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# Making buildings work

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Lessons learned from commissioning low carbon buildings



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Effective commissioning will significantly reduce a building's running costs, eliminate faults and keep occupants comfortable and productive ”

# What is commissioning?

Commissioning is the process of verifying that building systems are performing in a way that meets your requirements. This can lead to a fully optimised building, using less energy and keeping occupants comfortable and productive.

Commissioning is often thought of as a single point in a construction project, carried out before handover. In reality, if your building is to be as efficient as possible, commissioning will need to begin at the start of the project and include continuous monitoring and fine tuning during operation. *Figure 1* shows the best practice activities at different stages of the construction process.

## The team

The commissioning team should be formed early in the process and involve the following people:

- client representative
- commissioning specialist
- design representatives
- cost management representative
- construction specialist
- facilities or premises manager (where appointed).

This team should define, prepare and control commissioning activities. The facilities manager or another member of the client team needs to take responsibility for checking the commissioning plan. They will also need to make sure the commissioning records are complete and comply with the contract.

Figure 1 Commissioning activities throughout the construction process

Commissioning management plan				Initial (static) commissioning to satisfy the specification		Continuous commissioning, incorporating seasonal commissioning and system fine-tuning	
Preparation	Design	Pre-construction	Construction	Commissioning of engineering services	Pre-handover	Initial occupation	Post-occupancy aftercare
Commissioning team should be formed to develop the process and strategy	Commissioning team to review design to ensure commissionability and maintainability	Ensure that all commissioning information is carried to the construction phase and contractor	Ensure that the engineering systems are physically complete and correct, including static testing	Functional performance tests to verify performance before sign-off and handover	Training and familiarisation of the building occupants and managers to ensure the building operation is understood	Use feedback from performance in use and experience of occupants to fine-tune and debug systems	Fine-tuning of the building to reflect changes in energy load and usage patterns
The production of the commissioning plan can help you gain BREEAM Credits that are mandatory to achieve any rating.					Production of a building log book helps meet the requirements of Approved document Part L	Carrying out seasonal commissioning can lead to additional BREEAM credit and is required to get the top rating of 'Outstanding'	

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## The specialist

It is valuable for a commissioning specialist to be involved during the design stage. If your system is designed to be easily commissioned and maintained from the beginning, you can save money by avoiding late changes or post-installation work. Monitoring the installations to make sure that they are performing correctly will also help.

### Soft Landings Framework

One framework for a graduated handover of a building is the **Soft Landings Framework** published by BSRIA. The framework is designed to help you in the transition from handover to occupation and to extend commissioning beyond the handover period. It is freely available to use. *Figure 2* gives an idea of the level of activity needed as opposed to the conventional approach.

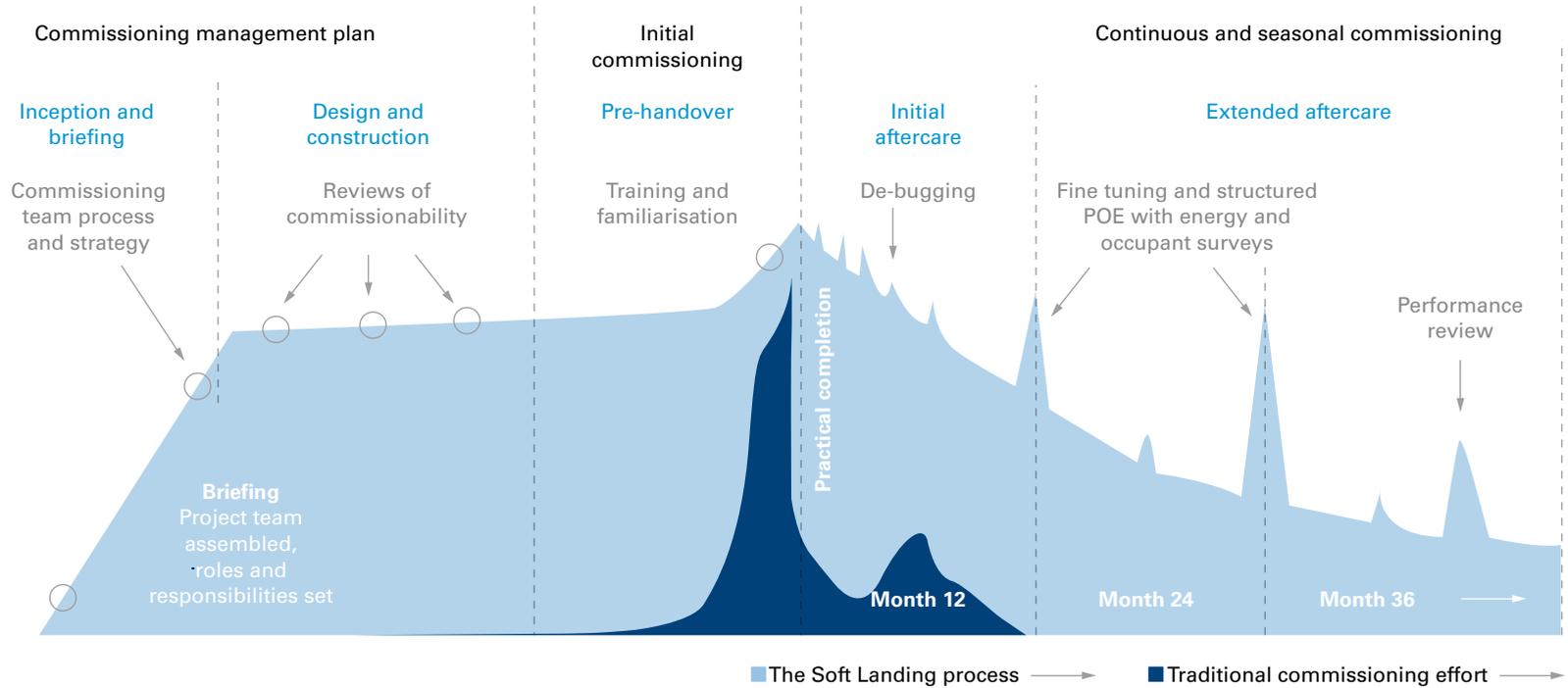
## The activities

Commissioning usually happens just before the building is handed over. This means that commissioning is almost always carried out in a rush to meet the handover deadline.

This basic level of commissioning required to satisfy a building's specification is known as static commissioning, initial commissioning or pre-completion commissioning. The essential operational checks are carried out, and commissioners check that performance meets the requirements of the specification. For example, they will look at the ability of a mechanical ventilation system to deliver the required air volumes, and the heating system to provide the required heat output. Commissioning tests also include health and safety checks, such as flow cut-outs on boilers, and testing of controls systems. Set-points are fixed, and recorded in the commissioning documentation.

Commissioning needs to be a thorough process, and should only be completed when everybody is happy with the results. It's commonly performed prior to handover. But you can only conduct static commissioning, based on theoretical rather than actual demands. This means that the initial commissioning is really part of a continual commissioning process. Systems will continue to be monitored and fine-tuned over time.

Figure 2 The level of commissioning activity required over the life of a project using a typical or recommended (soft landings) approach



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# Why care about commissioning?

Commissioning is a vital process for low carbon buildings. When carried out correctly it can significantly reduce a building's running costs, eliminate faults and ensure the success of energy efficient designs.

## Good commissioning reduces risk

Effective commissioning will help to ensure that your building is achieving its low carbon goals and is comfortable for occupants. All the clients in our case study projects set out to build a low carbon building, but over 40% did not achieve their goal at first because of problems that could have been eliminated or reduced through better commissioning.

Problems seen include heating and cooling systems fighting each other; energy saving control strategies which were never enabled, or metering systems which were never checked, preventing proper energy management.

If your building is properly commissioned, you will reduce your maintenance costs as equipment won't fail so quickly, and you'll also reduce your energy use through efficient use of mechanical and electrical systems.

## Research from the USA

Research has been published in the United States by Lawrence Berkeley National Laboratory, using a database of commissioning data derived from 643 buildings. The research revealed 10,000 energy-related problems resulting in average whole-building energy savings of 13% in new buildings when resolved. This equates to an average payback for commissioning of 4.2 years.

## Regulations and policy

Commissioning has become important enough to be included in the Building Regulations for England and Wales. They require “fixed building services to be commissioned by testing and adjustment as necessary to ensure that they use no more fuel and power than is reasonable...” A similar requirement is in place in Scotland.

BREEAM assessments are routinely included as part of planning conditions for a new building. There is a credit for commissioning in all BREEAM schemes that requires that a specialist commissioning manager be appointed during the design stage and that a plan is developed. An additional credit is available if seasonal commissioning is carried out, and now further credit is available for using the Soft Landings framework.



Lights switched on in an unoccupied daylight space

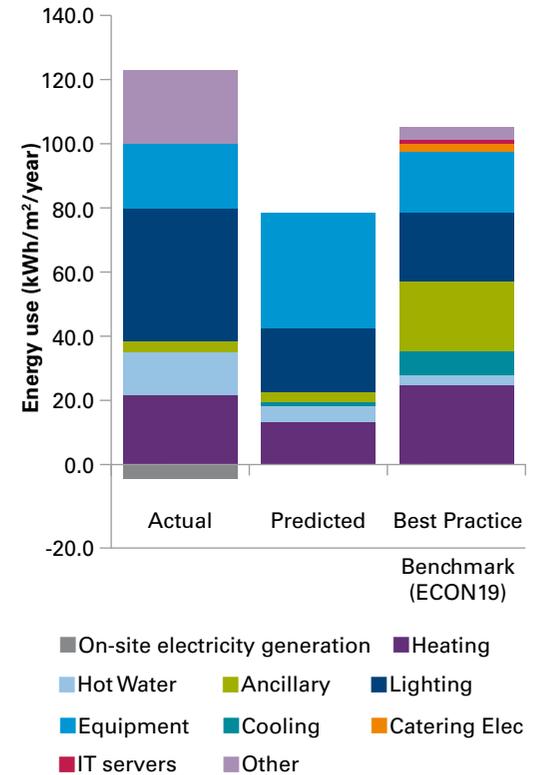
## Poor commissioning means extra lighting costs

Lighting in one case study building consumed nearly three times the energy predicted by the design team, costing a further £3,000 a year. This is partly due to design issues, but is also because of commissioning problems. While the building itself appears to have been well commissioned, the occupancy sensor controls proved to be over-sensitive, causing lights to come on in unoccupied rooms. The building also suffered the common problem of lighting staying on in areas already well lit by daylight. The usual causes are poor positioning or commissioning of daylight sensors, inadequate zone control of the lighting, or lack of local override switches.

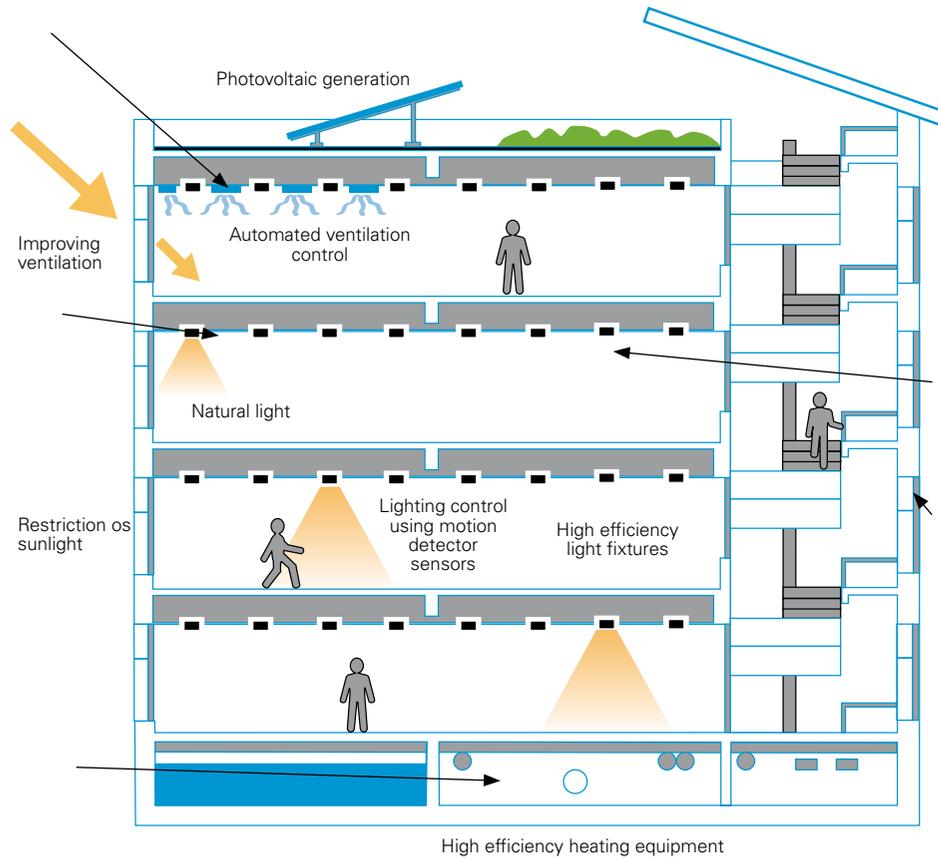
## Lessons learned

- Appointing a commissioning manager or commissioning team at an early stage will lead to a well-planned process and improve the operational outcomes, particularly when the commissioning engineer is appointed to follow through with seasonal re-commissioning.
- Commissioning engineers working within a graduated handover process, such as Soft Landings, are able to deal with issues as they emerge and reduce the running costs of equipment that would benefit from fine-tuning.
- Lighting controls in particular need more attention during commissioning, and fine-tuning after handover.
- System settings, as written into the specification and delivered during initial commissioning, often prove inappropriate during the operation of the building. Re-commissioning or fine-tuning is essential, requiring the commissioning team to stay involved after practical completion.
- Thorough commissioning and seasonal commissioning will reduce energy waste and ensure that systems are running optimally and meeting the occupiers' needs.

*Figure 3 High energy use from a poorly commissioned lighting system was one reason this case study performed worse than predicted*



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*Figure 4 Issues to look for when commissioning low-carbon buildings*

This diagram shows the key areas of a low carbon building and the main points to look for when commissioning.

Rollover numbers **1** to **8** for details

# Making commissioning easy

Successful commissioning depends on good planning. Getting the right people in place at the right time can help the whole process run smoothly. This could include employing a specialist.

## Have a plan

Commissioning activities tend to be scheduled towards the end of a project, but planning for this during the design and construction phases is just as important. Low-carbon building design requires many different specialists to be involved in the commissioning process.

Low-carbon technologies are usually commissioned by the specialist supplier or local agent, while another contractor will commission the system the product is connected to, such as a ground source heat pump in a heating system. Separate controls and BMS specialists may also be involved.

One common factor in successful cases is that the same people are continuously involved throughout design and construction and into occupation.

Without a coordinated commissioning plan, the performance of building systems will be compromised. This could lead to operational problems or conflicts between individual systems. If you have to re-commission systems later to make sure they all work together, this will be an additional cost.

Guidance on planning commissioning is available from both [BSRIA](#) and [CIBSE](#).

Several of the case studies provide good examples of planning the commissioning process. One common factor in successful cases is that the same people are continuously involved throughout design and construction and into occupation.

The Commissioning Specialists Association advises you to employ a commissioning verification engineer to oversee the commissioning process, and sign off approval on your behalf. This role is different from the commissioning manager, who is employed by the contractor to manage the whole commissioning process. Commissioning should be included in the employer's requirements, so that the contractor is clear as to what is required from day one.

### Lessons learned

- Considering all your commissioning needs and writing a commissioning plan during the design stage will identify all the issues that need to be planned for when full commissioning takes place several months or even years later.
- Make sure that commissioning expertise is available early in the project. This can reduce the number of problems encountered during the commissioning process.
- During the commissioning planning stages critical items should be identified to highlight likely special requirements, and to anticipate delays to the build programme. You should also develop a plan for resolving any problems that arise.
- While planning, consider the timing of the availability of key services (such as mains electricity and gas) to the plant being commissioned to avoid unnecessary delays and conflicts.

# Managing the process

How to set up a supportive team, check that your contract addresses your brief and why you should keep a tight rein on paperwork throughout the project.

## Managing the process

It is important for the commissioning process to be well managed. You'll find guidance on commissioning management in *CIBSE Commissioning Code M*, which states: "The main objective of commissioning management is to manage the overall commissioning activities, including programming, to achieve the project completion date."

## Forming a team

CIBSE guidance is supported by a number of practical guides published by BSRIA. These guides generally suggest that you should form a commissioning management team early on in a project, and appoint a specialist commissioning manager to oversee the activities.

Edge Hill University appointed a specialist consultant to oversee the commissioning and handover of their Faculty of Health building, and also to monitor the production of the operational and maintenance manuals. The consultant also had a data link to the building management system so that they could monitor the building's systems and operation.

The building is performing very well, and the monitored data is reporting average monthly energy consumption lower than both the best practice benchmarks.

Good co-operation between the commissioning consultant, the services engineers, the main contractor, and the principal sub-contractors resulted in a smooth handover and meant problems were quickly dealt with. This project has also benefited from a well-informed client with a good relationship with the design team, who have worked on other projects on campus. Lessons learned have therefore been passed on to newer university buildings, and issues have been dealt with quickly as the team are still in regular contact with each other.

## Energy metering and monitoring

Energy meters and monitoring systems are often missed out in the commissioning process. This includes the reconciliation of readings with the main meters and the recording by the building management system. This is a false economy as submeters are effective tools for both commissioning and monitoring the performance of the building.

The metering of Edge Hill has proved to be effective, which is a great help when judging the performance of a system during and after commissioning. This is a marked difference from many of the other case studies, where metering has been installed to gain BREEAM credits with little thought put into commissioning them correctly.

## Contractual arrangements

Contractual arrangements have changed in recent years to include the appointment of a specialist individual or company to manage the commissioning process. This approach has been recognised in BREEAM as good practice as it enables commissioning knowledge to be included in the design of a new building.

Clients, especially owner-occupiers, are now much more inclined to require proof that they have got what they have paid for. Commissioning is a tool that can help to prove performance levels.

A commissioning manager will usually be appointed through the main contractor, although they can be appointed directly by the client. This is particularly the case where the client is an owner-operator, such as a university, and has a vested interest in the commissioning being carried out correctly at the early stages to reduce long-term running costs.



Edge Hill University used a commissioning specialist

Projects where there has been a knowledgeable, interested client, and those who appointed a commissioning consultant to oversee the process, have in general had fewer ongoing defects with the building. Others, where there has not been any continuing involvement from those involved during the construction, have seen their energy use increase.

Allowing the commissioning period to become compressed into a small period can cause significant problems later on.

At one site, a rapid construction process and the lack of a commissioning plan reduced the time given over to commissioning. The client relied heavily on the framework contractor and the mechanical and electrical contractor to meet the deadlines, but two years after completion, the mechanical and electrical systems have yet to be signed off. Good relationships between the client and the build team are resolving the problems, but everyone involved is paying a price for the hurried and incomplete commissioning.

## Allowing the commissioning period to become compressed into a small period can cause significant problems later on

## Commissioning low-carbon technologies

Most systems in a low-carbon building will not be significantly different from those in a more conventional building. Water will still need to flow through pipes to taps and toilets, to the radiators for space heating, and to fan coils in ventilation systems. The big difference tends to be the technologies used to generate heat or electricity.

All the case study sites used some form of low carbon technologies commissioned by a specialist – in most cases either the installer or the manufacturer of the technology. Many manufacturers provide a commissioning checklist for their product. Once completed, the checklists are retained in the handover documentation. They are a useful *aide memoire* for those witnessing the commissioning.

Our research revealed that the suppliers of some low carbon technologies are based in continental Europe, which can affect the speed of response to calls for advice, information or maintenance.

Some companies have local representatives who are able to carry out commissioning functions. For example, while the biomass boiler serving the Cruddas Park estate was sourced from the Swiss company Schmid, all commissioning was carried out by Imperative Energy, Schmid's UK partners.

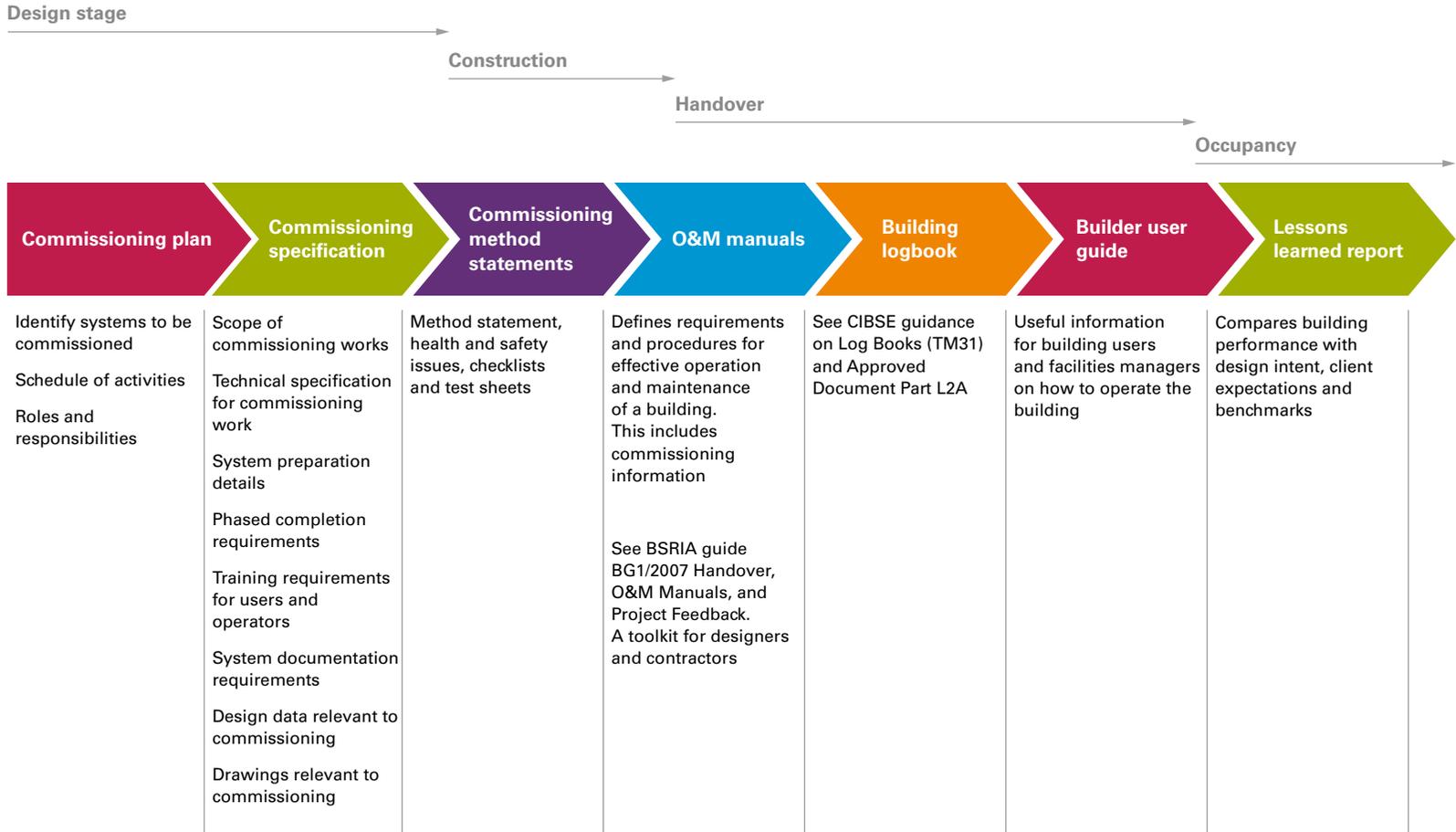
Some companies based in continental Europe have provided excellent support. For example, ground-source heat pump at Edge Hill University was commissioned by the German supplier, which visited the site three times in order to ensure the installation was correctly set up. The supplier also maintains a remote diagnostics facility, which helped to rectify an early problem. These remote diagnostic/monitoring systems are increasingly common for technologies, such as CHP plant and biomass boilers. Where available, they should be identified and included in the commissioning programme in order to realise the benefits.

## Documentation

Commissioning documentation is an important part of a building's handover from the construction team to the occupier. The documentation required is detailed in *Figure 5* on [page 17](#).



Figure 5 Commissioning documentation



## Lessons learned

- Employing a commissioning specialist allows you to co-ordinate the different activities and highlight potential issues early.
- Good co-ordination between all parties means any issues can be resolved efficiently, allowing for a smoother handover.
- The commissioning of energy meters and monitoring systems, (including the reconciliation of readings with the main meters and the recording by the building management system), is often missed. This is a false economy as submeters are effective tools for both commissioning and for monitoring the performance of the building during occupancy.
- Squeezing the time allowed for the commissioning process usually leads to problems and higher costs.
- Low and zero carbon technologies are best commissioned by the manufacturers or specialist installers as they have the detailed knowledge of the systems. In the future this may change as the knowledge in the industry increases.
- Good documentation helps to operate the building effectively.



# Optimising performance

Commissioning does not stop when the building is completed. Adjustments will need to be made to maintain efficient performance from all systems as the building's use and conditions change.

The building is complete. The occupants are settled in and all systems are running. This is usually the time when the project team has disbanded, left site and moved onto the next job, but it is also the time when the building most needs attention. As most buildings are prototypes rather than off-the-shelf, there needs to be some degree of proving and fine-tuning.

## Full-load commissioning

Full-load commissioning is carried out when the building is fully occupied. It is important for proving that the systems are capable of providing full-load performance. This is particularly critical for heating and cooling technologies. For example, ventilation systems working at full capacity might present noise or vibration problems, or the terminal units might create unpleasant draughts in the occupied zone.

## Fine-tuning

Fine-tuning may still be needed even if the building's systems are meeting the requirements of the specification. The building's occupants judge comfort levels, not the design or installation team. Most fine-tuning activities will involve tweaking set points, or adjusting ventilation grilles, dampers and controls. Passive infrared controls for electric lighting may need to be adjusted to prevent lights turning on and off automatically, which can be annoying. You may need extra internal blinds in rooms which you didn't realise would suffer from solar glare, or you may want to refine the control protocols for motorised windows.

## Case study

### Ceredigion Council Occupiers identify problems

The Ceredigion council building uses a natural ventilation strategy with motorised top lights in each window in the office areas, and motorised louvres in the atrium to promote stack ventilation.

There was initially a problem with the atrium louvres driving fully when the window toplights only opened a small amount. Feedback from occupants helped to identify and solve the problem.

## Seasonal commissioning

As its title implies, seasonal commissioning involves re-commissioning heating systems in winter and mechanical cooling systems in summer. Seasonal commissioning may also affect other systems, such as motorised windows and active solar shading devices – any building system affected by seasonal changes. Ideally, the original project team (or independent commissioning engineer if you've appointed one) should remain engaged to perform seasonal commissioning.

## Continuous commissioning

Continuous commissioning is the umbrella process that covers all the other forms of commissioning. It involves the building and its systems being continuously monitored, either via the BMS or through the use of dedicated logging devices. Systems can be re-commissioned or adjusted if performance isn't meeting requirements.

Continuous commissioning has become increasingly popular. The inherent flexibility of many contemporary buildings gives occupants the freedom to change their use of space, which may mean that the building services need to be adjusted or re-commissioned to suit the new use. Continuous commissioning is made easier with the use of addressable control systems. Adjustments to lighting and heating and cooling setpoints can be made via a central computer, reducing the cost and disruption that often comes with conventional commissioning activities.

This is typically a task that would come under a maintenance contract, although it can be useful for the sake of consistency to involve the original commissioning engineers.

Continuous monitoring helps you to identify when the building is moving away from optimum performance.

## Case study

### Cruddas Park Tax incentives

Cruddas Park is in a state of flux, with additional buildings being added to the community heating scheme well after the initial commissioning activities have been completed.

Instead of setting a strict commissioning schedule, the system is continuously monitored by Vital Energi, which is operating the system. Vital Energi has an experienced engineer who can adjust the system as required. This is essential in a residential community heating scheme, where occupation may vary.

## Handover

The handover to the occupants is one of the key milestones of a building's life. Initial commissioning will have proved that the building's systems work, although they may need continual fine-tuning during the first year as loads change. This fine-tuning is much more effective with the involvement of staff. Maintenance contracts with the equipment suppliers or contractor, or training of the facilities team, can make sure that this is the case.

Ceredigion County Council benefitted from a knowledgeable internal facilities team who could understand the technologies involved. At Pembrokeshire College the requirement for training was put into the contract, with the contractor required to submit a detailed programme of training to the client. The training was given to four key personnel by the main contractor and specialist installers over two days, with special sessions on the biomass boiler and BMS.

## Lessons learned

- Occupant/building user feedback can be used to identify shortcomings in performance, and can be used to gauge the success of any corrections.
- Systems that are likely to have loads that change often, such as residential schemes or schemes where additional loads are programmed to be added, are most likely to benefit from a continuous commissioning strategy.
- The presence of knowledgeable and experienced maintenance staff during the initial occupation period can help to optimise the building's performance, and is more likely to lead to sustained good performance.



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# Further information

## **BSRIA**

A site reference book for commissioning engineers and technicians.

[Model Commissioning Plan, BG8/2009](#)

[Commissioning Job Book, BG 11/2010](#)

[Commissioning Water systems, BG2/2010](#)

[Commissioning Air Systems, AG3/89.3](#)

## **CIBSE**

Guidance setting out the steps required to commission building services.

[Commissioning Code A, Air distribution systems, 1996](#)

[Commissioning Code B, Boilers, 2002](#)

[Commissioning Code L, Lighting, 2003](#)

[Commissioning Code M, commissioning Management, 2003](#)

[Commissioning Code W, Water Distribution Systems, 2010](#)

## **CSA**

A site reference book for commissioning engineers and technicians.

[Commissioning Engineers Compendium, 2000 Edition](#)

[www.csa.org.uk](http://www.csa.org.uk)

## **BSRIA Soft Landings Framework**

A framework for a graduated handover of a building designed to help you in the transition from handover to occupation

[www.bsria.co.uk/services/design/soft-landings](http://www.bsria.co.uk/services/design/soft-landings)

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