These sensors typically consume more energy than PIRs. Sensors that combine both methods of detection are available and reduce the potential of false activation.

Table 11 - Occupancy sensing energy saving

Control strategy	Saving[a] (%)
Auto on/dimmed	5 %
Auto on/auto off	10 %
Manual on/dimmed	10 %
Manual on/auto off	18 %

a. According to BS EN 15193:2007

Occupancy sensing works well in situations where people cannot easily operate the light switches, such as when carrying goods. However, occupancy sensing can be annoying to staff if it's not specified correctly. In such circumstances, lights may switch off due to not detecting movement for a period of time, but people are still present. Changing the delay timer may rectify this issue, but this leads to more energy consumption when the light is not needed and reduces the cost-effectiveness of the system.

Occupancy sensing can also hinder energy saving behavioural change as they remove the responsibility of the user to turn off the lights. This can have a knock-on effect to other areas. If the delay timer is set too long, lights may be left on for prolonged periods of time when there is no occupancy. These issues must be taken into account when specifying the system and behavioural/ awareness activities should run alongside technical interventions to maximise effect.

4.5.4.4 Photoelectric sensing

Photoelectric or daylight sensors are typically mounted in the ceiling. They measure the lighting level by daylight on a surface and then dim the artificial lighting to the required lighting level. This means the lowest possible amount of artificial light is used to obtain the required lighting level. However, they do not determine if the lights should be on or not. Manual switching, time switching or occupancy switching is necessary to determine that. As with occupancy sensing, sensors with the lowest power consumption should be used. Daylight sensors should be placed in the same area as the lights they control. Lamps should also be capable of being dimmed for this strategy to work correctly.

4.5.4.5 Dimming

A higher level of light may be delivered from a lighting system than is needed. This could be because the system was designed for a different task or because it was over-specified. Lighting level tuning or dimming can rectify this. It is recommended that lighting surveys of buildings be carried out periodically and the correct level of light set. Lighting levels of between 10 % and 100 % of rated output can be obtained by dimming.

4.5.4.6 Soft start

Soft start control can help reduce damage to certain lamps by reducing the switch on electrical surge. This can help extend the life of lamps.

4.5.4.7 Control systems

Digital addressable lighting interface (DALI) is the most commonly used type of lighting control protocol. DALI systems not only monitor typical lighting energy, but can also monitor emergency luminaires, and failures of ballast or lamps. Reasons for over lighting a space may be because the task that is carried out in the space is not that of the designed lighting system or the task was unknown at the design stage. With DALI, luminaires and switches can be reprogrammed so no rewiring is necessary. This is sometimes called soft wiring. DALI also helps integration with other control systems as it can communicate with heating, ventilation, and air-conditioning controls through the building management system.

4.5.5 Maintenance

Lighting systems need regular maintenance. Their output can reduce by up to 50 % over time. This is dependent on the lamp type and location. Overheating, frequency of switching, and voltage fluctuations affect lamp life.

To allow the most amount of daylight into a space as possible, regular cleaning of windows and skylights should be carried out. Lighting installations may also rely on a certain amount of internal reflection from walls and ceilings. These will also need to be cleaned and redecorated periodically. Colour selection is important for ceilings and walls to reflect as much light as possible. Lighting control sensors should also be cleaned regularly as dust can obscure them and reduce their effectiveness.

Time switches should be checked to ensure they are showing the correct time, especially during when the clocks change in March and October, and are set to operational needs.

4.5.6 Wall lighting

Floors and ceilings are typically in our peripheral vision, depending on the size of the space we enter. To make the space look brighter, it is important to illuminate vertical surfaces. A good way to do this is to have low lux levels at floor level, with brighter walls. This gives the impression that the area is brightly lit, but the lux level on the floor is actually at the minimum regulatory level.

As a result, you should consider the use of wall lighting in corridors and communal areas as a way of reducing energy use.

4.5.7 Exterior lighting – car parks, bridges, and architecture

Exterior lighting must be appropriate to its location and environment. Ensuring it is effective and efficient will save energy and reduce carbon emissions, but it will also lead to reduced light pollution. Selecting appropriate luminaires is also crucial to the elimination of light pollution.

LED technology is ideally suited to exterior lighting. Exterior luminaires are usually sealed to protect them from water damage, so retrofitting with more efficient lamps is not usually a viable option. However, the latest technologies and improved luminaire designs do offer the opportunity to save energy through luminaire replacement programmes.

The main applications for exterior lighting are:

- Street lighting
- Car parks
- Security
- Architectural

For road lighting and car parks, luminaires with a completely flat glass or a shallow bowl are preferable to deep-bowl luminaires as these cast light upwards and not towards the road.

LEDs are increasingly used for street and car-park lighting as they reach full output instantly, which enables them to be switched on and off easily. This is in contrast to high-pressure sodium and metal-halide lamps. These can take several minutes to reach full light output and take a long time to switch back on after they have been switched off, so are not suited to presence detector controls. It is important to only light at the right time. While it may be argued that some lighting needs to be on all night for safety or security reasons, the majority of applications should be more controlled.

Car park and security lighting can be controlled effectively with presence detectors, which could be combined with time clocks. Care should also be taken to avoid light trespass into windows.

Guidelines on appropriate lighting levels for different applications are given in the SLL Code for Lighting (www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I6xiAAC). In some instances, particularly for street lighting and pedestrian routes, the recommended light level changes according to the built environment – less light is needed in rural or semirural environments in comparison to that needed in a city centre. The recommended limits for light pollution also vary. More information can be found in SLL Factfile 7 (www.cibse.org/getmedia/b5b2c3b1-3e1d-4de5-8970-079d03d5df20/Lighting-Factfile-7-b.pdf.aspx).

Security personnel should be consulted prior to altering exterior lighting as this can greatly impact on the efficiency of the security systems.

4.6 Heating

Heating systems provide space heating and domestic hot water.

A heating system consists of an energy source (fuel), a heat generator (such as a boiler or heat pump), heat emitters (such as radiators and unit heaters), and a heat distribution medium (such as air and water).

Criteria that should be kept in mind when selecting these elements are:

- Reliability
- Time to repair
- Lead time
- Fuel source flexibility
- Layout flexibility
- Comfort in summer and winter
- Economic uncertainty
- Operational cost
- Investment cost

In offices, 50 % of energy consumption can be due to heating systems. Therefore, improvements to heating system efficiency can produce large savings.

General design criteria of heating systems and system selection is given in CIBSE *Guide B: Heating, Ventilating, Air Conditioning and Refrigeration* (www.cibse.org/Knowledge/knowledge-items/detail?id=a0q200000090JnqAAE) and CIBSE *AM14 Non-Domestic Hot Water Heating Systems* (www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7nuAAC). Heating systems must also comply with Building Regulations which can differ from location to location such as in Scotland and Wales

Due to the age of the rail industry, heating systems vary from building to building. These may include wet systems, such as low pressure hot water systems with radiators, electric systems (such as domestic-style oil-filled heaters), and air systems (such as fan-coil systems). Central all-air mechanical ventilation systems may also be present at some sites.

Some experts recommend that rooms should not be heated above 19˚C as costs rise by 8 % for each degree above this.

In general, insulation and air-tightness improvements should be made prior to making alterations to heating system. All heating vents should be checked to ensure they are unobstructed at all times.

Insulating pipework, changing oil boilers to natural gas boilers, and installing/altering controls are some methods that can reduce heating energy consumption. However, installing systems that product heat and electricity (such as CHP) have been seen to be the most effective way of improving heating systems.

4.6.1 Fuels

Fuel switching can offer cost savings. Options are to move to electricity for heat pumps, or to use a renewable fuel such as biomass, which attracts Renewable Heat Incentive (RHI) payments.

Fuel costs can be volatile over the lifecycle of an installation. Therefore, when selecting your fuel source, you need to consider the potential impacts of increases in fuel costs. Also keep in mind the need to store some fuels (such as biomass) and the space that this will need. Issues like fuel delivery and handling must also be taken into consideration.

Solid fuels, such as biomass, can also impact on local air quality, especially as boilers start and idle. Controllability of solid fuel combustion will also limit the capacity of these systems to load follow and may require the addition of a thermal store to help balance heat supply and demand.

Carbon emissions may also be a factor in your decision to adopt a specific fuel source for your heating system. Different fuels have different emissions – grid supplied electricity has the highest emissions factor and wood chips have the lowest. To do a comparison, visit the UK government website and look at heating fuel conversion factors (https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016).

4.6.2 Heat generators

The selection of a heat generator for your space heating system will depend on the fuel that you have chosen.

Gas boilers are relatively small and offer good flexibility in terms of location. Oil boilers are similar, but location will be limited due to the need to have the oil store close by. Biomass boilers are typically four times larger than a gas boiler for the same thermal output. They also require the fuel store to be next to the boiler and provision needs to be made for the flue and for processes (such as de-ashing).

Heat pumps are becoming more popular. Here, issues around location are dictated by the heat exchanger and if the system is air source or ground source.

When selecting a new heat source, you should ask yourself:

- Am I connected to the natural gas grid? If not, am I close to a source of biomass and, if so, do I have the potential to store it on site in a location that is accessible for fuel deliveries? This will help to start eliminating some technology options.
- What is the scale of my demand? Is it a constant or intermittent demand? Answers to these questions will inform the technology selection.
- Do I have restrictions in terms of the location of my heat source? Will the location support an air source heat pump collector of sufficient size? If not, is a borehole based ground heat collection feasible? This will help to eliminate or confirm heat-pump options.

Detailed information on heat generators can be found in CIBSE *Guide B1: Heating 2016*.

The key to heat generator selection will be the efficiency of operation. Gas and oil boilers are now almost all high-efficiency condensing models, which recover heat from the exhaust gases. Biomass boilers have economisers which effectively do the same thing. In the case of heat pumps, efficiency is measured by the coefficient of performance (COP). The COP of air source heat pumps can be improved by locating the collector close to a heat emitter.

4.6.3 Heat emitters

Heat emitters (such as radiators, radiant panels, fan coil units, and underfloor heating) release heat into the space from the distribution medium. Therefore, they should not be blocked by furniture, boxes, or other items as this will greatly decrease their efficiency.

The type of heat generator and fuel you choose will influence your choice of heat emitter and vice versa. As the heat emitter is what occupants of the space interact with in regards to the heating system, you may want to select the heat emitter first and work back to the fuel.

In considering these issues, you also need to look at the extent and suitability of any existing heat distribution system. For instance, old, high-volume central heating systems with heavy radiators may be ideal to match to a heat pump system. This is because heat pumps are limited in terms of the temperature of the water they provide making them ideal for maintaining a temperature in a high thermal mass system. Underfloor heating produces the same effect.

In areas where there are high levels of movement, fan coil units may offer a better means of delivering heat compared with traditional radiators.

Detailed information about heat emitters can be found in CIBSE Guide B1: Heating 2016.

4.6.4 Centralised and decentralised heating systems

A centralised heating system has a heat generator in a central location that typically supplies one large or several buildings and is remote from the heat emitters. The heat must be distributed from the central plant to the heat emitters using one of several mediums such as liquid, steam, or air. Centralised systems can be powered by a wide range of fuels such as gas, oil, renewables (such as biomass and waste heat), and may incorporate systems such as district heating and CHP.

Heat loss from the distribution network is an issue, which can be overcome to some extent with adequate insulation. It is possible that, due to the heat loss from the distribution network and the higher plant loads, a centralised system may be less energy efficient than a decentralised one (a system that has a heat generator and emitter in one such as an electric radiant panel or direct gas-fired heater).

The cost and disruption of installing a new heat distribution system may make it unattractive and may make the refurbishment of an existing distribution system worth considering.

Decentralised systems are typically limited to natural gas and electricity fuel sources.

4.6.5 Operational temperatures

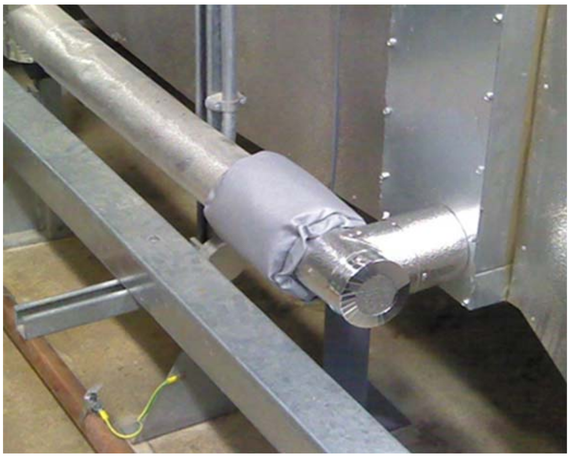
The lower the operational temperature of the fluid used for heat distribution (which is usually water), the less potential there is for energy loss. This is because heat loss is proportional to the temperature of the circulating water. In systems using a condensing boiler, having a lower return water temperature is also beneficial. This is because the condensing process only occurs with a return water temperature of 50°C or below. However, it must be recognised that the distribution network will need to pump significantly more water at a lower temperature to achieve a given room temperature than it would if the circulating water were hotter. For this reason, it is important to balance circulating water flows using radiator valves to maintain the desired room temperature while also ensuring that as far as possible return water temperatures do not exceed 50oC.

4.6.6 Plant insulation

Substantial heat loss can occur in a heating system if boilers, pipework, valves, and flanges are uninsulated. This leads to poor efficiency. You should check your plant's insulation regularly for damage or leaks. Wet insulation caused by leaks may not be effective at reducing heat loss. The leak should be fixed and insulation dried out or replaced. While most modern boilers have adequate insulation, older boilers can have heat losses due to poor insulation of up to 10 % . You should assess and replace insufficient insulation and insulation showing signs of degradation.

Valves can regularly be left uninsulated due to concerns about access. Modern valve-wraps solve this issue. It insulates the valve, but allows for easy access to the valve using quick-release fastenings.

4.6.7 Case study: Pipework insulation upgrade



At Ebbsfleet and Stratford stations, an infrared thermographic survey was carried out to identify missing or damaged thermal insulation on heating pipework, and ancillary equipment in plantrooms. Many of the shortfalls in insulation were found to be around complex shapes in the pipework such as valves, elbows, and drain points.

Following the survey, an insulation upgrade project was carried out to cover the complex shapes with removable insulation jackets.

Further details of the project are in Table 12.

Table 12 - ROI figures on pipework insulation upgrade at Ebbsfleet and Stratford stations

Capital cost of project	£13,200
Estimated annual savings (£)	£12,710
Estimated annual savings (kWh)	306,271 kWh
Project payback	1 year
Lessons learned	• Even relatively small uninsulated areas of pipework can result in high heat loss. • Fitting removable insulation jackets meant that insulation did not become damaged when it needed to be removed for routine maintenance or repair. • A post-installation survey must be carried out to ensure that insulation has been installed effectively.

4.6.8 Variable speed drives

Variable speed drives (VSDs) fitted to electric motors on fans and pumps that are part of the heating system can save significant auxiliary energy. On forced or induced-draught boilers, a VSD will control the speed of the fan so that air flow through the boiler is reduced when it is not required. A 10 % reduction in fan speed leads to an energy saving of around 20 %. A reduction of 20 % of fan speed can save around 40 %.

The same principle works with pumps on the heating system. When the load on the system is lower, the pump speed can be reduced, so significantly reducing the amount of energy consumed by the pump.

VSDs are best suited to variable loads, as speed control on fixed-speed fans and pumps is not required.

4.6.9 Controls

Better control over your heating system should improve your energy efficiency and, importantly, make the building occupants more comfortable. The best control will provide the right conditions at the right time. Factors that have a major impact on the performance of your heating systems are:

- Where the controls are located
- How controls are set
- How often the controls are checked

Proper control of your heating system will also minimise maintenance, repair, and replacement costs as wear and tear is reduced.

The three main types of control are time, occupancy, and condition. For a heating system, 'condition' primarily refers to temperature, but it can also refer to humidity and carbon dioxide levels. These three types of control can be combined in different ways to obtain different outcomes.

4.6.9.1 Control by time

Time switches are simple controls that switch plant on and/or off at predetermined times of the day. They include 24-hour timers, 7-day timers, and more complex yearly timers that take into account holiday periods.

An optimum-start controller learns how quickly a building reaches the desired temperature and turns the heating on to achieve the correct temperature as people arrive. This typically works by switching on heating later on mild days as the warm-up time required is shorter. Up to 10 % energy improvements have been reported compared to 7-day time switching. They work best in well-insulated buildings.

Most optimum-start controllers use internal and external temperature readings to determine the appropriate time to turn on the heating system. Generally, they teach themselves how to operate. Simpler versions use internal temperature only and are less accurate. Using optimum stop control, the heating is switched off as early as possible without compromising the comfort of occupants. Other features, such as day economy and frost protection, can also be specified. Ensure that actual building occupancy times are programmed in.

If out-of-hours heating is required occasionally throughout the whole building, consider fitting advanced controls, also known as boost controls. This is a more efficient option than constantly reprogramming time switches. If only a part of the building is to be used, it may be more economical to provide local heating and shut down the main system.

Delayed off controls are particularly useful where heating needs to be extended beyond normal hours (for example, evening working) or when occupancy in an area is unpredictable (such as in function rooms). Heating is switched on by the occupant, but automatically switches off after a pre-set period.

You should have a recording facility of when the boost button is pressed. If it is repeatedly pressed on a site during a short period of time, you may have to adjust your time switches or set points.

It is recommended that the boost button is the only heating control that building occupants have access to. If other controls are available, occupants are likely to adjust them, including breaking open tamper-proof protective boxes. Ensuring that local control is not available may be the only way to optimise the efficiency of a heating system. However, regular feedback should be sought from occupants to fine tune the system to their needs.

4.6.9.2 Control by occupancy

Occupancy sensors can help to ensure that building services only operate when someone is present. These types of control are mainly used in lighting systems, though they can also be used for fast-response heating systems such as electric radiant heaters.

4.6.9.3 Control by condition

It is important to position room temperature sensors in locations that provide overall temperature sensing for the area. For large spaces, this may involve using several sensors and the location and type of sensor should reflect the activity taking place in the space. It is recommended that sensors do not have a control function to avoid occupants adjusting them. A boost button for heating should be present in the spaces so that occupants can request additional heat if necessary. The heating system will return to its usual setting after a fixed period of time.

There should be a gap of no less than 5°C between a heating set point and a cooling set point, which is known as the 'dead band'. This prevents energy being wasted as heating and cooling systems will not be on at the same time.

In a radiator-based heating system, thermostatic radiator valves (TRVs) give greater control. It is recommended that tamperproof TRVs are fitted as they lock at a fixed setting so preventing staff from using them as on/off switches. It may be prudent to install a switch so that occupants can turn the heating off temporarily if they feel too warm. This should have a time delay on it so that it will return to its usual setting after a fixed period of time. If an adequate number of temperature sensors are located in the space, overheating should not occur.

Room temperature sensors should be located on a wall or column, around 1.5m above the finished floor level, away from heat sources, and out of direct sunlight. For radiant heating, use a black bulb sensor placed in direct line of sight of the heat source, but far enough away to prevent any non-radiant heat produced from affecting it.

Humidity control is specific to certain applications and is achieved through 'humidistat' control of heating, ventilation or cooling services. Some buildings can be affected by damp which may cause deterioration of the buildings fabric. This is particularly relevant to older buildings. Dehumidifiers controlled by humidistats may improve conditions.

Humidity control can also be used in drying rooms. When the items are dry, the humidity in the room will drop and the heating can be reduced.

Frost and condensation damage should be prevented by the heating controls. They should automatically switch on heating when the space, external air, or return water temperature falls below a pre-set minimum level.

Night-time or unoccupied setback reduces the space temperature during specific time periods, most commonly at night. This reduces the need for heat during these periods, but does not let the temperature inside the building drop to below a pre-set level.

4.6.10 Zoning

Different areas in large buildings need different levels of heating. Creating 'zones' in the building based on occupancy, time, and condition, will improve local conditions and reduce cost.

Zoning should be considered when there are:

- Different occupancy patterns
- Different temperature requirements
- Different activities taking place
- Heat gains such as solar and from equipment

4.6.11 Interlocking controls

An interlocking control switches off the system when triggered. It is used to minimise the possibility of two systems competing against each other. This could be the heating and cooling system operating in the same space at the same time. Simple interlock controls are relatively cheap to install and can be effective in achieving energy savings.

4.6.12 Boiler sequence control

When a system comprises two or more boilers, a 'sequence control' should be installed. This matches the number of boilers producing heat to the heat demand. This increases efficiency of the total system as boilers operate more efficiently nearer to their rated output. Good sequencing will also avoid short cycling. It will also rotate boiler order to evenly distribute wear on the plant. Good sequence control could save between 5 % and 10 % of the overall energy consumption of the boiler plant.

4.6.13 Building management systems controls

A building management system (BMS) is a single system that controls and monitors all a building's services. It can take various environmental parameters into account when making control decisions. Between 10 % and 20 % of heating energy can be saved by installing a BMS rather than having several independent controls. BMSs should be regularly checked for errors and reconfigured if necessary. Set points should also be reviewed periodically.

4.6.14 Operational issues with advanced controls

'Keep it simple' is a good general rule for systems. However, more complex systems give greater potential for energy saving if they are applied and controlled correctly. The level of control complexity should match the size and complexity of the building. It is likely that small buildings with uniform occupancy patterns will not use a BMS to its full potential, so any investment in such a system will be wasted. Bigger buildings are likely to benefit from complex control systems. You should check to see if existing systems are able to respond effectively to the level of control proposed. This may lead to the need for new equipment.

4.7 Cooling and ventilation

Air-conditioning use and associated costs are likely to rise due to climate change. Cooling set points should not be below 24°C. Server rooms should not be set below 25°C, although Google Inc. has run its server rooms at 32°C for a number of years with no issues.

It is also important to avoid heating and cooling being on at the same time in the same area. As with the heating systems, air-conditioning should use controls such as time switches to match occupancy patterns.

There are a number of ways of reducing the energy consumption of air-conditioning systems. These include removing sources of unwanted heat (such as uninsulated pipework and excessive solar gain) and eliminating the need for air-conditioning by using free cooling, natural ventilation, solar shading, and night-time purging.

Free cooling is the use of cooler outside air to cool the inside of the building. This is drawn into the building using an air system with fans. When the outside air temperature is lower than that of the inside air temperature, the system draws in the cooler air to lower the internal temperature of the space.

Natural ventilation is similar to free cooling, but is as simple as opening a window. It supplies and removes air from the building though natural means without using fans or other mechanical systems. It uses pressure difference between the building and its surroundings to provide ventilation and space cooling. Adaptive thermal comfort has become popular in the UK recently. It is based on the simple principle that if someone is made uncomfortable, they will react in ways to become comfortable. All that is needed is to provide the opportunities to allow them to make changes to become comfortable. This has significant potential for removing the need for office air-conditioning in the UK. These opportunities could be, but not limited to:

- Access to openable windows
- Cold drinking water facilities
- Flexible work attire
- Hot desking so they can move around to areas they find more comfortable
- USB desk fans
- Blinds to reduce solar gain

Solar shading is a very cost-effective method of reducing air-condition needs. This can be as simple as internal or external blinds. Vegetation is also a great means of solar shade. It not only provides a more pleasant environment to work in, but also increases oxygen levels in the work space, which is linked to humans being more alert. In the UK, it is preferable to have movable solar shading so that during winter time, no solar gain is blocked as this will increase heating consumption.

Night-time purging is using natural ventilation at night when the outside temperatures are at their lowest. This works best in conjunction with buildings that have a high thermal mass. They absorb the heat during the day and release it at night to the atmosphere when there are no occupants.

4.7.1 Ventilation

When upgrading or replacing an existing mechanical ventilation system, its lifecycle performance should be improved. CIBSE *TM30: Improved life cycle performance of mechanical ventilation systems* outlines methods that can be used to achieve this, CIBSE *Guide A, Environmental design* gives general guidance on ventilation and air infiltration. CIBSE *Guide B: Heating, Ventilating, Air Conditioning and Refrigeration* gives more detailed information on ventilation requirements and systems. BSRIA *Rules of Thumb* (Hawkins, 2011) gives an overview of the operating characteristics of ventilation systems. BSIRA *TN8/98* (Kendrick, Martin et al., 1998) provides excellent guidance on incorporating natural ventilation or mixed-mode ventilation strategies into air-conditioned buildings. CIBSE *AM13* (CIBSE, 2000) outlines information on mixed-mode systems, and their control and design. The impacts of ventilation on a building's overall energy performance is provided in Annex E of BS EN 15239 (BSI, 2007).

4.7.2 Heat recovery

Cooling systems cannot make heat disappear – they just move it from one place to another. It is possible to recover this heat for useful heating of air or water. Most buildings that use cooling systems also require heat. You could use the high-grade heat to heat domestic hot water. Low-grade heat can be used to preheat boiler feed water. If boilers heat water from 7°C to 80°C in winter, and the heat recovery system preheats this water to 20°C, then boiler energy consumption will be significantly reduced. Low-grade heat can also be ducted from the external condensers into a warehouse to provide heating. Alternatively, you could install a separate condenser inside the warehouse to provide direct heating in winter. Some systems use a heat pump to raise the temperature of the recovered low-grade heat to exactly that required by the factory processes. In general, the payback on a good quality heat recovery system is between 3 years and 5 years. This length of time is due to the high capital cost of the heat exchangers, and the costs of additional pipework and controls. The savings are significant though, as any heat recovered is essentially free.

4.7.3 Controls

Ventilation and cooling systems should incorporate some form of time and temperature control. For larger sites, consider including optimum start and stop controls. Depending on the type of cooling or ventilation system, temperature sensors may be room or duct-mounted. These sensors are usually used to control heating and/or cooling coils to regulate the supply temperature to the space.

With large systems, control must be designed so that the effect of control on one zone does not affect another zone or system, such as simultaneous heating and cooling.

Minimum fresh air quantity is normally controlled via the supply, re-circulation, and extract ductwork dampers in relation to air quality. In full fresh-air systems, the air volume can be controlled in relation to air quality via variable speed controls.

VSDs should also be installed to control the fans of any air system.

4.8 Compressed air

Compressed air is a form of stored energy that is used to move points and operate machinery. A typical air compressor takes approximately 7 volumes of air at atmospheric conditions, and squeezes it into 1 volume at elevated pressure using electricity. The resulting high-pressure air is then distributed to where it is needed to do work, released, and useful energy is used to move the point while the air expands back to atmospheric pressure. The operating cost of a typical air-cooled compressor can be as much as 88 % of its total lifetime cost. The capital cost and installation account for the remaining 12 %. If the compressor is water cooled, additional sewerage and water charges, pumping costs, chilled water system operating costs, and chemical treatment will need to be taken into account.

4.8.1 Technology

As air demand reduces, air compressors generally become less energy efficient. Even when there is no demand for air, a compressor can be consuming up to 65 % of its rated electrical power. Retrofitting VSDs to a compressor can reduce energy consumption and costs.

With positive displacement compressors, varying the speed via a VSD is the best option to regulate output. This means that when demand for air reduces, the compressor's speed reduces and so does the energy consumption.

The following should be considered when installing a VSD on an air compressor:

- Suitability of the compressor and its motor – when operating at lower speeds, the oil pump and cooling fan on the compressor motor will also run more slowly. This needs to be taken into account at the specification stage on retrofits to avoid the compressor and motor overheating.
- Overheating – retrofitted VSD controllers need to be installed in an environment that is within a defined temperature range and has a good supply of cooling air.
- Location of the air pressure sensor – this is critical, especially on systems with long pipe runs. If the sensor is in the wrong position, the equipment at the end of the distribution system may not receive enough pressure.
- Control systems – most older control systems are only designed for on/off load compressors that control between two set pressures. Machines with VSDs operate at a fixed set point. Care should be taken on commissioning to ensure the VSD compressor control and fixed-speed machines stay on base load at all demands. To achieve this, it may be necessary to run a VSD outside the control system or to upgrade the control system to a more modern system that has been designed to control VSDs.
- Harmonics – the use of VSDs can create harmonic distortion in the power supply. When the VSD load size is small and the available power is large, the effects generally go unnoticed. However, when either a large number of low-current VSDs, or just a few very large-load VSDs are used, they can have a negative impact on the electrical system, which can affect other equipment. Specialist advice can help you to avoid problems later on.
- Electromagnetic interference – inverter VSDs may produce electromagnetic interference that can affect radio and telecoms equipment. Most manufacturers incorporate special filters, but you should take care with the layout keeping the length of wiring to a minimum and ensuring all motor-side cables have earth screens. Specialist advice can help you to avoid problems later on.

Air compressors that operate continuously generate substantial amounts of heat that needs to be removed. This can be achieved by using air or water. To maximise heat transfer, coolers should be cleaned periodically. Temperatures above 38°C will generally cause moisture problems by overloading the air dryers. It is generally believed that cooler air entering the compressor maximises energy efficiency. Therefore, supply air should come from a cool source.

4.8.2 Air leakage

Evaluating your compressed air system is the first step in improving its energy efficiency performance. Measuring all the important operating parameters of the complete system should highlight areas that need attention.

Time-proven measures to improve the energy efficiency of compressed air systems include:

- Identifying and repairing air leaks
- Minimising pressure drops
- Minimising end use of compressed air
- Examining compressor heat recovery
- Optimising compressed air production equipment

Leaks from compressed air systems waste a significant amount of energy – between 20 % and 30 % of a compressor's output can be lost in this way. However, by running an effective leak management programme, this can be reduced to below 10 %.

Leaks occur most often at joints and connections. Fixing leaks can be as simple as tightening a connection or replacing faulty equipment. To reduce the amount of air that leaks from a compressed air system, make sure the pressure is not higher than that required by the end-use equipment, use high-quality fittings, isolate redundant distribution pipework, and ensure fittings are installed properly with sealants.

4.8.3 Minimise use

Minimising the use of compressed air is the best way to reduce energy consumption. This can be achieved by replacing inappropriate end-use applications, installing flow controllers to lower plant pressure, turning off consuming equipment when not needed, not using an air tool without a load, and grouping end-use air equipment that have similar air pressure requirements and air quality requirements.

4.8.4 Heat recovery

Up to 80 % of compressor electrical energy is converted to heat. Between 50 % and 90 % of this heat can be recovered using a properly designed heat recovery system and used to offset space or water heating. The final location of a new compressor may be determined by the heat recovery potential.

4.8.5 Controls

Significant amounts of energy can be saved by running compressors in more efficient operation modes. With regard to compressor control, the following should also be considered:

For optimum energy and operational performance, systems with several compressors require more advanced controls or control strategies (cascaded pressure bands, and network or system master controls) to coordinate compressor operation and air delivery to the system.

Remember to consider the element of time when designing or tuning a compressor control system. Some compressors require time to start and be brought up to speed. This may require extra storage receiver capacity.

Pressure bands need to be adjusted from time to time.

The 'trim compressor' should be the one most capable of running efficiently at partial loads.

4.9 Variable speed drives

VSDs are commonly used in applications where different operational speeds are required. For example, many pieces of mechanical equipment demand adjustment of flow from a pump or fan. The principle of operation is based on varying the frequency of the alternating current (AC) power supplied to the motor using electronic devices. By varying the frequency, the speed of the motor can be adjusted over a wide range. These drives are relatively expensive, but provide a high degree of control over operation and, in many cases, reduce energy use.

VSDs are typically between 92 % and 98 % efficient. Losses are due to heat created by the high-frequency electrical switching and the energy required by the electronic components.

4.9.1 Technology

The potential for energy saving from slowing down the load depends on the characteristics of the load being driven. There are three main types of load:

- Variable torque
- Constant torque
- Constant power

Centrifugal fans and pumps are typical variable torque loads. These have the largest energy saving potential.

Conveyors, positive displacement pumps, and air compressors are typical constant torque applications. These do not have the same potential energy saving as variable torque loads. However, halving the speed will result in a 50 % energy saving.

Machine tools are typical constant power applications. They rarely have any energy saving opportunities.

Using VSDs on systems with a high static head will have reduced benefits. This is because a higher speed needs to be maintained to overcome the resistance due to the high static head. Using VSDs in applications where flow demand varies, such as HVAC circulation pumps, will have a greater energy saving potential.

Using soft starters for motors limits the electrical current at start-up, reduces motor heating, and enables more frequent starting, while limiting the demand on the mains electrical supply. Dynamic braking can decelerate loads in a rapid and controlled manner. Features such as soft starting reduce excessive stresses being placed on the motor and drive train, which can prolong equipment life.

Overall, the most appropriate applications for VSDs are those where the motor output may not be fully used and is variable. You should ensure that the capacity of the motor system is matched to the load it is driving.

Motors controlled by VSDs tend to run hotter than those connected directly to the electricity supply. When motors run below their rated speed, the internal cooling fans lose effectiveness and other methods of cooling are required.

While the use of VSDs can be highly beneficial in many cases, there are situations where they contribute little in terms of energy savings. These are usually all situations where the drive is operated continually at a constant speed and where the ability to reduce speed to lower energy consumption is not possible or desirable. As a result, the application will have to be critically reviewed before a decision to fit a VSD is made.

4.9.2 Favourable application criteria

The efficiency of an electric motor is reduced when it runs at low loads. However, the efficiency of a motor that runs continuously or for long periods at less than 50 % of full load can be improved by fitting a motor power optimiser. Typical applications include:

- Retail fridges, freezers, and process refrigeration plant that are in frequent use.
- Air-conditioning equipment in continuous operation – such as in a computer server room.
- Manufacturing machines with cyclical loads and long periods of low-load operation or idling – such as presses or grinding machines. Savings are usually greatest on old, small, single-phase motors that tend to be less efficient. You should not use motor power optimisers on motors with VSDs, including VRF air-conditioning systems.

4.10 Power management

4.10.1 Voltage management

Voltage management covers various technologies including:

- Voltage optimisation
- Voltage stabilisation
- Voltage regulation
- Voltage power optimisation or voltage reduction

You could be wasting energy if your site is being supplied with electricity at a higher voltage than you need. By reducing the voltage to a level that you need, you save energy. The energy consumption of a voltage-dependent load varies with the voltage being supplied to it. On the other hand, the energy consumption of a voltage-independent load does not. To estimate the potential saving, you need to determine the energy consumption of all voltage dependent loads and the potential voltage drop you can achieve.

A few examples of voltage dependent loads are:

- Incandescent lamps
- Fluorescent lamps – inductive ballast
- Metal halide/SON lamps (possibly)
- Motor loads (uncontrolled)
- Process loads (possibly)

And voltage independent are:

- Fluorescent lamps – electronic ballast (also known as high frequency)
- LED lamps
- Motor loads controlled by VSD
- Electronic loads and information and communications technology (ICT)

The steps for estimating potential savings are:

- Measure voltage and power
- Measure voltage drops across the site
- Determine the proportion of energy consumption that is voltage dependent
- Identify any critical loads
- Calculate potential energy savings
- Decide power rating of voltage management equipment

Once you have determined if you can save by managing the supply voltage, you have three broad options available:

- Install voltage management equipment (this can be a site-wide or technology-specific solution)
- Adjust or modify incoming electrical supply infrastructure (applies to sites supplied at high voltage only)
- Replace voltage dependent loads

You must also consider if you wish to apply voltage management across the entire site. It is possible to voltage manage individual loads if necessary.

4.10.2 Power quality

A number of different terms are used to describe the various power quality problems that can occur in an electrical supply. The most common are spikes, surges, and harmonics. There is a range of retrofit solutions for these power quality problems.

Isolation transformers are a high-cost remedy to harmonic problems but, as a retrofit solution, can be cost-effective. They act as a filtering device between supply and load that significantly reduces the harmonics. To work effectively, they require balanced and relatively constant loads.

Rewiring of electrical installations in most cases is not cost-effective to address harmonic issues. Harmonic filters can be effective as they prevent harmonic currents in the supply reaching the equipment on other circuits.

Uninterruptable power supply (UPS) systems are often considered to be the definitive answer to power quality issues. This is due to their ability to provide clean and stable power supplies without spikes, surges, or harmonics.

4.10.3 Power factor correction

The ratio of true power (kW) to apparent power (kVA) is called the power factor. A power factor of 1 means that 100 % of supplied power is used effectively. A low power factor is undesirable as it means you must consume more power to get the same amount of work. Avoiding a low/poor power factor will save energy and financially as smaller cabling and switchgear can be purchased, and all power purchased is used to do work.

4.11 Combined heat and power

Increasing concerns about energy security has encouraged on-site generation assessments for a number of industries. These have focused on fuel cells, renewable energy technologies, and CHP systems.

4.11.1 Technology

CHP is the simultaneous production of electricity and heat (for space and/or water heating), and potentially of cooling (using thermally driven chillers). CHP technologies can reduce carbon dioxide (CO2) emissions in a wide range of applications and avoid emissions of CO2 from central electricity generating plant. CHP can also reduce transmission and distribution losses, and improve energy security and the reliability of energy supplies, particularly when combined with thermal energy storage.

CHP offers the most significant single opportunity to reduce total fossil fuel consumption from on-site boilers and imported electricity.

Typical CHP systems have an efficiency of between 75 % and 85 %, some plants even achieve an efficiency of 90 %. CHP systems are generally more efficient, from a systems perspective, than the separate centralised production and distribution of electricity and local production of heat as they require less primary energy.

A wide range of CHP technologies are already available, with different performance characteristics and costs. There are a number of mature technologies available.

While all CHP units perform the same broad task, the heat and electricity ratio differs from device to device. Conventional CHP technologies with an internal or external combustion engine or a turbine prime mover have high overall efficiencies, but tend to provide more heat than electricity.

Commonly, a CHP unit is sized to provide the base heat load for a building, supplemented with boilers to meet the higher levels of thermal load. The electrical generator of a CHP unit typically produces electricity at 415V, 50 Hz, 3 phase.

4.11.2 Applications

CHP has become popular for retrofitting to larger buildings and sites. This is encouraged by the European Cogeneration Directive (OJ, 2004), which provides incentives to increase the use of cogeneration throughout EU Member States to improve energy efficiency and security of supply. In view of the increased future risks of summer overheating, tri-generation (combined cooling, heating, and power) systems may become more popular.

A CHP unit only generates economic and environmental savings when it is running, so it will only be viable if you have a high and constant demand for heat – as a rule, at least 4,500 hours per year. However, it could still be suitable on some sites with a lower demand for heat, particularly if there is a high demand for cooling, so it could still be worth exploring.

CHP has been shown to reduce energy bills by between 20 % and 30 %. As well as reduced energy bills, CHP also offers other financial incentives, such as reduced tax liabilities if it qualifies as 'Good Quality' under the CHP Quality Assurance Programme (CHPQA).

If you pay the Climate Change Levy (CCL), you may be eligible for reductions or even a full exemption on your payments by using CHP. You will need to register your system with CHPQA and the size of reduction will depend on how efficient it is. If you export power from your CHP, you may receive a Levy Exemption Certificate (LEC). You can either sell these on, with the exported electricity, or sell them separately to a buyer who can then gain exemption on the corresponding number of units of electricity.

CHP improves a site's environmental performance because the primary fuel consumption per unit of energy generated is lower. Fuels with high greenhouse (GHG) emissions can be replaced with cleaner fuels. Electrical losses are reduced because the electricity is generated at, or close to, the point of use and is not transmitted over large distances.

CHP enables you to generate power independently, helping you to meet demand and reduce your dependence on electrical imports. It can be used to balance your maximum electrical demand and help you avoid penalty payments for exceeding your maximum agreed supply levels from the electricity distribution network.

CHP can provide emergency power in the event of a mains power failure. It can also be configured so your site can operate fully independently of the distribution network, which means your energy supply is more secure.

4.12 Renewable energy solutions

It only becomes cost-effective to consider renewable sources of energy generation once energy efficiency measures have been installed to reduce demand. While installing a solar photovoltaic (PV) panel is a highly visible statement of your commitment to sustainability and mitigating the effects of climate change, it should really be considered as the icing on the cake. After all available opportunities have been taken to reduce your energy demand and to increase the efficiency of the energy supply, CO2 emissions and energy bills can be further reduced through the use of on-site renewable energy and low-carbon technologies.

4.12.1 Solar thermal

Solar thermal systems use the Sun's energy to provide hot water. The technology is well established, but its success depends on factors such as location and orientation. It is usually economically viable only when installed in buildings with a sufficiently high hot-water demand.

Solar thermal (or solar hot water) systems use solar collectors to absorb energy from the sun and transfer it, using heat exchangers, to heat water. Solar thermal systems can be used to provide hot water at temperatures of between 55°C and 65°C.

There are two main types of solar heating collector that are suitable for mounting on buildings – flat plate collectors and evacuated tube collectors.

A sheet of black metal, that absorbs the Sun's energy, encases the flat plate collector system. Water is fed through the system in and removes the heat.

In evacuated tube collectors, parallel glass heat tubes are grouped together. Each tube contains an absorber tube enclosed within a vacuum. Sunlight passing through the outer glass tube heats the absorber tube contained within it and, in doing so, transfers the heat to a liquid flowing through the tube. Evacuated tubes are the most efficient type of solar water collector at around 80 % efficiency (compared to around 70 % for flat plate collectors). However, they also cost more to manufacture leading to higher installed costs.

The UK has an average annual solar radiation of between 900kWh/m2 – 950kWh/m2. Solar radiation varies with the time of day and year. As such, the output from a solar thermal system is likely to be at its greatest during the summer months and at midday.

In determining whether there is a suitable location for solar thermal, the following should be taken into consideration:

- Does the building have an open-aspect south-east to south-west facing roof? Ideally, the collectors should be mounted on a south facing roof, although south-east/south-west will also function successfully at an elevation of between 10˚ and 60˚ – the optimum elevation is around 30˚. Collectors positioned on flat roofs can be mounted on an A-frame to achieve some elevation. Systems can be orientated more easterly or westerly and at a higher tilt angle if peak hot water demand that the system is to supply occurs in the morning or the afternoon (respectively), as this will increase energy capture at these times. However, less energy will be captured overall.
- Is the roof area unshaded? Systems should be positioned in locations that will be unshaded at all times of day if possible. Check for gable roofs, chimneys, trees, and other buildings in the vicinity that could potentially shade the collectors and cause the performance of the system to fall in the early morning or late afternoon.
- Is there sufficient space for a hot-water cylinder(s) in, or close to, the roof space and the site where the panels would be located, or could the roof area be altered to provide more space?
- Is the roof structurally capable of supporting the collectors?

4.12.2 Photovoltaics

PV installations convert sunlight into electricity. PV electricity generation uses the energy in the light from the Sun to cause an electrical current to flow between different atomic energy levels in specially processed materials. PV, like solar thermal, is a truly intermittent renewable energy technology. It requires the user to obtain electricity from an alternative source during the night when it cannot generate electricity or to use a battery back-up system where some of the energy generated can be stored during the day, for use at night. In an effective installation, PV can provide a clear visual demonstration of commitment to sustainability. Setting up a meter display for the public can help demonstrate how much electricity is being generated and to what extent carbon emissions are being offset.

The introduction of the Feed-in Tariff (FIT) in the UK in 2010 has helped stimulate rapid growth in the solar PV market.

Crystalline silicon is the most common type of material used in PV technology and has an average efficiency of between 12 % and 15 %. It is typically available in the form of panels or 'cells', and requires a strong, flat surface for mounting – such as a roof or wall. Groups of PV cells can be connected together to form an array – the more cells, the greater the amount of power generated.

Thin-film PV is made by applying a thin layer of a PV material to a substrate such as glass or metal. Thin film PV is less efficient than crystalline-silicon cells (between 6 % and 10 %), but has a lower cost. This makes it ideal for applications where higher efficiency is not required, but low-cost, light, and flexible construction is important. Many existing PV systems have been retrofitted to buildings. However, it is becoming increasingly common for PV to be available that is integrated into building materials (for example, roofing). PV arrays are connected into the building electrical system via an inverter.

Grid-connected PV systems are connected to the public grid and use an inverter to convert the direct current (DC) PV array output to the AC required by the grid. The inverter also ensures that the PV system output is compatible with the voltage, phase, power factor, and frequency characteristics of the grid. However, it consumes some power itself, resulting in a slight drop in system efficiency. On the DC side of the inverter, a switch is required as a manual means of isolating the PV system for maintenance and repair work. This should be located close to the inverter or integrated into the inverter itself.

For optimum results, roof-mounted PV arrays should face between south-east and south-west at an elevation of between 30° and 40°. The PV array should be free from shading as performance can be significantly affected even if panels are only partially shaded. PV panels can suffer power reduction of up to 10 % if they are not regularly cleaned. If the array is tilted by more than 15°, rain will help to keep the panel clean.

4.12.2.1 Case study: Solar powered Customer Information System (CIS)

In 2010, the Highland and Island Transport Partnership (HITRANS) and ScotRail installed CIS at six rural stations in the Scottish Highlands. The project, CIS Lite, used standalone solar-powered CIS, which uses the 3G mobile network to receive real-time train departure information.

As well as being non-disruptive to install (no trenching is required), such systems can be used in locations where installing conventionally powered systems would be financially non-viable. The use of solar power to run the CIS also means there is no ongoing energy costs or carbon emissions.

CIS Lite was undertaken as a development project, part-funded by HITRANS and Innovate UK. Further details of the project are provided in Table 13.

Table 13 - ROI figures for CIS Lite project at HITRANS

Technology used	Nexus Alpha Low Power Systems CHRONOS Flip-Dot Signs, which has a lifetime of between 3 years and 5 years more than traditional technology.
Capital cost of project	• Equipment: £11,000 per unit. • Installation: £1,500 per site.
Estimated annual cost savings	Up to £250 per unit.
Estimated annual energy savings	Up to 151kWh per unit.
Non-financial benefits	• The visibility of the solar-powered systems sends a positive message to station customers. • Staff are able to access a remote view of the CIS display, as well as real-time information on solar panel generation and battery level. • Audio and a push-button help point are integrated into the system.
Lessons learned	• The storage battery associated with each unit was originally installed underground. This presented problems as it filled with water. A replacement system to keep the battery dry had to be provided.

4.12.3 Heat pumps

Heat pumps provide space heating and cooling, and hot water in buildings, with the possibility of providing all three services from one integrated unit. They are the predominant technology used for space cooling, either in simple air-conditioners, reversible air-conditioners or chillers. Heat pumps are highly efficient, although their overall primary energy efficiency depends on the efficiency of the method used to generate the electricity (or other energy source) they use. They are proven, commercially available technologies that have been available for decades.

Heat pumps that provide heating and cooling for buildings are described by the medium from which they extract energy (air, water, or ground), the heat transport medium they use (air or water), and the service they provide (cooling, space heating and/or water heating). Hybrid systems with higher efficiencies are also possible, such as those that couple heat pumps with conventional boilers or solar thermal collectors.

Most heat pumps use a vapour compression cycle driven by an electric motor, although other cycles exist and some heat pumps are driven directly by gas engines.

Heat pumps using the ground, water or the outside ambient air as an energy source can provide heating and cooling. For refurbishment projects, air source heat pumps are of particular interest due to their relative ease of installation and because they do not need extensive building works on site. Electrically operated air source heat pumps typically have coefficients of performance (COPs) of between 2.0 and 4.0, where higher COPs indicating higher efficiency. COPs of 2 or more make air source heat pumps attractive for off-gas-grid retrofit projects. Gas-fired heat pumps have COPs of around 1.4.

When retrofitting air source heat pumps, care needs to be taken regarding potential disturbance from fan noise since the building fabric's soundproofing might be poor. Any heat pump systems installed as part of a refurbishment project should meet the minimum COP and control requirements set out in section 3 of the Non-Domestic Building Services Compliance Guide (DCLG, 2011). Further information on heat pump systems is given in CIBSE AM14 (CIBSE, 2010). Due to the generally lower operating temperatures of heat pumps compared with boilers (typically 35°C to 55°C), larger emitters may need to be installed to provide the required space heating. Heat pumps are particularly suited as a retrofit solution where an existing underfloor heating system is being re-used. Depending on the required heating load, heat pumps may also be suitable as a retrofit solution for systems using fan coil units. As the existing system will usually be designed according to the cooling loads, such a solution will help to reduce an inherent overcapacity within the heating coil, since the temperature difference between the heating set point and the heating fluid is equivalent to that of the cooling cycle. Similarly, in all-air mechanical ventilation systems, heat pumps may help to reduce energy requirements for heating.

4.12.4 Biomass

Biomass fuel is most commonly used renewable energy fuel and the market for biomass boilers is well established in the UK. For commercial scale use it is usually supplied in the form of wood chips or pellets, but supply can vary from region to region and checking fuel availability is essential before embarking on a biomass project.

The most common application of these fuels is as fuel burnt in boilers to provide space and water heating, but large (2MWe plus) scale CHP plant are in operation in commercial premises and the UK also has operating biomass power stations supplying the grid. The economics of biomass-fired CHP in the UK can be challenging unless fired by waste wood or residues from food or timber processing.

The issues with biomass at all scales are the need to store fuel and potentially with emissions from the flue in built up areas. Compared with other solid fuels like coal, biomass is less dense and produces less energy per tonne and m3 of fuel. This leads to the need for larger fuel storage areas than for coal and more frequent fuel deliveries. The physical size of combustion plant has to also be larger as more wood fuel is needed to produce a given heat output compared to coal. On the plus side, wood only produces less than half the ash of coal and it is naturally low in sulphur.

As with all solid fuels, while most combustion plant are automatic in operation, more operator intervention is required compared with gas or oil systems. All of these issues combine to give higher boiler and operating costs for biomass compared to solid fuel fired heating systems, however on a £/GJ basis, wood chip is often far cheaper than gas and much cheaper than oil. Wood pellets are more expensive and offer less of a cost advantage, but their physical uniformity means that the cost of pellet boilers can be lower than for wood chip.

Biomass boilers are best suited to constant heat demands as they are not as responsive to variable demands as modern gas and oil boilers are. If the load is uneven it may be necessary to use accumulators, or a fossil boiler to manage peaks. Where the biomass boiler is supplying the heat baseload, this will best exploit the benefit of lower fuel costs and this can lead to attractive economic performance, especially if oil fuel is being replaced.

4.12.5 Thermal energy storage

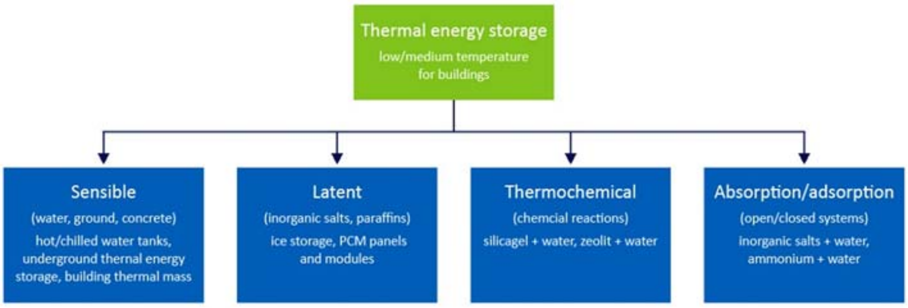
Thermal energy storage (TES) systems can be charged with heat or cold and are capable of holding this energy over time. The most common example is hot water tanks, which are usually insulated to reduce losses. These systems are cheap and can store heat for days or even a week or two at acceptable cost. However, they are bulky and not an ideal solution for long-term storage. The key parameters of thermal energy stores are their capacity, power rating (ability to discharge), efficiency (losses over time and with charge/discharge), and cost. In the building sector, there are three major reasons for using thermal energy storage:

- Improving system efficiency by avoiding partial load operation, operation at other sub-optimal times or by taking advantage of waste energy (such as heat released from chillers). This can involve storage over hours, days or months.
- Shifting demand over time to reduce peak loads. This can help improve overall energy system efficiency, reduce investment in energy infrastructure, and reduce costs. Storage is typically required for hours or several days.
- Facilitating the greater use of renewable energy by storing the energy produced so it can coincide with demand (storing solar thermal energy over days, weeks or months to match water and/or space heating demand).

The installation of larger-scale ice and chilled water storage is growing rapidly in some countries as utilities seek to reduce peak loads and customers seek to reduce peak load charges. Typically, integrated ice storage allows systems to reduce chiller capacity by 50 %, with a similar reduction in the electrical peak demand for chilled water production.

Thermal energy storage will also allow solar thermal systems to provide a larger share of space and water heating and cooling. But to achieve this will require low-cost compact thermal storage systems to be offered commercially. This will enable much larger systems to be installed with heat being stored until the winter, enabling 100 % of space and water heating needs to be met for much of the year.

Figure 24 - Thermal energy storage characterisation



Sensible heat storage uses a storage medium that is heated or cooled. This has a relatively low energy density. Large-scale stores are often placed underground to use the ground as insulation. Aquifer thermal energy storage systems exchange heat through boreholes, and use natural water-saturated and permeable underground layers as a storage medium. Sensible heat can also be stored in building fabric if the building has high thermal mass.

Latent heat storage uses the phase change of a substance to store and then release energy without any change in temperature. These offer storage densities that are 5 to 15 times greater than sensible stores.

Thermo-chemical storage uses reversible chemical reactions to store energy. The technology can achieve densities that are 5 to 12 times greater than sensible stores and perhaps up to 20 times greater, while being able to deliver thermal energy at different discharging temperatures, dependent on the properties of a specific thermo-chemical reaction.

Sensible heat storage systems and some latent heat stores are mature technologies. However, developments in advanced phase-change materials (PCM) and chemical reactions are creating new application possibilities, such as PCMs embedded in building materials such as bricks, wall boards, and flooring. PCMs are well suited to cooling because of the relatively low temperature change required for the release of energy. Hybrid systems are also possible, for instance plastic PCM nodules can be put into a tank where the heat-transfer fluid (usually water) melts or solidifies the PCM. The storage density of this hybrid system is higher than that of water, but less than that of a pure PCM system.

4.13 Payback periods and persistence factors

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Boiler	Electric trace heating of oil lines instead of steam	2 % – 7 %	0.5 – 2	
Boiler	Condensing boilers	15 % – 20 %	3 – 4	14.44
Boiler	High-efficiency boiler	5 % – 7 %	2 – 3	
Boiler	Replacement combination			7.22
Boiler	Replacement modular			10.83
Boiler	Burner management			6.84
Boiler	Burner replacement			13.50
Boiler	Retrofit economiser			10.83
Boiler control	Burner combustion control – oxygen trim	1 % – 3 %	3 – 6	
Boiler control	Boiler sequence controls	3 % – 5 %	2 – 5	
Boiler control	Automatic total dissolved solids (TDS) control of steam boilers	1 % – 3 %	2 – 6	
Boiler control	Boilers – control systems	Up to 30 %	0.25 – 4	6.84
Building management systems	BEMS – bureau remotely managed	Up to 30 %	0.25 – 4	9.00
Building management systems	BEMS - not remotely managed	Up to 30 %	0.25 - 4	6.84
Building management systems	BEMS - remotely managed	Up to 30 %	0.25 – 4	8.42
Building management systems	M&T Software	3 % – 10 %	0.1 – 0.25	
Building management systems	Installation of building energy management system	5 % – 10 %	3 – 6	
Combined heat and power	Biomass CHP	30 % – 55 %	2 – 7	7.60

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Combined heat and power	Gas turbine CHP	30 % – 55 %	2 – 7	11.40
Combined heat and power	Gas, diesel, gasoil engine CHP	30 % – 55 %	2 – 7	15.20
Combined heat and power	Electric to gas – heating using CHP	30 % – 55 %	2 – 7	15.20
Compressor	Air compressor upgrade			14.44
Computers and IT solutions	Cathode ray tubes (CRT) to flat screen LCD			7.20
Computers and IT solutions	CRT to LED monitors			7.20
Computers and IT solutions	Energy efficient file storage replacement			9.00
Computers and IT solutions	Energy efficient server replacement			9.00
Computers and IT solutions	Hot-aisle/cold-aisle containment			10.83
Computers and IT solutions	LED monitors instead of LCD (cost difference)			7.20
Computers and IT solutions	Multi-function devices			4.50
Computers and IT solutions	Network PC power management			4.00
Computers and IT solutions	Thin client			9.00
Computers and IT solutions	Uninterruptible power supplies			18.00
Computers and IT solutions	Virtualisation			9.00
Computers and IT solutions	Office equipment improvements for non-ICT			3.00
Controls	Time switches			6.84

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Cooling	Cooling – plant replacement/upgrade			8.21
Cooling	Free cooling	5 % – 15 %	1 – 2	13.68
Cooling	Replacement of air conditioning with evaporative cooling	5 % – 15 %	1 – 2	13.68
Cooling Control	Cooling control system	5 % – 15 %	1 – 2	6.84
Equipment	Time controls on drinks machines, photocopiers and office equipment	20 % – 60 %	1 – 2	
Equipment	Increased factory or process automation	Up to 80 %	1 – 4	
Equipment	Electric to gas – tumble driers			8.40
Hand dryers	Hand dryers – replacement to more efficient type			4.18
Heat recovery	Steam boiler blowdown heat recovery	1 % – 2 %	2 – 6	
Heating	Presence detector controls on electrically heated rooms (full time and dual temperature set back)	10 % – 40 %	0.5 – 3	
Heating	Connect to existing district heating via plate heat exchanger			28.50
Heating	Direct electric heating to heat pump (air source)			10.83
Heating	Electric to gas – heating using condensing boilers			14.44
Heating	Heat recovery			10.83
Heating	Heating – direct fired system			9.50
Heating	Heating – discrete controls			6.84
Heating	Heating – distribution pipework improvements			15.20
Heating	Heating – TRVs			6.84
Heating	Heating – zone control valves			11.88
Heating	Oil to gas – boiler fuel switching			7.92

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Heating	Replace steam calorifier with plate heat exchanger			28.50
Heating	Steam trap replacements			15.20
Heating	Thermal stores			18.00
Heating	Zone control valves	5 % – 10 %	1 – 5	
Heating	Gas radiant heaters	30 % – 50 %	2 – 4	
Heating	Upgrade insulation of main circulation pipework	60 % – 80 %	1 – 3	
Heating	Insulation of valves and flanges on distribution pipework	50 % – 70 %	1 – 5	
Heating	Point-of-use hot water heaters to avoid long runs of distribution pipework	10 % – 30 %	2 – 3	
Heating	High-speed shutter doors	12 % – 18 %	2 – 3	
Heating	Destratification fans	10 % – 20 %	1 – 2	
Heating	Microswitches fitted to warehouse doors	10 %	3 – 5	
Heating	Thermostatic radiator valves	5 % – 10 %	2	
Heating	Upgrading heating control systems (optimisers, compensators, zone controls)	5 % – 25 %	1 – 5	
Heating	Reflective foil behind radiators on external walls	5 % – 10 %	0.5 – 1	
Heating	Draught stripping	10 % – 15 %	1 – 3	
Heating	Local supplementary heating for small areas with occupancy	10 % – 30 %	1 – 5	
Heating	Decentralised heating services using direct-fired warm air or packaged local boiler plant	10 % – 25 %	3 – 8	
Heating	Low limit (frost) operation of heating plant based temperature	3 % – 5 %	1 – 3	
Heating	Loft insulation*	10 % – 20 %	2 – 4	

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Heating	Cavity wall insulation*	10 % – 20 %	3 – 6	
Heating	Internal wall insulation*	10 % – 20 %	5 – 8	
Heating	Self-closing devices to external doors (based on building total energy for space heating in naturally ventilated buildings)	2 % – 10 %	0.5 – 2	
Heating	Biomass boilers			15.12
Hot water	Hot water – chlorine dioxide dosing and biocide treatment			9.50
Hot water	Hot water – distribution improvements			18.00
Hot water	Hot water – efficient taps			11.00
Hot water	Hot water – point of use heaters			9.50
Hot water	Time controls on electric HWS cylinders	20 % – 50 %	1 – 2	
Industrial kitchen equipment	Steriliser to dishwasher replacement			10.80
Insulation – building fabric	Cavity wall insulation			30.00
Insulation – building fabric	Double glazing with metal or plastic frames			28.00
Insulation – building fabric	Dry wall lining			30.00
Insulation – building fabric	Loft insulation			27.00
Insulation – building fabric	Retrofit single glazing units			8.00
Insulation – building fabric	Roof insulation			30.00
Insulation – building fabric	Secondary glazing			7.92
Insulation - draught proofing	Insulation – draught proofing			29.25

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Insulation – other	Air curtains – ambient			11.40
Insulation – other	Air curtains – heated			10.83
Insulation – other	Automatic speed doors			8.45
Insulation – other	Automatic/revolving doors			8.45
Insulation – other	Draught lobby (external)			29.25
Insulation – other	Draught lobby (internal)			29.25
Insulation – other	Radiator reflective foil (external walls)			8.00
Insulation – pipework	Heating pipework insulation (external)			9.00
Insulation – pipework	Heating pipework insulation (internal)			22.50
Lighting	Compact fluorescent lamps to LED including new fitting	up to 80 %	0.1 – 3	25.00
Lighting	Compact fluorescent lamps to LED using same fitting	up to 80 %	0.1 – 3	13.00
Lighting	Floodlighting to LED including changing the fitting	up to 80 %	0.1 – 3	20.00
Lighting	Halogen to LED including changing the fitting	up to 80 %	0.1 – 3	25.00
Lighting	Halogen to LED using same fitting	up to 80 %	0.1 – 3	13.00
Lighting	Incandescent to LED including new fitting	up to 80 %	0.1 – 3	25.00
Lighting	Incandescent to LED using same fitting	up to 80 %	0.1 – 3	13.00
Lighting	Fluorescent T12/T8 to LED including new fitting	up to 80 %	0.1 – 3	25.00
Lighting	Fluorescent T12/T8 to LED using same fitting	up to 80 %	0.1 – 3	13.00
Lighting	Replace tungsten GLS lamps with CFLs	40 % – 70 %	1 – 3	
Lighting	Replace tungsten GLS spotlights with low-voltage tungsten halogen	30 % – 60 %	2 – 3	
Lighting	Replace 38mm diameter fluorescent tubes on failure with 26mm tubes	8 %	2 – 3	

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Lighting	HF ballasts for fluorescent tubes	15 % – 20 %	3 – 12	
Lighting	Replace opal diffusers or 'egg crate' louvres with prismatic panels or specular reflectors	20 % – 50 %	2 – 6	
Lighting	Localised instead of general lighting (task lighting)	30 % – 70 %	4 – 8	
Lighting	Replace high-pressure mercury discharge lamps with plug-in SON replacements	15 %	1.5 – 2	
Lighting	Replace high-pressure mercury discharge lamps with complete new lamp/gear SON (DL)	50 %	2 – 5	
Lighting	Compact fluorescent lamp including changing the fitting			20.00
Lighting	Compact fluorescent lamp using same fitting			10.00
Lighting	Electronic ballast with dimming control			11.40
Lighting	High pressure sodium including new fitting			20.00
Lighting	Induction fluorescent including changing the fitting			20.00
Lighting	Replace halogen with HID metal halide			20.00
Lighting	T12/T8 to cold cathode fluorescent lamp (CCFL) including new fitting			20.00
Lighting	T12/T8 to CCFL using same fitting			10.00
Lighting	T5 lighting including changing the fitting			20.00
Lighting	T5 lighting retrofit using adaptors			10.00

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Lighting	T8 lighting including changing the fitting			20.00
Lighting	T8 lighting retrofit using adaptors			10.00
Lighting CCFL external	Non-illuminated bollards			30.00
Lighting – external	Replace control gear			12.72
Lighting – external	Replace luminaire incorporating electronic ballast			15.00
Lighting – external	Replace luminaire with LED			20.00
Lighting – external	Solar powered bollards			10.00
Lighting controls	Install automatic lighting controls	20 % – 50 %	2 – 10	
Lighting controls	Intelligent lighting controls	Over 40 %	1 – 4	
Lighting controls	Lighting – discrete controls			8.89
Lighting controls	Lighting control system centralised			10.26
Lighting controls – external	Fit centralised controls			12.72
Motor controls	Variable speed drives	20 % – 70 %	0.25 – 5	10.26
Motor controls	Voltage controllers for constant speed motors	5 % – 10 %	2 – 5	11.40
Motors	Motors – high efficiency	3 % – 6 %	0.25 – 3	15.00
Signalling	Replace with LED including new fitting			20.00
Signalling	Replace with LED using same fitting			10.00
Transformers	Low loss			30.00
Transformers	Low loss (cost difference)			30.00
Transformers	Low loss and voltage management			30.00
Transformers	Low loss and voltage management(cost difference)			30.00
Transformers	Transformer tapping change			30.00

Table 14 - Payback periods and persistence factors

Area	Measure	Typical energy saving (%)[b c]	Typical payback (Years)	Persistence factor[a]
Ventilation	Fans – air handling unit			23.75
Ventilation	Fans – high efficiency			14.25
Ventilation	Phase-change material			23.75
Ventilation	Ventilation – distribution			30.00
Ventilation	Ventilation – presence controls			6.84
Voltage management	Voltage optimisation	5% – 15%	2 – 5	19.00
Voltage management	Power management solutions		1 – 4	19.00

a. http://salixfinance.co.uk/system/public_files/technology_list_aug16.pdf
b. https://w3.siemens.co.uk/home/uk/en/aboutus/Documents/Top10_energy_saving%20options_0911UK.pdf
c. Scottish Executive Guidance on the Public Sector Energy Efficiency Fund, Annex A – Technical Energy Efficiency Measures

5 Application of opportunities to non-traction assets

Potential end use of energy consumption is outlined in this section along with potential energy saving measures that could be applied. Specific considerations to the asset in question are also outlined.

LED lighting will benefit all asset types. However, their control may be slightly different due to occupancy, safety, and security concerns.

5.1 Stations

Stations consume significant energy use. In general, this is weighted towards high electrical energy consumption. This section outlines potential energy saving measures for platforms, concourses, car parks, foot bridges, rail bridges, storage rooms, and tenants.

5.1.1 Potential station energy saving measures

End use: Heating

Potential energy saving measure

Heating control systems

Specific considerations

Typically, stations are heavyweight, low air-tightness buildings. Heating should be minimised to background heating for most areas. Staff areas should have central control with only a boost button present for local control. Ventilation should be by means of natural ventilation.

Potential energy saving measure

CHP

Specific considerations

Heating requirements may be too low for CHP. However, due to station locations, it may be possible to sell excess heat to tenants and neighbouring buildings. This will add an extra revenue stream to the business. Savings of up to 30 % have been seen from the installation of CHP plants.

Potential energy saving measure

Biomass

Specific considerations

Stations have favourable supply routes (that is, the railway). Biomass could be delivered to the station in bulk and stored in unused areas. This can provide a carbon emission reduction in conjunction with CHP. Similar systems have been installed in Finland that use the rail network to significant benefit. Carbon reductions of around 90 % can be achieved from using biomass.

Potential energy saving measure

Multiple heating systems

Specific considerations

Some areas of stations have multiple heating systems. These being a radiator circuit and fan coil units. Fan coil units should be used for cooling mode only and locked out for heating. Electricity should not be the primary heating fuel for these areas. Electric heating can be up to 35 % more expensive than natural gas using a heat pump. With direct electric heating, this can be up to 250 % more expensive.

Potential energy saving measure

Air locks

Specific considerations

Ingress of external air through open doors can cause significant discomfort due to draughts. Using double-door systems with extended L-shaped walk routes between doors and/or rotating doors can reduce these draughts. This can also help with the security of the station. Due to frequency of use, doors are often left open all day. Closed door can also make customers think the station is closed.

End use: Cooling

Potential energy saving measure

Natural ventilation and free cooling

Specific considerations

Cooling is mainly focused in office areas of stations. Due to the heavyweight nature of the building, natural ventilation combined with night-time purging should be used.

End use: Tenant energy consumption

Potential energy saving measure

Energy sharing networks

Specific considerations

Substantial benefit exists for energy sharing networks with larger stations. Removing heat from tenant areas to zones that need heat can reduce energy consumption of the site significantly and open additional revenue sources. In conjunction with a biomass CHP plant, substantial revenue could be created.

Potential energy saving measure

Separate supplies

Specific considerations

For a number of stations, tenants are billed by the station owner and do not have their own mains supply. Providing tenants with their own mains supplies will remove the energy consumption from a station's consumption figures. However, it will decrease the potential for additional revenue streams from the sale of energy to tenants.

End use: Points movement

Potential energy saving measure

Variable speed drives

Specific considerations

VSDs will decrease the part-load energy consumption of the air compressors used for points movement. Using VSDs can reduce energy consumption by up to 50%.

Potential energy saving measure

Air leakage reduction

Specific considerations

Air leakage can account for up to 30% of an air compressors energy consumption and substantially more if it is not maintained correctly. Prompt repair of air leaks will reduce a compressor's energy consumption substantially.

Potential energy saving measure

Removal of compressed air

Specific considerations

Air compressors could be changed to electrical mechanical movement. However, issues do arise with the safety of electrical wiring so close to track movements.

Potential energy saving measure

Points movement planning

Specific considerations

Planning when points will need to be moved in advance, and only charging the air compressors for these periods, can reduce the period of compressed air creation. This could have substantial benefit and will, in turn, reduce the amount of air leakage.

End use: Lighting

Potential energy saving measure

LEDs

Specific considerations

These can have significant benefits when compared with other forms of lighting, but the benefits are not as great when compared with T5 fluorescents, high pressure sodiums, and metal halides. The largest saving comes in the form of reduced maintenance and replacement. However, this can cause issues with safety concerns over column integrity.

Potential energy saving measure

Dimming controls

Specific considerations

During periods of no occupancy or appropriate levels of daylighting, lighting levels can be reduced. Safety and security concerns must be addressed prior to carrying out dimming. It has been noted that some station platforms are now dimming lights during periods of no occupancy, which drivers have suggested aids them in identifying if the platform is occupied or not.

Potential energy saving measure

Switch off

Specific considerations

During periods of no occupancy, some lights could be switched off, but safety and security concerns must be addressed. Platform lights could be turned off during periods of no occupancy, but this will need to be discussed with safety and security officers. Station lighting could also be turned off in concourses and ticket offices when there is no occupancy. However, customers may wrongly believe the station is closed. To counteract this, illuminate entrances and windows during opening hours.

For areas of intermittent occupancy, such as store rooms and corridors, occupancy switch should be incorporated. If lamps are not LEDs, restrike times should be assessed. The occupancy profile for the space should be assessed so that a real estimate for energy saving can be calculated. It has been seen in a number of spaces that lights are constantly on even though occupancy sensing has been installed. This is because the spaces have low occupancy density and not intermittent occupancy sensing. The lamp types limit the restrike time, and so the time and effort installing the PIRs has been wasted.

Architectural lighting on rail bridges should be switched off between the hours of midnight and 4 am. This has the potential to reduce lighting energy by 30 %.

End use: Display boards, ticket gates, vending machines, and other customer appliances

Potential energy saving measure

Switch off

Specific considerations

During unoccupied periods, these should be switched off. Any obstructions to ticket gate or vending machine heat rejection should be removed daily. Vending machine rental costs should be linked to energy prices. It has been noted that some vending machine rental costs do not cover the cost of energy they consume.

End use: Escalators

Potential energy saving measure

Variable speed drives

Specific considerations

Escalator speeds can be reduced when they are not being used.

Potential energy saving measure

Footfall activation

Specific considerations

Escalators can be turned off and activated using footfall plates at either end of the escalators.

End use: Lifts

Potential energy saving measure

LED lighting

Specific considerations

Lift lighting can use more energy in a period than the actual movement of the lift. These should all be fitted with LED lighting and only activated when occupied. LEDs can achieve a 30 % reduction in total lift energy.

Potential energy saving measure

Lift movement drives

Specific considerations

VSDs should be used for lift movement and old motor generators replaced. This can achieve savings of up to 35 %. Regenerative drives should also be investigated. This can achieve a further 10 % saving. Savings potential is dependent on lift use and should be monitored.

End use: Car park lighting

Potential energy saving measure

LEDs and controls

Specific considerations

LEDs combined with occupancy sensing and daylight switching can lead to substantial savings. It would be prudent to use occupancy dimming rather than occupancy switching to avoid customers and staff feeling unsafe

End use: Domestic appliances

Potential energy saving measure

Highest energy rating

Specific considerations

Domestic appliances should be matched to their need. For example, instead of purchasing 10 kettles, a hot water urn would be more energy efficient. Domestic appliances should only be operational during occupied hours. Time switching can eliminate out-of-hours energy waste. Fridges and freezers will need to be on constantly. These should be an optimal size for their use. A packed small fridge will not keep food at the correct temperature and may overload. An empty large fridge wastes energy. Canteen and mess room occupancy times should be staggered for large numbers of staff. Not only will this reduce the size needed for these areas, but it will also reduce the number of domestic appliances necessary and the instantaneous peak load caused by multiple domestic appliances being used at the same time.

End use: Office IT

Potential energy saving measure

Highest energy rating

Specific considerations

IT equipment should be the highest energy rating available. Operating costs should be taken into account when procuring new equipment.

Potential energy saving measure

Screensavers

Specific considerations

No screen savers should be allowed. Screens should be set to standby if the computer is not in use. The computer should switch to standby if it is not in use for an extended period of time.

5.1.2 Tenants

End use: General

Potential energy saving measure

Sustainability charter

Specific considerations

All new tenants should sign a sustainability charter. This sets out high-level principles and commitments that will be translated into priority actions through a sustainability plan. This plan should outline default installation requirements such as LED lighting and time-switch control.

Potential energy saving measure

Energy-sharing networks

Specific considerations

Substantial benefit exists for energy sharing networks with larger stations. Removing heat from tenant areas to zones that need heat can reduce energy consumption of the site significantly and open additional revenue sources. In conjunction with a biomass CHP plant, substantial revenue could be created.

Potential energy saving measure

Purchase of on-site electrical generation

Specific considerations

As part of their lease, a flat rate per unit electricity could be charged to tenants. The station could use this revenue to purchase on-site generation or energy storage. Thus, tenants pay for infrastructure that benefits the station.

End use: Lighting

Potential energy saving measure

LED

Specific considerations

Concessions/tenants are mainly retail stores that use a significant level of light. LED lighting should be specified as the default.

Potential energy saving measure

Time-switching control

Specific considerations

All lights in the unit should be switched off by time switches. It may be necessary to leave on low-level lighting for security purposes (such as CCTV).

5.2 Depots

This section is pertinent to all depots including light maintenance depots, maintenance delivery units, and national delivery services.

End use: Heating

Potential energy saving measure

Heating control systems

Specific considerations

Depots are a mixture of light and heavyweight buildings. Typically, they are not very airtight. Heating should be minimised to background levels for most areas. Staff areas should have central control with only a boost button present for local control. Natural methods should be used for ventilation. Areas with very low air tightness should be assessed for radiant heating potential. An example of this would be storage areas with vehicle roller doors. Dump radiators should not be used and boiler bypass valves fitted. This will reduce the heating loads present in the spaces.

Potential energy saving measure

Building fabric

Specific considerations

Some temporary buildings, which have been used for long periods of time, have very poor insulation and airtightness levels. They are typically very lightweight and use electric heating systems. These are extremely energy intensive due to these factors. By increasing insulation levels and providing radiant heating source with PIRs, heating energy can be reduced.

Potential energy saving measure

CHP

Specific considerations

Heating requirements may be too low for CHP. However, if it is on an industrial estate, heat could be sold to neighbouring buildings. This will add an extra revenue stream to the business and lead to potential costs savings of up to 30 % without taking account of mark up on energy sales.

Potential energy saving measure

Biomass

Specific considerations

Depots in remote locations should be assessed for biomass potential. Biomass has significantly lower carbon emissions than electricity, which is the likely fuel source for heating in remote locations. Carbon savings of around 90 % can be achieved by using biomass.

Potential energy saving measure

Multiple heating systems

Specific considerations

Some areas of depots have multiple heating systems. These being a radiator circuit and fan coil units. Fan coil units should be used for cooling mode only and locked out for heating. Electricity should not be the primary heating fuel for these areas.

Potential energy saving measure

Roller doors

Specific considerations

It is common for roller doors to be left open all year round for ease of access. Closing doors more often can save up to 20 % of heating energy. It will also decrease uncomfortable draughts. Rapid roller doors should be fitted with audible alarms that are sounded when they are left open too long. A button should be fitted that will turn off the alarm for a period of time to allow extended time for loading and unloading vehicles. This button should need a press and release to activate, not just a press. This will reduce the possibility of people resting material against the button to override the alarm. The alarm and button should be tamperproof. An emergency stop button and presence detection should be also fitted to the rapid door for safety.

Potential energy saving measure

Destratification fans

Specific considerations

Destratification fans blow warm air back to occupied levels where it is needed. This can save up to 20 % of heating energy consumption for spaces with high ceilings. The associated fan energy should be taken into account when determining its feasibility.

End use: Cooling

Potential energy saving measure

Natural ventilation and free cooling

Specific considerations

Cooling is mainly focused in office areas. Some sites may also use temporary cooling units which are rented. Solar shading should be used to mitigate solar gains into the space. In some cases, drying rooms are located close to office spaces. These are heated constantly and the transfer of heat to the office through building fabric may be the cause of the overheating. This heat is valuable during the heating season. Drying rooms should have dehumidification control to minimise its heat loads during dry periods.

End use: Points movement

Potential energy saving measure

Variable speed drives

Specific considerations

VSDs will decrease the part-load energy consumption of the air compressors used for points movement. Using VSDs can reduce energy consumption by up to 50%.

Potential energy saving measure

Air leakage reduction

Specific considerations

Air leakage can account for up to 30% of an air compressor's energy consumption - substantially more if it is not maintained correctly. Prompt repair of air leaks will reduce a compressor's energy consumption substantially.

Potential energy saving measure

Removal of compressed air

Specific considerations

Air compressors could be changed to electro-mechanical movement. However, issues do arise with the safety of electrical wiring so close to track movements.

Specific considerations

Planning when points will need to be moved in advance, and only charging the air compressors for these periods, can reduce the period of compressed air creation. This could have substantial benefit and it will, in turn, reduce the amount of air leakage.

End use: Lighting

Potential energy saving measure

LEDs

Specific considerations

These can have significant benefits when compared with other forms of lighting, but the benefits are not as great when compared with T5 fluorescents, high pressure sodiums, and metal halides. The largest saving comes in the form of reduced maintenance and replacement. However, this can cause issues with safety concerns over column integrity.

Potential energy saving measure

Dimming controls

Specific considerations

Daylight dimming should be installed in office spaces that have daylighting potential. Large open-plan offices should also have zone occupancy dimming. Sitting in one location of an open-plan office with lights on, while the rest of the room is in darkness can make staff feel uncomfortable due to security concerns. Dimming the unoccupied areas of the space can save energy, but not impact on staff.

Potential energy saving measure

Switch off

Specific considerations

During periods of no occupancy, some lights could be switched off, but safety and security concerns should be addressed. For areas of intermittent occupancy, such as store rooms and corridors, occupancy switches should be incorporated. If lamps are not LEDs, restrike times should be assessed. The occupancy profile for the space should be assessed so that a real estimate for energy saving can be calculated. In some spaces lights may be constantly on even though occupancy sensing has been installed. This is because the spaces have low occupancy density and not intermittent occupancy sensing. The lamp types limit the restrike time, and so the time and effort installing the PIRs has been wasted.

Potential energy saving measure

Lighting levels

Specific considerations

Background lighting levels should be set to minimum with task lighting provided at desks. This can be in the form of desk LED strip lighting to achieve the required lux level.

End use: Vending machines

Potential energy saving measure

Switch off

Specific considerations

During unoccupied periods, these should be switched off, but the vending machine provider should be consulted prior to switching it off. Any obstructions to vending machine heat rejection should be removed daily. Vending machine rental costs should be linked to energy prices. Some vending machine rental costs do not cover the cost of energy they consume.

End use: Drying rooms

Potential energy saving measure

Dehumidification

Specific considerations

The majority of drying rooms use conventional heating systems, radiators, and electric heaters. The electric option is an extremely expensive way to dry clothes. Dehumidification units should be used to dry outdoor safety clothes. Once the dry humidity level is reached, the dehumidification unit should be switched off. Dehumidification units can lead to energy saving of up to 85 % over direct electric heaters.

Potential energy saving measure

Room fabric

Specific considerations

If dehumidification systems are not to be fitted, the drying room should be fitted with high levels of insulation and extraction fans with heat recovery units. This will keep the rooms at hot as possible while removing high humidity air.

Potential energy saving measure

Door alarms

Specific considerations

Drying room doors should be fitted with audible alarms that sound if the door is open for a long time. This style of alarm is commonplace in the cold-storage food industry to reduce energy leakage from the space. It should be implemented in drying rooms also. These alarms will need to be tamperproof.

End use: Car park lighting

Potential energy saving measure

LEDs and controls

Specific considerations

LEDs combined with occupancy sensing and daylight switching can lead to substantial savings. It would be prudent to use occupancy dimming rather than occupancy switching to avoid staff feeling unsafe.

End use: Domestic appliances

Potential energy saving measure

Highest energy rating

Specific considerations

Domestic appliances should be matched to their need. For example, instead of purchasing 10 kettles, a hot water urn would be more energy efficient. Domestic appliances should only be operational during occupied hours. Time switching can alleviate any out-of-hours energy waste. Fridges and freezers will need to be on constantly. These should be an optimal size for their usage. A packed small fridge will not keep food at the correct temperature and may overload. An empty large fridge wastes energy. Canteen and mess room occupancy times should be staggered for large numbers of staff. Not only will this reduce the size needed for these areas, but also the number of domestic appliances necessary and the instantaneous peak load caused by several domestic appliances being used at the same time.

End use: Office IT

Potential energy saving measure

Highest energy rating

Specific considerations

IT equipment should be the highest energy rating available. Operating costs should be taken into account when procuring new equipment.

Potential energy saving measure

Screensavers

Specific considerations

No screensavers should be allowed. Screens should be set to standby if the computer is not in use. The computer should switch to standby if the computer is not in use for a long period of time.

End use: Canteens

Potential energy saving measure

Occupancy sensing

Specific considerations

A number of canteens use heating systems intermittently and for short periods of time. However, the heating systems installed are slow-response systems that are left on constantly due to the unknown nature of arrivals. Using radiant heat sources or other forms of fast-response heating systems with PIR sensing, can reduce this energy consumption dramatically. Waste heat from onsite compressors could be used to provide background heating for the space, increase the air temperature. Lights should also be fitted with PIRs.

5.3 Train control and signalling

This section outlines potential energy saving measures for crossing huts and cabins, relay rooms, signal boxes, signalling centres, and switch rooms.

End use: Heating

Potential energy saving measure

Heating control systems

Specific considerations

Control and signalling buildings are typically heavyweight, although more modern, medium and lightweight buildings exist. Typically, they are of medium to low airtightness. Heating should be minimised to background heating for most areas. Staff areas should have central control with only a boost button present for local control. Ventilation should be by means of natural ventilation, though security issues can exist. When this is the case, mechanical ventilation is needed. Fans should have VSDs, the systems should include heat recovery and the fresh air be dependent on internal carbon dioxide sensing. Dump radiators should not be used and boiler bypass valves or interlocking controls fitted. This will reduce the heating loads present in the spaces. Protection of relays and switchgear in relay and switch rooms is paramount, and the heating set point should be set accordingly. If the temperature drops below this level, relays and switches may get damaged causing disruption to service.

Potential energy saving measure

CHP

Specific considerations

Heating requirements may be too low for CHP. However, if it is on an industrial estate, heat could be sold to neighbouring buildings. This will add an extra revenue stream to the business and lead to potential costs savings of up to 30 % without taking account of mark up on energy sales.

Potential energy saving measure

Biomass

Specific considerations

Depots in remote locations should be assessed for biomass potential. Biomass has significantly lower carbon emissions than electricity, which is the likely fuel source for heating in remote locations. Carbon reductions of around 90 % can be achieved from using biomass.

Potential energy saving measure

Multiple heating systems

Specific considerations

Some areas of stations have several heating systems. These include a radiator circuit and fan coil units. Fan coil units should be used for cooling mode only and locked out for heating. Electricity should not be the primary heating fuel for these areas.

Potential energy saving measure

Roller doors

Specific considerations

Roller doors are often left open all year round for ease of access. Closing doors more often can save up to 20 % of heating energy. It will also decrease uncomfortable draughts. Rapid roller doors should be fitted with audible alarms sounded when they are left open too long. A button should be fitted that will turn off the alarm for a period of time to allow extended time for loading and unloading vehicles. This button should need a press and release to activate, not just a press. This will reduce the possibility of people resting material against the button to override the alarm. The alarm and button should be tamperproof. An emergency stop button and presence detection should also be fitted to the rapid door for safety.

Potential energy saving measure

Destratification fans

Specific considerations

Destratification fans blow warm air back to the occupied level where it is needed. This can save up to 20 % of heating energy consumption for spaces with high ceilings. The associated fan energy should be taken into account when determining its feasibility.

End use: Cooling

Potential energy saving measure

Free cooling

Specific considerations

Typically, control and signalling buildings have higher internal gains due to electrical equipment. Natural ventilation is limited due to security risks. Free cooling can be used in place of air-conditioning. This could be provided by the mechanical ventilation system if sized accordingly. For heavyweight buildings, exposing the thermal mass and using night purging via the free cooling system can reduce cooling needs.

End use: Points movement

Potential energy saving measure

Variable speed drives

Specific considerations

VSDs will decrease the part-load energy consumption of the air compressors used for points movement. Using VSDs can reduce energy consumption by up to 50 %.

Potential energy saving measure

Air leakage reduction

Specific considerations

Air leakage can account for up to 30 % of an air compressor's energy consumption - substantially more if it is not maintained correctly. Prompt repair of air leaks will reduce a compressor's energy consumption substantially.

Potential energy saving measure

Removal of compressed air

Specific considerations

Air compressors could be changed to electrical mechanical movement. However, issues do arise with the safety of electrical wiring so close to track movements.

End use: Lighting

Potential energy saving measure

LEDs

Specific considerations

These can have significant benefits when compared with other forms of lighting, but the benefits are not as great when compared with T5 fluorescents, high pressure sodiums, and metal halides. The largest saving comes in the form of reduced maintenance and replacement. However, this can cause issues with safety concerns over column integrity.

Potential energy saving measure

Dimming controls

Specific considerations

In the majority of control centres, no daylight is present. This is to reduce glare and distractions. A high level of light quality is needed for occupants to perform their tasks and energy savings should be secondary to these tasks. Relay and switch rooms use a significant amount of lighting, but due to the high racks and lower ceilings, PIRs would need to be located at each rack to be efficient. Background high-level lighting with manual push-button switches and delay off for task lighting at each rack could prove beneficial. The delay off could be replaced with a 24-hour timer switch that resets all task lighting at the end of a working day. This will reduce the possibility of task lighting switching off while tasks are being carried out, when potentially no hand is free to switch it back on.

Potential energy saving measure

Switch off

Specific considerations

During periods of no occupancy, all lights should be switched off, but safety and security concerns should be addressed. For areas of intermittent occupancy, such as store rooms and corridors, occupancy switches should be incorporated. If lamps are not LEDs, restrike times should be assessed. The occupancy profile for the space should be assessed so that a real estimate for energy saving can be calculated. In some spaces lights may be constantly on even though occupancy sensing has been installed. This is because the spaces have low occupancy density and not intermittent occupancy sensing. The lamp types limit the restrike time, and so the time and effort installing the PIRs has been wasted.

Potential energy saving measure

Lighting levels

Specific considerations

Background lighting levels can be set lower for non-critical spaces. However, for critical areas, lighting should create no glare. All workspaces should be fitted with no-glare OLED fittings if cost-effective. These produce no glare with even distribution of light. If this is uneconomical, which at today's prices is likely, LED task light should be fitted in accordance with lux levels, colour rendering, and limiting glare. Colour rendering in relay and switch rooms is extremely important as the colours of wires need to be identified.

End use: Vending machines

Potential energy saving measure

Switch off

Specific considerations

During unoccupied periods, these should be switched off, but the vending machine provider should be consulted prior to switching it off. Any obstructions to vending machine heat rejection should be removed daily. Vending machine rental costs should be linked to energy prices. Some vending machine rental costs do not cover the cost of energy they consume.

End use: Drying rooms

Potential energy saving measure

Dehumidification

Specific considerations

The majority of drying rooms use conventional heating systems, radiators, and electric heaters. The electric option is an extremely expensive way to dry clothes. Dehumidification units should be used to dry outdoor safety clothes. Once the dry humidity level is reached, the dehumidification unit should be switched off. Dehumidification units can lead to energy saving of up to 85 % over direct electric heaters.

Potential energy saving measure

Room fabric

Specific considerations

If dehumidification systems are not to be fitted, the drying room should be fitted with high levels of insulation and extractor fans with heat recovery units. This will keep the rooms at hot as possible while removing high humidity air.

Potential energy saving measure

Door alarms

Specific considerations

Drying room doors should be fitted with audible alarms that sound if the door is open for a long time. This style of alarm is commonplace in the cold-storage food industry to reduce energy leakage from the space. It should be implemented in drying rooms also. These alarms will need to be tamperproof.

End use: Car park lighting

Potential energy saving measure

LEDs and controls

Specific considerations

LEDs combined with occupancy sensing and daylight switching can lead to substantial savings. It would be prudent to use occupancy dimming rather than occupancy switching to avoid staff feeling unsafe.

End use: Domestic appliances

Potential energy saving measure

Highest energy rating

Specific considerations

Domestic appliances should be matched to their need. For example, instead of purchasing 10 kettles, a hot water urn boiler would be more energy efficient. Domestic appliances should only be operational during occupied hours. Time switching can alleviate any out-of-hours energy waste. Fridges and freezers will need to be on constantly. These should be an optimal size for their use. A packed small fridge will not keep food at the correct temperature and may overload. An empty large fridge wastes energy. Canteen and mess room occupancy times should be staggered for large numbers of staff. Not only will this reduce the size needed for these areas, but it also reduces the number of domestic appliances necessary and the instantaneous peak load caused by several domestic appliances being used at the same time. TVs should not be left on in unoccupied staff rooms. These could be placed on occupancy sensors to switch off when not in use. Most modern TVs will switch off if the channel is not changed for a long time. This feature should be enabled.

End use: Office IT

Potential energy saving measure

Highest energy rating

Specific considerations

IT equipment should have the highest energy rating available. Operating costs should be taken into account when procuring new equipment.

Potential energy saving measure

Screensavers

Specific considerations

No screensavers should be allowed. Screens should be set to standby if the computer is not in use. The computer should switch to standby if the computer is not used for long time.

End use: canteens

Potential energy saving measure

Occupancy sensing

Specific considerations

A number of canteens use heating systems intermittently and for short periods of time. However, the heating systems installed are slow response systems that are left on constantly due to the unknown nature of arrivals. Using radiant heat sources, or other forms of fast-response heating systems, with PIR sensing can reduce this energy consumption dramatically. Waste heat from on-site compressors could be used to provide background heating for the space. Lights should also be fitted with PIRs.

5.4 Administration

At many sites, office equipment is one of the biggest consumers of energy that staff have direct control over. This represents a great opportunity to involve staff in saving energy and improving efficiency.

5.4.1 IT equipment

Studies have shown that the average computer is only used for a small fraction of the time that it is on, as people leave them on while making tea, attending meetings or undertaking other work that does not require the computer. People are often reluctant to switch their computers off during the day, as they can take time to reboot. Most operating systems will allow you to switch off different parts of the system to save power. Modern solid state drives decrease boot time for computers to a fraction of older hard drives. This could encourage users to shut down computers for periods of time when they are not in use. You should draft an IT energy management document and circulate to staff. Your IT department should also be able to help in removing screen savers from all computers and enable the monitor to switch to standby. Typically, a mix of desktop computers and laptops are found throughout administration buildings. Laptops consume less energy than desktops. However, a number of risks are associated with replacing desktops with laptops. Laptops are easier to misplace and can be brought out of offices easily which, in turn, increases the risk of crime. A number of large office-based companies are now using virtual desktop cloud computing, which can lower site energy consumption substantially. Virtual machines can save in the region of 75 % of computer energy consumption. However, it does increase server loads.

Using Wi-Fi routers instead of network cables is becoming more commonplace in office environments. Wi-Fi routers do not consume a massive amount of energy for the convenience. However, the selection of routers should be assessed for their energy efficiency for future procurement.

Some sites provide televisions in staff rooms, meeting rooms, and corridors. The majority of these are used intermittently for meetings. However, some televisions are used to notify staff of train times and news items, and for them to watch during work breaks. You should use a staff intranet for notifications and PIR sensors/timers should be placed on televisions in lunch areas. It was found that a number of televisions in lunch areas were left on with no members of staff present. Most modern TVs will switch off if the channel is not changed for a long time. This feature should be enabled.

In general, IT equipment in the rail industry is of average energy efficiency level. The energy efficiency of IT equipment should be factored into the IT equipment procurement process.

5.4.2 Printers and photocopiers.

Network printers and photocopiers are usually shared within an office, so people do not feel as much responsibility for them as they do their own computers. Most modern photocopiers and network printers have energy saving or hibernation modes. You should have these enabled on all printers and photocopiers. Equipment should be switched off at the end of every day and only switched on again when required the following day. Staff should also be encouraged not to print unnecessary documentation and only print the specific pages of documents that they need.

5.4.3 Refreshments

Whether refreshments are provided for staff using a kettle, fridge, or vending machine, there are cost and energy savings to be made.

Vending machines can contain a heating element and/or chiller to dispense drinks and food items. Their energy consumption varies depending on the insulation of the casing, temperature settings, internal lighting, and the overall size of the machine. When considering installing a vending machine, you should discuss with your supplier the most energy efficient option.

Larger sites should use hot water urns due to the number of staff. Hot water urns can be wasteful for very small sites. Urns should be fitted with seven-day timers.

You should select the correct sized fridge for the site. An empty large fridge wastes energy, while an overfull small fridge will not hold its temperature and will potentially overload. Unused fridges should be switched off. In general, it is more energy efficient to have a full, single, large fridge than several full, small fridges.

5.4.4 Portable heaters

All portable heaters in the workplace are subject to portable appliance testing (PAT), which enables you to police their use. The PAT label can be used to distinguish between official and ‘illicit’ heaters. You should keep a log of who

PAT labelled heaters have been issued to, and unlabelled items should be removed from the workplace.

If it is found that a site is requesting or using a high number of portable heaters, you should carry out an investigation into the heating system and its control. The solution to this issue may be reworking the layout of the office so that people that prefer warmer environments are closer to heat emitters.

A survey of rail industry staff found that the reason for using portable heaters were:

- Lack of another heating source
- Replacement heating source being undersized
- Heating system constantly breaking down
- Controls for the heating system located in inaccessible areas
- Lack of understanding of how to use the heating controls
- Personal thermal comfort differences between occupants of the space

Repairing, replacing, and educating staff on the operation of the heating system could eliminate a significant number of portable heaters, saving a significant amount of energy (up to 55 %) and carbon (up to 40 %).

5.4.5 Office lighting

LED light should be the default installation option for administration buildings. Background lighting should be of minimum lux level with task lighting provided by LED strip lighting on desks. Lights should have daylight dimming and occupancy detection. Lights should be banked with zoning in mind, such as daylighting zones and occupancy detection zoning. A digital addressable lighting interface (DALI) should be installed if you envision administration building layouts changing frequently. The lighting controls can be optimised after each layout change without the need to rewire.

5.4.6 Office heating control

Training high numbers of staff on complicated heating controls can be a time-consuming and ineffective task. Local heating controls for administration buildings should be as simple as possible. This could be a 'boost' button, which increases the set point by a degree for a period of time and then resets to its original set point. All heating controls should be tamperproof. Heating controls should be zoned according to the building's layout, orientation, occupant's activity, internal gains, set points, and occupancy profile. A log should be kept of when and where the 'boost' button is pressed. If it is pressed a significant amount of times in a single location, or around the same time throughout the building, you should carry out and investigation. This may result in fault detection or optimisation of occupants' preference for heating.

5.4.7 Server rooms

Data centres and server rooms use a significant amount of energy for data processing. A by-product of this energy consumption is heat, which can be extremely useful to other areas of the building (such as offices). Data centres should be heavily metered due to their energy consumption. Not only should the IT equipment be metered, but all associated systems (such as cooling and UPS systems).

It has long been believed that IT equipment needs to be run at low temperatures – between 15°C and 21°C. A number of rail industry server rooms have a cooling set point of 19°C. However, ASHRAE recommends that cold-aisle temperatures of up to 27°C should be maintained, which companies such as Google have found to have no detrimental effects on equipment. Most IT equipment manufacturers specify machines at 32°C or higher, so there is plenty of margin for error. In addition, most computer room air-conditioners (CRACs) are set to dehumidify the air down to 40 % relative humidity and to reheat air if the return air is too cold. Raising the temperature and turning off dehumidifying and reheating provides significant energy savings. An elevated cold-aisle temperature allows CRACs to operate more efficiently at higher intake temperatures. It also allows for more days of free cooling if the facility has air or water side economisation.

The simple act of raising the temperature from 19°C to 27°C in a single 200kW networking room could save tens of thousands of pounds annually in energy costs.

The density of equipment in a number of rail industry server rooms is extremely low meaning that the space was not used to its maximum potential. Thus an extremely large volume of air is being cooled for no reason. This could be rectified by zoning areas and installing highly insulated partitioning walls.

From a study carried out by Google of retrofit solutions for server rooms, it was found that with an investment of £18,800, an annual energy saving of 670,000kWh could be achieved easily, saving £50,400. This included controls optimisation, cold-aisle containment, adding CRAC air return extensions, and adding new CRAC controllers. Each retrofit measure had a payback period of less than a year.

Altering server room settings can be detrimental to the equipment and potentially could cause equipment failure if not monitored very closely. Each server room is slightly different, so bespoke design is necessary. A specialist server room designer should be consulted before alterations to server room settings are carried out.

Energy sharing is where heat is moved from areas where it is not wanted (such as server rooms) to areas where it is (such as office spaces). It is rare to get a case where you have such a quantity of heat being produced (server equipment) located so closely to an area that needs heat (office area). However, when these opportunities arise, it is extremely important to take full advantage of them. Hot air from the server rooms can be ducted into areas that need heat. If the distances between the two is large, heat exchangers and pipework can be used. Low grade heat can be uplifted using heat pumps if necessary. However, supplying warm air between 27°C and 32°C directly into a space matches well with typical air heating design criteria. Not only is this type of energy sharing suitable to large server rooms, but also to small server rooms in smaller administration buildings. Internal gains in a server room should be limited to only the IT equipment and necessary staff. No windows should exist by which daylight can enter. Free cooling or cold water sources can also be used to offset the need for chillers.

Further information about Google's data centres and how to learn from them can be found at https://www.google.co.uk/about/datacenters/

6 Glossary

Term	Definition
Airtightness	The measure of how leaky a building is.
Automatic meter reader	A meter that automatically provides energy use readings at set intervals.
Baseline	A starting point, to be used for future comparison.
Baseload	The minimum level of demand on a site or property.
Benchmark	A standard point of reference for comparison.
Building fabric	Consisting of a building's roof, floor slabs, walls, windows, and doors. The fabric controls the flow of energy between the interior and exterior of the building.
Building Regulations	Regulations that set out the minimum requirements for buildings.
Business case	The documented justification for undertaking a project.
Conservation area	An area, protected by law that is of environmental or historical significance.
Corporate social responsibility	The assessment and management of an organisation's impacts on society.
CRC Energy Efficiency Scheme	A UK government scheme that mandates which qualifying organisations report on and pay for their carbon emissions from electricity and gas.
Data loggers	An electronic device that records data over time.
Distribution medium	Fluid used to transfer heat around the property, such as water or air.
Driving-factor data	Data on the factors that directly influence energy use.
Energy action plan	A time-bounded plan setting out specific actions and responsible persons for energy management activities.

Term	Definition
Energy efficiency	Optimising the use of energy, so that less energy is used to provide the same service.
Energy hierarchy	A classification system for energy options, prioritised to assist progress towards a more sustainable energy use strategy.
Energy management	The process of monitoring, controlling, and reducing energy use in a building, system, or process.
Energy policy	A document that sets out an organisation's intentions and aspirations for the way that it will manage its energy use.
Energy Savings Opportunity Scheme	A UK government scheme that mandates which qualifying organisations undertake audits of their energy use every four years.
Energy strategy	The framework that guides an organisation's decisions about its purchase, use, and management of energy.
Environmental management	The management of an organisation's environmental initiatives in a planned, systematic, and documented manner.
Fiscal electricity meters	Electricity meters that are directly used by suppliers as a reference for billing.
Half-hourly meter	A meter that provides an energy consumption reading every half hour.
Heat emitters	Equipment that releases heat into the space from the distribution medium, such as a radiator.
Heat generator	Equipment that produces the heat to heat a building, such as a boiler.
Illuminance	The amount of light falling on a surface (measured in lux).
Interlocking control	Switches off the system when triggered.
Internal rate of return	A metric used to measure the profitability of investments.

Term	Definition
kelvin	Unit of temperature.
Key performance indicator	A measurable value that an organisation can use to measure progress against its objectives.
Listed building	A building that is recorded as being of national importance in terms of its historical or architectural value.
Luminaires	Lighting cases that physically support the lamp.
Luminous efficacy	The efficiency at which a lamp converts electricity into light (measured in lumens/watt (lm/W))
Maximum demand	The highest level of electrical demand measured during a period of time.
Monitoring and targeting	An energy management technique that enables businesses to understand their energy consumption, identify factors that impact this consumption, and set appropriate targets for improvement against which they can monitor performance.
Net present value	A measurement of the profitability of an investment.
Non-critical loads	Loads that are not essential and will not affect your business drastically if they are turned off.
Non-traction	Those parts of the rail industry not directly related to trains. For example, station buildings, platforms, and depots.
Rating plate information	A metal plate that is located on the equipment that gives details of the rated power of the equipment and other information.
Residual life	The remaining life of an asset once its economical or technological lifespan has been reached.
Retrofit	Adding a measure, such as a technology or system, to an existing building or site.
Risk assessment	A process for evaluating risks and identifying any necessary mitigation measures.

Term	Definition
Scheduled monument	A historic building or site that is recorded as being of significant value and is protected accordingly.
Sequence control	Controls the order of one transaction to another.
Stakeholder	Any person with an interest in the activities of an organisation.
Stakeholder engagement	The process by which an organisation engages the people that have an interest in its activities.
Sub-metering	The installation of meters in addition to existing primary billing meters.
Transient spaces	Spaces used for passing through, such as corridors, and not intended to be occupied for a long period of time.
Zone	An area with particular characteristics, purpose or use.

RSSB
Floor 4, The Helicon
1 South Place
London
EC2M 2RB

enquirydesk@rssb.co.uk

http://www.rssb.co.uk