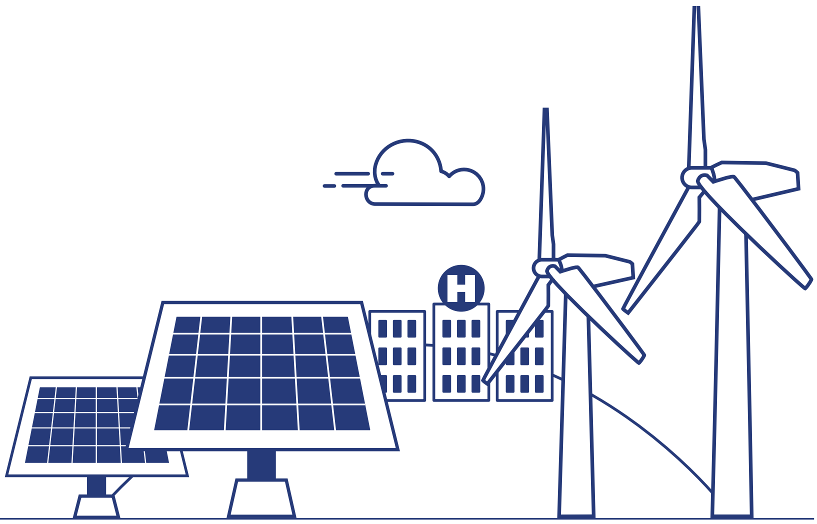
HEALTHCARE ENGINEERING FOR A NET ZERO FUTURE

MARCH 2021

A HEALTHCARE ENGINEERING ROADMAP FOR DELIVERING NET ZERO CARBON

A best practice guide for Healthcare Estates

CPD ACCREDITED



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A HEALTHCARE ENGINEERING ROADMAP FOR DELIVERING NET ZERO CARBON

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Foreword

I am delighted to introduce this roadmap to net zero carbon outlining a recommended strategy to net zero carbon for the NHS and public sector estate. If we are to deal with the most pressing environmental challenge facing the world, then the NHS as the largest public sector carbon generator needs to take the lead and be a beacon to the whole public sector in the UK and beyond where NHS standards are widely applied.

In 2019, the UK Government and the devolved administrations committed to the net zero target as recommended by the Committee on Climate Change. Reaching net zero greenhouse gas (GHG) emissions requires extensive changes across the economy, but the foundations are in place. Major infrastructure decisions need to be made in the near future and quickly implemented. These changes are unprecedented in their overall scale, but large-scale transitions have been achieved successfully in the UK before, such as the natural gas switchover in the 1970s or the widespread harvesting of wind energy of the last decade.

The Committee on Climate change identified the following required changes

- *resource and energy efficiency, that reduce demand for energy across the economy*
- *societal choices that lead to a lower demand for carbon-intensive activities*
- *extensive electrification, particularly of transport and heating, supported by a major expansion of renewable and other low-carbon power generation*
- *development of a hydrogen economy to service demands for some industrial processes, for energy-dense applications in long-distance HGVs and ships, and for electricity and heating in peak periods*
- *carbon capture and storage (CCS) in industry, with bioenergy (for GHG removal from the atmosphere), and very likely for hydrogen and electricity production.*

Furthermore, the NHS has now also identified a commitment for the emissions controlled directly (the NHS Carbon Footprint), to net zero by 2040, with an ambition to reach an 80% reduction by 2028 to 2032.

It must be vital to the whole of government and to every level of government in the UK that the country moves swiftly to zero carbon. Overall, a well-managed transition can be achieved and lives can be improved. People can benefit from better physical and mental health, an improved environment and, crucially, a reduced exposure to climate risks.

The roadmap outlined in this document, if diligently applied, will form a significant part of the required changes as they apply to the NHS and public sector estate.

Baroness Brown of Cambridge DBE FREng FRS FInstP CEng FRAeS
Committee on Climate Change

View from Pete Sellars

IHEEM Chief Executive & President of IFHE-EU

The impact of the Covid-19 pandemic has brought together the worldwide scientific and public health community to lead the fight against this deadly virus. The global response across this community to develop a swathe of vaccines in such a short time is truly remarkable. Geographic, personal and political boundaries have been cast aside in the interests of a united global approach to the challenges faced through Coronavirus.

The pandemic has also resulted in engineers worldwide having to actively deal with a raft of new and complex healthcare engineering challenges. These challenges predominately centred around managing and maintaining critical engineering infrastructure services as demand increased and reached levels above and beyond their intended design. Up to this point core services such as medical gases, ventilation, water, electrical and decontamination services had, in most cases, been taken for granted by clinical and medical teams worldwide.

The "Delivering a Net Zero NHS" document recognises that COVID-19 will continue to impact how the hospitals plan to deliver their care models. The urgent requirement to ensure resilient healthcare infrastructure systems worldwide are available to meet these increased demands will almost certainly directly conflict with the ambitions to reduce the environmental impact of those services.

The scale of the task must not be under-estimated. The global impact of our healthcare sectors contribution to the deliver the Net Zero ambitions is significant. Healthcare engineers cannot forget the urgent need to address the increased clinical expectations and demands of these services. Our current engineering solutions to provide increased capacity and resilient healthcare infrastructures, in many instances, conflict with delivering the Net Zero Carbon aims.

The need for healthcare engineers and academics worldwide to collectively work together, share best practices and develop new innovative solutions has never been more needed than now. Our worldwide healthcare engineering profession needs to be informed of and have access to new technology and innovation and the latest thinking. New engineering solutions are likely to be extremely complex and highly specialised and require a strong network and platform for our healthcare engineering profession to engage and share new ideas and solutions.

I am delighted that IHEEM, in collaboration with our wider international partners of International Federation Healthcare Engineers (IFHE) & International Federation Healthcare Engineers Europe are creating a platform for the sharing of knowledge throughout our community. We are committed to working together in partnership with our engineering profession worldwide to promote the development of new engineering solutions that safely manage patients, protect staff and the public whilst responding to the climate change agenda.

Embracing the known and future advances in knowledge, innovation, and technology will be vital for healthcare engineers worldwide together with transferrable engineering science to help them meet whichever government policies or targets are required. This document will provide an excellent platform and reference point to work with.

The intention is to keep this document updated as new technologies and solutions come to light. Please help support this by contacting IHEEM, IFHE & IFHE-EU to enable us to continue to share worldwide with our healthcare engineering networks.

I do hope you find this engineering roadmap useful.

Pete Sellars
IHEEM Chief Executive, IFHE-EU President

Introduction

Since the publication of the original version of this guide there has been a lot of changes in the World. Efficiency in healthcare estates is still of vital importance as is minimising the environmental impact from its operations. The recent surge in interest in the environment, that emerged from the focus brought about by the Climate Emergency agenda has seen the NHS both at national, regional and Trust level set increasingly ambitious environmental targets.

As with its predecessor, this Guide has been developed to assist NHS Trusts in identifying, assessing and delivering commercially viable strategic energy solutions. It is intended to provide information for Directors of Estates, Directors of Finance and their teams, as well as other senior Investment decision makers with responsibility for wider Trust affairs. The content and technical detail of the document is a valuable source of information for designers, engineers and technical personnel directly involved in the development and delivery of energy solutions.

The development of this guidance document has been supported by The Institute of Healthcare Engineering and Estate Management (IHEEM) and Health Estates and Facilities Management Association (HEFMA). Both these organisations are committed to providing ongoing professional support and sharing of best practice guidance with their members as the NHS landscape continues to evolve. The content available within this guide is CPD accredited with CPD points available. More information is available at **www.carbonandenergyfund.net/CPD**

NHS target for net zero by 2040

In October 2020 the NHS published its ***"Delivering a 'Net Zero' National Health Service"*** report, which identifies proposed targets for decarbonising and establishes the objective to achieve a net zero emissions position by 2040, which is 10 years in advance of the UK Governments objectives set in June 2019. Net zero means any remaining emissions would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere, such as planting trees or using technology like carbon capture and storage.

The NHS 2040 net zero target places it at the forefront of decarbonising healthcare, making it the world's first national health system to commit to become 'carbon net zero', backed by clear deliverables and milestones.

Crucially, the NHS ***"Delivering a 'Net Zero' National Health Service"*** report, has identified an 80% reduction in emissions that needs to be achieved within the next 8 to 12 years. The NHS ***"Delivering a 'Net Zero' National Health Service"*** report also cites that within the Secondary Care estate it anticipates 25% carbon reductions coming from on-site generation of renewable energy and heat, 20% carbon reductions coming from up grading existing buildings and 24% carbon reductions coming from optimising buildings.

This guidance document has been set out to show how a potential road map can be established that enables Trusts to plan a pathway starting from today, to lead towards the 2040 position through making planned and strategic investments in energy and building infrastructure helping to deliver against the objects defined within the NHS ***"Delivering a 'Net Zero' National Health Service"*** report.

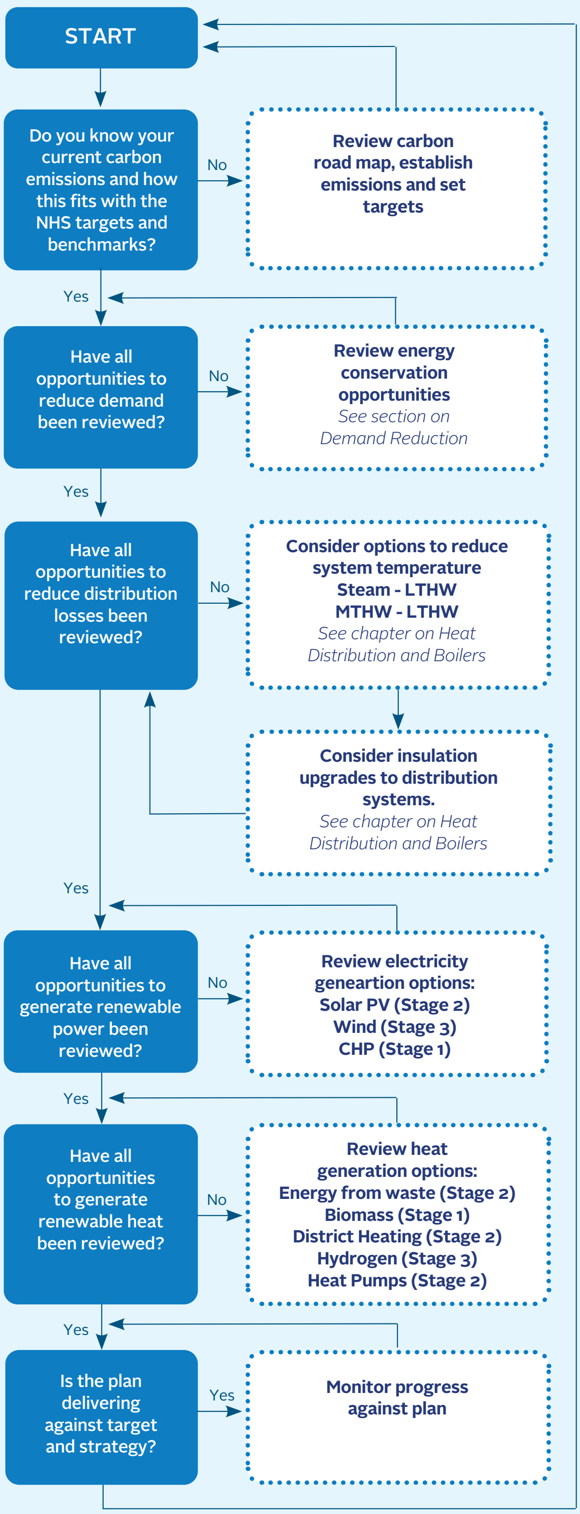
Looking beyond the now - a staged approach to energy projects

The 2040 NHS carbon reduction plan clearly places a sense of purpose and a need to deliver on significant carbon reduction milestones by the end of this decade and so well within the life of typical investments being made in energy projects today. So we need to look at energy projects not just in the here and now, but also in the 15 year life of a typical energy performance contract and to view projects as a continuum. There are technologies that are in development today that will eventually mature and be appropriate for hospital projects in the near future. However, action needs to be taken now to ensure investments are made in energy infrastructure to deliver savings today and meet the milestone carbon reduction targets that are just on the horizon; while at the same time not precluding the easy adaptation of these investments to accept the technology of tomorrow.

In this latest version of this guide we are introducing a staged approach to energy projects. There are technologies, such as gas CHP, that can generate large revenue savings today and in a carefully constructed project, can be recycled into preparing the estate for future technologies by including items such as upgrading the heat distribution systems to low-temperature-hot-water, that will in turn be ready for technologies such as heat pumps.

An obvious question is why not jump straight to stage 3 and avoid stage 1? This could be possible for some technologies; however many NHS Trusts do not have

A staged approach to energy projects



capital available to deploy such a rapid approach. The staged methodology will enable many healthcare estates to make a transition over several years without impacting their income and expenditure budget.

The changing NHS agenda

The NHS is a continually changing and evolving organisation. With a changing demographic and phenomenal advances in medical technology, the NHS is always on a programme of change. For some Trust's this can be more significant than others; however, almost all Trusts without exception will be involved in planning expansion or remodelling of their existing provision. The new NHS carbon reduction milestones; mean the ability to ignore the impact of carbon emissions and consequential impact to energy infrastructure as part of clinical facilities planning is not going to be possible. It is important that projects are progressed in parallel with other works. A well-developed energy project can complement a wider estates programme and help reduce cost burdens. The complexity of many major estates' capital programmes can mean they take many years to bring to completion. Energy projects on the other hand are a well-trodden path with established procurement methods and contracts. With focus, energy projects can be procured and in construction within a year. It is essential that energy projects, even major ones, are designed with inherent flexibility, ensuring that they work with wider and potentially changing strategic objectives of Trust boards and don't risk creating infrastructure that becomes useless due to an unforeseen future. This imperative toward strategic flexibility is now strengthened by the need to show progress towards the 80% carbon reduction needed by the end of this decade and eventual net zero position by 2040.

Decarbonising of the electricity grid

The UK Government has been successful in reducing the environmental impact of electricity production, with carbon emissions per kWh produced now around half of that ten years ago and a trajectory that will see that value halve again by 2030. This achievement is of enormous importance but challenges energy professionals when considering new projects. Within the current international carbon calculation methodology, new projects now appear to be delivering lower carbon savings than those delivered when carbon emissions per kWh were higher.

A technology of note is gas fired combined heat and power (CHP). Whilst CHP is a huge generator of revenue

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A 6.7MW solar array for New Cross Hospital (Wolverhampton) to be installed on an old landfill site that will be rented by the hospital from the local council.

savings for NHS Trusts; the overall carbon saving impact of gas CHP is reducing because the national grid electricity carbon factor is reducing much faster than that of natural gas. As UK electricity grid decarbonisation is realised, CHP starts to produce more carbon than simply using grid electricity and gas boilers. Legislation is likely to follow that will correct for the cash-carbon imbalance and ensure that overarching international and national environmental objectives are protected.

Meanwhile it is very unlikely that it will be possible to simply move all existing hospital heat infrastructure currently on natural gas over to low carbon electricity for large acute hospital sites.

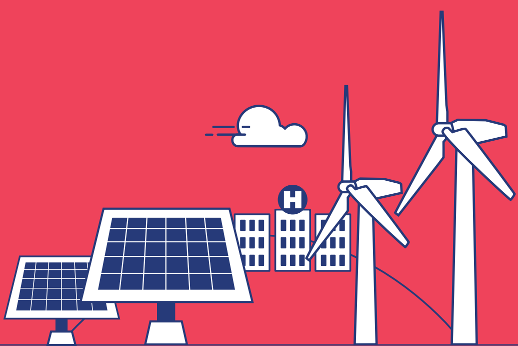
So, there is not necessarily a single silver bullet available now, that delivers net zero at a practical and affordable level today. But the journey must be started now, with as far as possible, the right strategic choices being made. The right choices may differ from site to site, but it should be possible to invest today to deliver savings revenues today and into the future. Investments should also set the right foundations in place which can easily be evolved in the coming years, to progressively deliver the huge investment needed to transform large complex hospital infrastructure to a position that achieves the NHS and ultimately the country's net zero carbon position.

How to use this guide

As with the first edition of this guidance document, this guide has been ordered primarily to reflect the high-level sequence of planning activities you would carry out when developing a strategic energy programme. For example, undertaking a full technical review of the existing site infrastructure and services to identify and establish existing energy and water saving demand reductions first, will almost certainly reduce the level of capital required to deliver a complete strategic energy solution.

However, in this edition, we have added a section at the start called A Staged Approach to Net Zero. This section considers how different technologies can be combined in innovative ways to progress through a three-stage route to net zero carbon. This section provides some worked examples based on a series of different healthcare estates. It is not the intention of this section to mandate approaches to the different estates but rather introduces how one might use the guide to address issues on a particular site or sites. The remaining sections of the guide have all been updated as appropriate to account for changes in technology and technology application that have occurred since the first publication. For those familiar with the previous content, the authors would like to particularly highlight significant updates in: heat distribution (in particular de-steaming), heat pumps, and hydrogen energy systems.

A ROADMAP TO 'NET ZERO'



The journey so far

The UK government has been aligning itself to a series of carbon budgets introduced under the 2008 Climate Change Act. Each budget provides a five-year statutory cap on total greenhouse gas emissions, which when taken together, define a path toward Britain's long-term climate change response. We are currently in the third carbon budget which has a target to cut emissions to 37% by 2020 relative to 1990. The fourth budget sees this target expanded to 51% by 2025 and the fifth to 57% by 2030. At the moment the UK is not on track to achieve the fourth or fifth budget targets. Notwithstanding this, the UK Government has recently increased its ambition to set the 2050 long-term objective to net zero emissions.

The NHS has been monitoring its emissions for some years, albeit they have not always been in alignment to the UK carbon budgets or baselines. The NHS Long Term Plan published in January 2019, identified the aim to reduce the NHS carbon footprint by a third from 2007 levels by 2020 and to align with the UK government Climate Change Act carbon budgets; citing the challenge to achieve 51% by 2025.

Sir Simon Stevens has announced that the NHS is establishing an expert panel to chart a practical route map to enable the NHS to reach 'net zero', becoming the world's first major health service to do so. In October 2020 the NHS published the ***"Delivering a 'Net Zero' National Health Service"*** report, which sets out the NHS targets for decarbonisation. The report proposes two targets for the NHS net zero commitment:

- for the emissions we control directly (the NHS Carbon Footprint), net zero by 2040, with an ambition to reach an 80% reduction by 2028 to 2032 (based on a 1990 baseline)
- for the emissions we can influence (our NHS Carbon Footprint Plus), net zero by 2045, with an ambition to reach an 80% reduction by 2036 to 2039 (based on a 1990 baseline).

This guide primarily focuses on the emissions under direct NHS control (the NHS Carbon Footprint) as these are directly linked to the way the built estate is operated. It should be borne in mind that while efforts are made to reduce carbon emissions from buildings and infrastructure, there is also a direct interface with the associated supply chain that helps facilitate this. The NHS Net Zero plan is therefore also signalling its intention that by the end of this decade, it will only purchase from suppliers that also meet or exceed the NHS commitment to net zero.

Given the extent of reduction in emissions now required in the next two decades, there will need to be a move away from using fossil fuels for most activities such as electricity generation, heating and transport. It is important to note the interim NHS target of an 80% reduction in carbon emissions (from 1990 baseline) is aimed for achievement by 2028 to 2032. This brings into sharp focus the need to take action now in order to bring about the sea change needed across the NHS estate, on the basis that the lion's share of reduction needs to have happened by the end of this decade. The challenge is huge and will not be achieved in a single step. Despite this, there are already now, some NHS Trusts that have declared a 'Climate Emergency' and have targeted aspirations to achieve net zero positions much earlier than 2040, with Cornwall and Isles of Scilly STP the first region in the NHS to target net zero emissions by 2030.

What is net zero?

The context and meaning of net zero needs to be fully understood. While it is perfectly possible to aim for a net zero position today, current practical ability to effectively achieve this is very hard to deliver in a way that carries real financial benefit to the estate; and at the same time provide the wider beneficial impact to the NHS emissions reduction effort. This is because in the context of estate operations, a true net zero position is only achieved when an organisation has reduced its carbon emissions to the point where they are avoiding utilisation of fossil fuels as far as practically possible on site; and only the remaining unavoidable emissions are then off-set, through the organisation's investment in carbon offsetting projects elsewhere. Clearly, the less the investment that is made in reducing reliance on fossil fuels on site, the greater the reliance in offsetting emissions elsewhere that is needed. If offsetting is seen as easier and cheaper than investment to effect real emission reductions from under a Trust's control on site, then there is a danger that offsetting will be seen as a quick fix, that does not address the bigger picture NHS and ultimately UK carbon reduction objectives.

By way of example, it is now possible and actively being encouraged from April 2021, for NHS estates to procure grid-electricity from certificated renewable energy electricity contracts (REGO backed supplies). These efforts signal welcome support to grid supplied renewable energy investment at national level, but do not serve to deliver real 'additionality' at project or site level, since they do not change the cause of the emissions being offset or necessarily promote the idea of making changes to behaviour. A Trust could opt to offset all electricity consumption through a REGO backed supply purchase without taking any action to reduce its electricity demand or self-generate on site. There has therefore been no change to the business as usual position, only a penalty paid to procure more expensive 'green' electricity. Clearly, if everybody adopted that approach there would be less likelihood of a true net zero target being met at a combined NHS organisational level.

Drivers that govern emissions

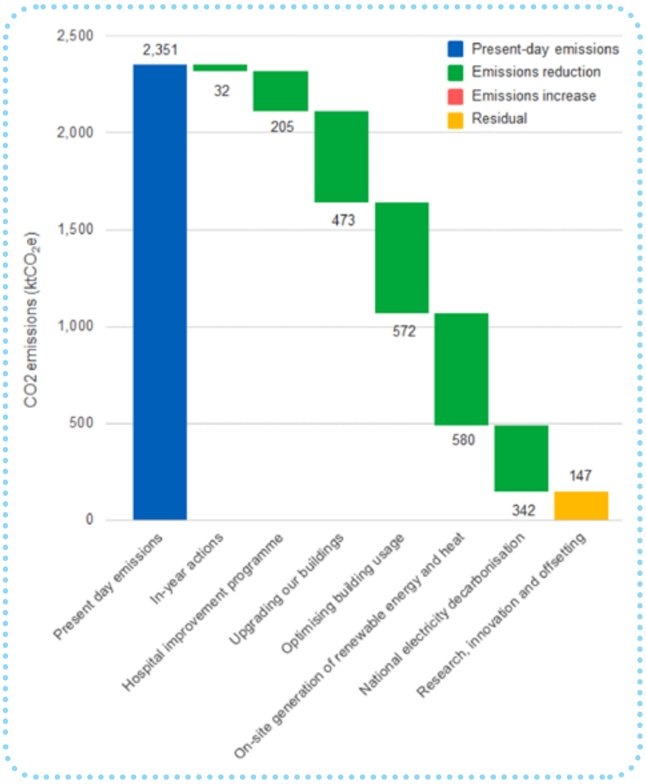
Electricity, gas and oil consumption are usually by far the largest influencers to a healthcare facility's carbon footprint, although there are still other important contributors from waste and transport and clinical activities such as dialysis for kidney patients and anaesthetic gas use in operating theatres.

Carbon emissions from buildings and associated infrastructure is led by primary energy consumption, which in turn is influenced by type of fuel utilisation, plant age and efficiency (including HVAC and lighting), building usage, occupancy patterns, fabric condition and levels of thermal insulation.

The NHS report *"Delivering a 'Net Zero' National Health Service"* identifies targets for carbon footprint reduction from the Secondary Care estate. It suggests that key areas of estates led interventions that will drive the reduction of the current NHS carbon footprint of 2,351 kT CO2e as:

- **25% carbon reductions coming from on-site generation of renewable energy and heat**
- **20% carbon reductions coming from upgrading existing buildings**
- **24% carbon reductions coming from optimising buildings**

The report also identifies that for the Secondary Care estate, only 15% of carbon reductions coming from reliance on the decarbonising electricity grid, suggesting that most of the reductions are anticipated to come from demonstrable reduction in demand from site activity, buildings consumption or from self-generation, thereby maximising 'Additionality'.



Interventions to reduce emissions in the secondary care estate ("Delivering a 'Net Zero' National Health Service" NHS Report)

Decarbonising utilities

The UK has managed to decarbonise the electricity national grid significantly in the last 5 years. In fact, 75% of all UK carbon emission reduction since 2012 has come from the power sector. This decarbonisation is anticipated to increase with more renewables, increased localised levels of grid power management and storage and ultimately, the potential future incorporation of carbon capture and storage technology on retained fossil fuel generation.

This investment has come at a cost, with electricity non-domestic consumer tariffs encompassing significant premiums over and above the basic commodity price that have subsidised the greening of the grid, as well as historically higher levels of climate change levy tax paid for each kWh of electricity used.

Meanwhile, there has been negligible decarbonisation of natural gas to date, the most common fuel used in the NHS for space heating and domestic hot water generation. National Grid is currently at the start of a 10 year Gas Market Plan (GMaP) for decarbonisation which is looking at, amongst other issues the potential for hydrogen utilisation in the gas grid.

Wholesale changes to decarbonise natural gas and attempt to move in the long term towards hydrogen as a "drop in" replacement at scale would be costly, and these costs would no doubt be passed on to the consumer. By the same token, the costs for remaining with fossil fuels for heating will also become more expensive from increasing levels of taxation applied in the short to medium term. The UK Government has already committed to increase the climate change levy (CCL) on natural gas at a faster rate compared to electricity in the next five years.

Context for investment in decarbonising the NHS estate

It seems likely that NHS Trusts will be operating their estates in the context that significant gas decarbonisation in the next 10 years is likely to be small, compared to the increasing levels of electricity decarbonisation possible over the same period. Therefore, any investment in energy efficiency that displaces grid electricity is likely to result in good levels of financial savings but will have a diminishing impact to a Trust's carbon footprint per kWh as the national grid greens. On the other hand, investment in energy efficiency that displaces each kWh of natural gas (and other fossil fuels) will show more resilient carbon footprint savings and a lower but improving level of financial saving by comparison.

The realisation of this should be guiding the strategy for ensuring NHS Estates do not get left behind on the road to decarbonisation. But how does it influence the principle approaches to be prioritised set against backlog on plant and infrastructure that in many cases were designed and installed many decades ago and will struggle to evolve into the solutions needed to deliver increasing levels of decarbonisation and ultimately net zero carbon by 2040? It is difficult to show attractive financial viability for implementing big solutions while gas prices remain relatively low. Also, there is a degree of uncertainty about the future, in terms of what is going to be the best replacement technology to incorporate and whether gas remains viable in the medium to long term, or whether it is even possible to switch heat demand from fossil fuel over to low carbon electricity without incurring hugely prohibitive capital and running costs.

A staged approach

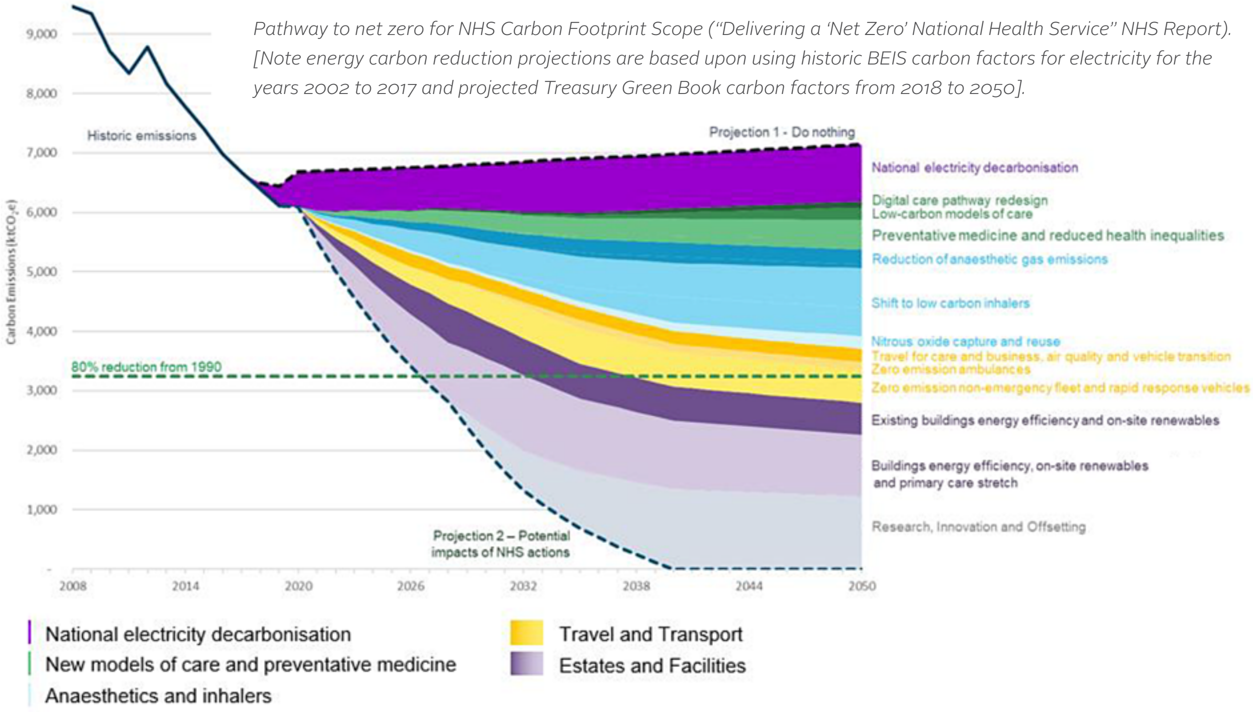
It is very unlikely that it will be technically or financially practical to jump from where we are now, straight into a net zero position. There is a likely route map that must be established, so that investment decisions on future plans for the estate can be accommodated and so that infrastructure is developed along lines that will not annex off a Trust from adopting future low carbon solutions, or lead to dead ends where the ability to adapt becomes completely unviable or totally cost prohibitive.

The NHS *"Delivering a 'Net Zero' National Health Service"* report illustrates the potential 2040 net zero pathway trajectory as being heavily reliant on energy efficiency and on site renewables within new facilities and to a lesser extent on existing building energy efficiency. It also illustrates the reliance placed upon continuing decarbonisation of the national electricity supply grid as being a key cornerstone in emissions reduction. It is important to note that the net zero pathway shown in the NHS report relies on resolving issues beyond just lowering estate energy use in order to hit the 2040 target. For example, the NHS carbon footprint reduction to net zero relies heavily on the ability to reduce anaesthetic gas impact and other medical treatment impacts including a significant move to low carbon medical inhalers. The NHS net zero projection to 2040 also shows an ever growing need for research and innovation roles, suggesting that the delivery of net zero will in part, be played by measures as yet not currently available or commercially viable. It is clear from the NHS *"Delivering a 'Net Zero' National Health Service"* report that a progressive evolution is envisaged, but that the change needs to start now, followed by a rapid expansion in the effort to meet the initial 80% reduction milestone by the end of this decade and onwards toward the 2040 net zero target.

Such a staged approach needs to start addressing fundamental building blocks for each site's energy infrastructure, in order that it can be evolved to play its part and including aspects which can be addressed now and how this will then be progressively built upon in the coming years. This evolution must also be ready to take advantage of new emerging technology and innovation as it becomes affordable and commercially available. The following approach is outlined, based upon a typical acute hospital:

Stage 1 - immediate to short term

Many acute hospital sites will be at a stage, whereby good work may well have been undertaken to date with lighting replacements and other demand side reduction measures, but primary heat infrastructure will not have changed significantly for many years. Some sites may have already adopted combined heat and power (CHP) in an effort to achieve revenue savings. At these sites it is common to



Pathway to net zero for NHS Carbon Footprint Scope ("Delivering a 'Net Zero' National Health Service" NHS Report). [Note energy carbon reduction projections are based upon using historic BEIS carbon factors for electricity for the years 2002 to 2017 and projected Treasury Green Book carbon factors from 2018 to 2050].

see the utilisation of centralised gas fired boilers with high temperature heat distribution (steam and MTHW) to serve the various parts of the hospital estate.

The response to this typical scenario is likely to need consideration to the ongoing viability of the primary heating plant and associated high temperature heat distribution, since this represents the biggest influence on ability to reduce the site's carbon emissions going forward. If gas fuelled CHP has already been deployed, it will already have reduced a proportion of the heat load and associated losses from the high temperature heat distribution side through utilisation of CHP engine jacket heat recovery, to provide some low temperature heat distribution instead.

Whereas when these sorts of solutions were originally conceived the carbon savings opportunity would have been significant, but because of the greening electricity grid, they will now be less likely to show carbon saving persistence beyond a few years, unless further measures are undertaken to build upon the concepts started.

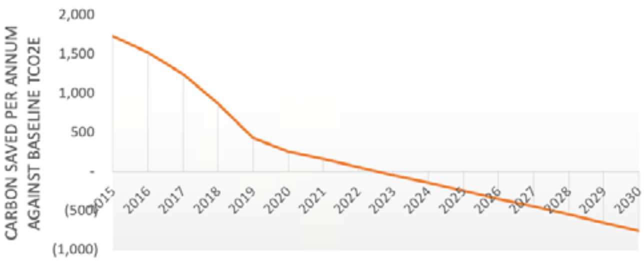
Stage 2 - short to medium term

The next stage is one where significant investment may be needed to move into a position where a site is ready for the future and where, if CHP is still operated, it is done so in a way that saves carbon rather than making emissions worse.

Stage 2 solutions need to be laying the foundations for heat delivery that can use the best available technology now and will also be able to accept future technology as it comes to commercial maturity.

Most high temperature heating distribution systems lose a great deal of heat from higher exhaust temperatures, poor insulation levels and in the case of steam, through low levels of condensate recovery, unreliable steam trap operations and large standing losses. In a recent study one 500 bed hospital had a standing loss of 300kW from its steam system. While the level of heat transferrable by steam maybe much higher than that conveyed by low temperature heat distribution (LTHW), these inefficiencies usually outweigh the case for their continuance when compared with more efficient LTHW incorporating variable flow pumping and lower heat losses.

Initially, gas fired steam boilers can usually be replaced with modern part condensing LTHW gas boilers, embedded in a new LTHW heat network. These may in turn ultimately be replaced with electric heat pumps, which in the next few years will be able to deliver the temperatures needed to work even more efficiently with



A typical existing unoptimized (electricity led) gas CHP potential carbon saving performance in the future - based upon assumed continuing decarbonisation of UK National Electricity Grid

LTHW networks, resulting in increased transfer of heat generation away from fossil fuel boilers over to low carbon electricity.

For CHP, when the focus is on prioritising carbon saving, we find solutions that once drove down carbon now need to be reoptimized, as otherwise they start to deliver detrimental results in a low-carbon electricity grid landscape. An inappropriately sized or unoptimized gas CHP will generate more carbon than it saves over its life, based upon a continuing fall in grid electricity carbon intensity. There are arguments that say it is fairer to judge CHP fuelled by natural gas against the time of day and seasonal variance in electricity grid carbon content, rather than the annual average carbon, which is the norm for reporting protocol. However, gas CHP solutions tend to operate at the same output all year round to maximise financial savings. Unless they are modulated against available renewable content on the grid at any one time, then we must expect to see CHP carbon saving performance fall away as the annual average grid carbon content reduces.

For solutions that fall into stage 2, we should see much smaller CHP capacities that are 'heat led' rather than electricity led, such that they modulate downwards in output and even switch off when there is low heat demand and may not operate at all in the summer, unless a viable alternative use of the heat can be found, such as for space cooling using heat powered absorption chillers, or thermal stores that can store the heat for reuse later in the day.

Removal of steam requires replacement equipment in plant rooms as well as laying new LTHW heat mains. This is a significant investment and while saving energy and carbon, the payback is not short term, although it often yields large backlog reductions and these can help improve financial viability. Conversely, the cash release savings from CHP are still anticipated to be significant, due to the ongoing spark gap (difference between electricity and gas costs). This significant cash saving ability means CHP remains an interim measure able to help underpin concurrent investment in modernising heat infrastructure, making overall energy project schemes with shorter paybacks than would otherwise be seen and delivering the foundation that will be compatible with emerging lower carbon technologies.

It is also very important to consider air quality, since all fossil fuel (and biomass) plant are emitters of NOx, impacting air quality and human health and directly relevant for the NHS. It is possible to limit the NOx impact from modern gas boilers and CHP using ultra low NOx plant and catalytic reduction, although these measures may impact operational costs so they should be factored into net savings.

Stage 3 - medium to long term

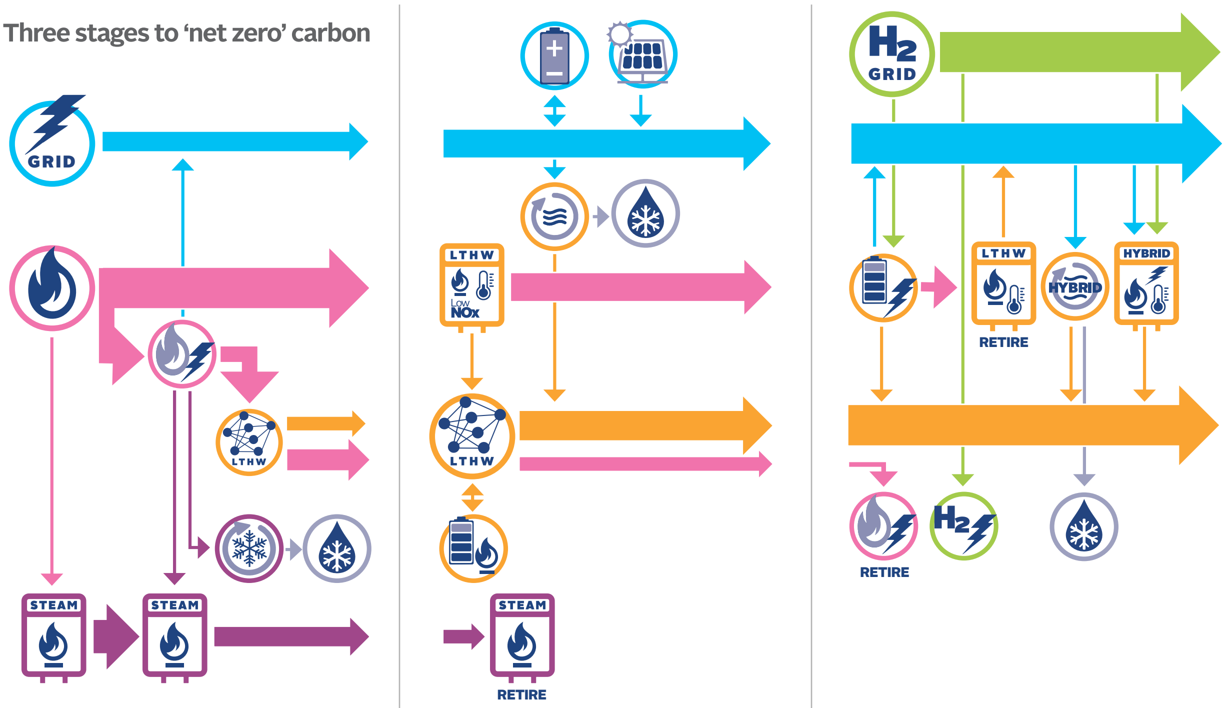
An acute hospital site that has developed an efficient low temperature distribution network with efficient low NOx gas boilers, heat pumps and / or heat led CHP will be well placed to accept future further decarbonising technology as it starts to become more commercially available.

This technology is likely to comprise of higher temperature heat pumps, electric boilers and hydrogen fuel cells. Some of these are available now, but their implementation or running cost makes them generally unaffordable. But this will change in the next few years as investment costs come down whilst energy prices rise, or as grant subsidies are made available.

Any switch from fossil fuel over to low carbon electricity needs to consider the impact to the local electricity supply network and on site power distribution; and the risk that local capacity limitations will govern how much electricity can be used to provide heat. For this reason, it is likely that significant levels of solar PV generation will need to be adopted onto sites alongside battery storage. These technologies will assist in reducing the increased power consumption resulting from a move from gas to electricity heating with battery storage helping to attenuate peak electricity load. To be effective, the amount of solar PV deployed will need to be significant and the cost of implementing at scale needs to reduce sufficiently so that solar PV carpark canopies as well as building mounted arrays become more affordable. Battery storage technology is also an area seeing rapid growth and more sustainable models that utilise recycled electric vehicle batteries to repurpose as power management solutions.

A ROADMAP TO ‘NET ZERO’

Three stages to ‘net zero’ carbon



STAGE 1

Intermediate to short term

Low impact to site infrastructure:

- Existing heat from gas boilers
- Steam still used
- Partial de-steaming with efficient use of gas CHP
- Technology available now
- Good financial savings
- High NPV
- Low carbon savings

STAGE 2

Short to medium term

Medium-high impact to site infrastructure:

- No steam heating
- Efficient gas CHP (heat led)
- LTHW heat networks
- Technology available now
- Higher cap-ex, lower financial savings
- Lower NPV
- Higher carbon savings, lower NOx

STAGE 3

Medium to long term

High impact to site infrastructure:

- Gas engine CHP retired, or converted to hydrogen
- Heating by electric heat pumps, hydrogen fuel cells, hydrogen fuelled boilers
- Technology not widely adopted or available yet
- Highest carbon savings
- Zero NOx

KEY TO ICONS:

The shift away from a fossil fuel dominated heat supply may ultimately see the retirement or conversion / adaptation of natural gas boilers and CHP installed in stage 2 in favour of hydrogen or bio-methane fuelled plant, as well as introduction of more efficient hybrid heat pumps and hydrogen fuel cells in stage 3. All of these solutions will be feeding heat to buildings utilising the same low temperature energy infrastructure deployed in stages 1 and 2 described earlier.

A ROADMAP TO 'NET ZERO'

Summary

The recent publication of the NHS *"Delivering a 'Net Zero' National Health Service"* report, has set into sharp focus the significant challenges immediately before us. The response required from the built estate is significant - and becoming increasingly urgent if we are to make the headway needed to meet the carbon emission reductions targeted by the NHS by the end of this decade and beyond.

It's clear a 'do nothing' approach is not an option, since there is a mountain to climb to hit 2028/32 80% reduction targets, let alone 2040 net zero and this needs to be tackled in achievable and affordable stages. If the investments made at each stage are strategically planned and delivered in a way that delivers a guarantee of affordability, then getting close to the 2028/32 targets and 2040 net zero becomes more realistic and a way forward more believable.

From this standpoint can be seen the benefit of strategic investment in the fundamentals of a future proofed energy infrastructure that can be started now (Stages 1 and 2); that maintains savings throughout its life and is ultimately adaptable and capable of utilising future technologies as they come on stream during stage 3 and beyond.

Utilising the Roadmap - a typical example

The following is an example of how an energy infrastructure investment to a typical acute hospital site might be viewed in the context of planning a pathway towards net zero carbon emissions by 2040. Achieving a total net zero position from energy infrastructure measures alone may not be practically possible for many campus sites and in any event maximum net zero potential cannot be delivered immediately from day one. But the aim of this strategic approach, is to attempt to model potential outcomes and ensure any solutions started now, facilitate further iterations along the way as and when technology or costs allow, while at the same time, providing benefit from revenue savings by implementing a progressive approach right from the start.

Stage 1 - Existing on site generation measures

Most Trusts will have already taken steps to reduce carbon emissions and save energy costs with many utilising natural gas combined heat and power (CHP) also acting as a significant revenue generator. Under the 'road map' approach presented here, these sites would be classed as having achieved level 1 carbon saving measures.
In the example graph shown above, a Trust installed a gas CHP (electricity led) in 2013, which has an operational life expectancy of 15 years. The red solid line shows the savings achieved by the Trust's decision to enact an energy scheme in 2013, which is planned to run until 2028.

The graph shows how the scheme saved significant amounts of carbon at the beginning of the energy project compared to running the site from all national grid power.

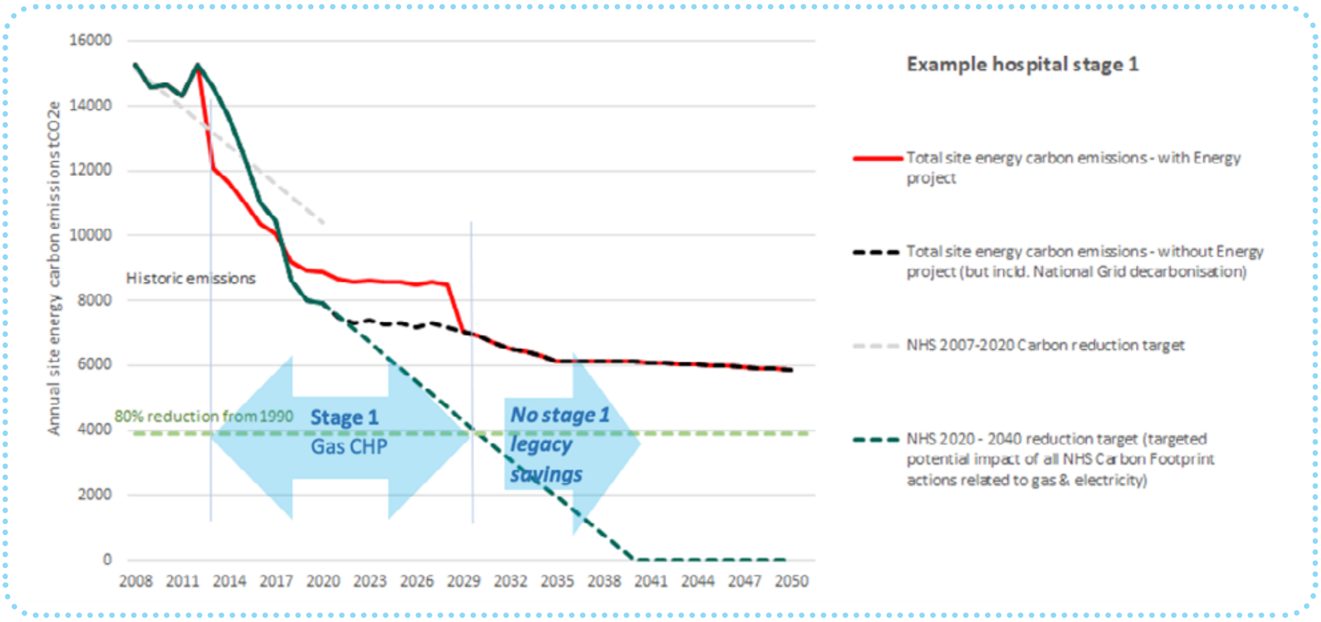


Figure: Stage 1 CHP carbon savings compared to "Do Nothing" (Using same basis of forward projecting carbon emission factors as NHS "Delivering a 'Net Zero' National Health Service" report)

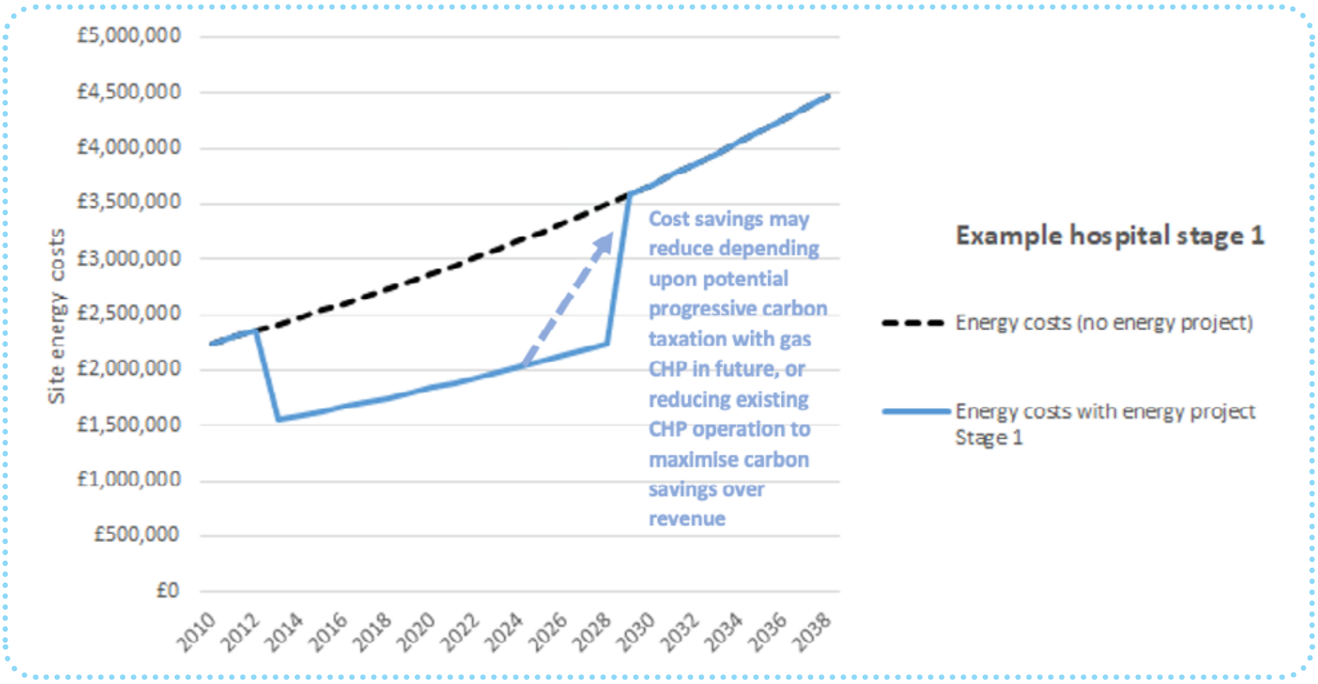


Figure: Stage 1 Existing CHP energy savings likely to remain attractive subject to extent of future carbon taxation impact or change in the way plant is operated to prioritise carbon savings over revenue.

Indeed, it can be seen how it enabled the site to exceed the previous NHS 2007-2020 carbon reduction targets. However, it can also be seen that these carbon savings are reducing as time goes by as the national grid further decarbonises. By the end of the scheme operation in 2028, it leaves no legacy savings, and it is predicted that the scheme will no longer be saving the Trust any carbon. It is evident that without further investment, the site will make no further contribution towards the 80% reduction milestone targeted in 2030 or the 2040 net zero position. Significant energy cost savings are delivered while operating the example gas CHP and these are shown compared to 'do nothing' below.

In this example, gas CHP financial energy savings start after installation in 2013 and the scheme is predicted to maintain energy savings throughout its life to 2028, although there is likely to be a progressively negative impact of additional 'cost of carbon' (notional price of CO_2e) to be taken into account in the next few years. This is only shown indicatively on this graph as the extent of progressive carbon taxation and how it might be applied in the medium to long term is not yet fully clear.

Moving to Stage 2

Any scheme started now that wishes to include gas CHP because of the significant operational cost avoidance currently still possible, must ensure that the CHP minimises carbon emissions as far as practical. Such a scheme will almost certainly only include CHP because it enables affordability of other additional savings measures that make the overall energy scheme positive carbon saving, or else risk the solution worsening a Trusts carbon footprint over its operational life.

While the continuation of generous financial savings from CHP operation will be welcome, a deterioration in a sites carbon footprint will become less and less acceptable and be seen as a move in the wrong direction from a corporate sustainability perspective. Schemes that are started now also need to leave a viable savings legacy to ensure solutions deliver infrastructure that sets a Trust in a better position to adapt and invest in further carbon reduction technology, while at the same time encompassing technology that is commercially available and affordable and above all, avoid stranding assets.

Stage 2 - Creating a low carbon infrastructure legacy

The following figure, shows an example of the potential impact of moving a site energy infrastructure into stage 2, where although the existing gas CHP is still utilised, it is now operated in a heat led mode, recovering as much heat as possible using thermal storage and operating during the

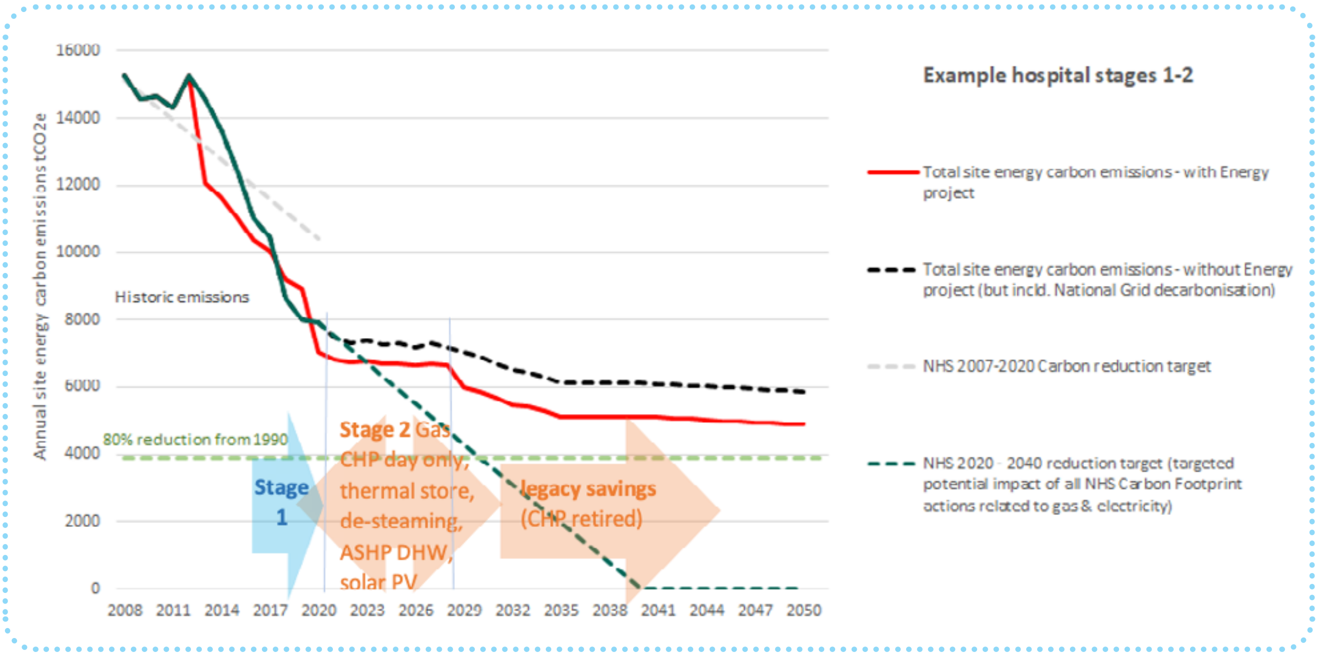


Figure: Stage 2 CHP daytime operation only, thermal store, small DHW ASHP and other demand side carbon savings compared to "Do Nothing"

day time only, as well as converting the site infrastructure from high temperature steam to low temperature hot water, allowing the interface with a conventional air-source electric heat pump to preheat some of the sites domestic hot water. This moves a modest proportion of site's heat away from fossil fuels and helps to retain a legacy carbon saving that could persist (towards 2040) long after the original gas CHP has reached end of life.

The graph shows carbon savings achieved beyond 'do nothing' with the CHP operating during the day only to ensure generated heat is either used directly or sent to thermal store for use during the night so as to maximise carbon savings. Operating the CHP still 'costs' carbon, but for this scheme there is an improvement on carbon saved compared to operating the CHP electricity led 24-7 and throwing unused heat away. By the time the CHP has reached the end of its life, the carbon savings improve from switching it off, as by this time the predictions are that the national grid should have further reduced its carbon content. As with stage 1, relying on the long-term greening of the National Grid on its own, will not achieve a net zero 2040 carbon position, and the expectation remains that a further move of heat generation capacity away from conventional fossil fuel use will be needed by 2040.

Stage 3 - Seeing a way forward

Stage 1 has shown historical carbon savings and refreshing the scheme for a stage 2 should enable the site to maintain further continuous carbon savings, even with a greening electricity grid. Stage 2 should offer improvements over the 'do nothing' carbon savings position, placing this example Trust in a proactive light while delivering meaningful cost avoidance. The potential to consider stage 3 may also now exist, although the ability to enact all of it will be limited by commercial availability and affordability of some potential stage 3 plant solutions, depending upon what technology options are considered. Investments made at Stage 2 in de-steaming all of a site and utilising more efficient LTHW boilers and variable volume pumping systems will deliver long term energy and carbon savings and enable more likely adoption of 'stage 3' commercial scale heat pumps to take more of the heat away from fossil fuels in the future.

The opportunity to save carbon from the progressive introduction of larger air or ground source heat pumps delivers the potential for more significant carbon savings. This assumes that the site can accommodate larger electric heat pump capacity both in terms of space for plant and in terms of electrical capacity, which will increase as the site moves more heating from fossil fuel over to electricity. The alternative may be to wait for the potential availability of hydrogen fuel infrastructure which may eventually replace natural gas at some point in the medium to long term.

By 2030, further investment is likely to be needed to contribute further towards meeting 2040 net zero carbon, but with a progressively decarbonised solution developed by Stage 2, perhaps it may be more straightforward and less costly to implement additional heat pump capacity. This is because the site considered in this example has already been fully de-steamed and electrical infrastructure capability is likely to be the only limiting factor. The stage 2 graph shows there is still a need to save much more carbon by 2040 and that for this example, as with many similar infrastructure schemes, its highly likely significant reinvestment in existing and potentially new buildings is also going to be needed to drive emissions down closer toward the 2040 net zero position.

There will be a financial energy running cost penalties to pay for moving heat over to electricity, particularly in the early years where electricity is still significantly more expensive than gas. In the example considered, the gas CHP option has been retained (until 2028) – which while having a progressively limiting contribution to carbon saving, is still anticipated to maintain positive financial energy savings, which may help pay for more expensive decarbonising investment.

Example capital and O&M costs

This example project indicates an iterative process is needed with periodic but continuous reinvestment in energy infrastructure. The table below gives an indication of typical notional capital and O&M costs to implement schemes of this nature. Capital and O & M costs may vary considerably to those shown, depending on project scope, funding available and specific site constraints and opportunities.

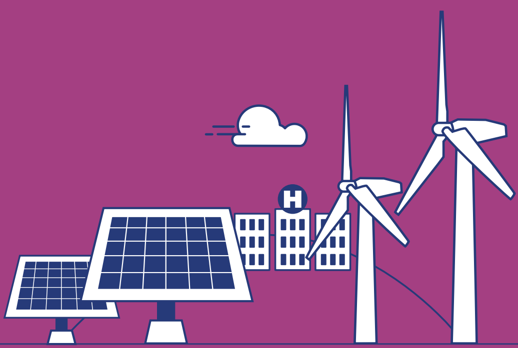
Cost savings	**Stage 1**	**Stage 2**	**Stage 3**
Gas CHP	Y	Y	Y
Lighting refit	Y	Y	Y
Partial de steam	Y	N	N
Full de-steam	N	Y	Y
Boiler improvements	N	Y	Y
Thermal store	N	Y	Y
Controls/BMS improvements	N	Y	Y
Modest ASHP to preheat DHW	N	Y	Y
Larger LTHW ASHP	N	N	Y
Capital cost for staged additions	*£3,174,288*	*£8,366,872*	*£3,174,288*

Cumulative capital cost	**£3,174,288**	**£11,541,159**	**£12,512,933**
O & M Cost	£247,799	£273,410	£275,656
Finance costs	£241,246	£877,128	£950,983
Service Contract costs	£18,544	£522,564	£561,627
Total annual year 1 costs	**£507,589**	**£1,206,055**	**£1,286,306**
Energy savings	£908,267	£1,052,562	£1,040,085
Service improvement savings	£174,549	£522,564	£561,627
Total annual year 1 savings	**£1,082,815**	**£1,575,126**	**£1,601,712**
Net cash release year 1	**£575,226**	**£369,071**	**£315,405**
NPV 15 years	*£7,795,721*	*£5,001,811*	*£4,274,511*

Table: Potential scope and high level financial impacts for stages 1,2 and 3 (an example project, costs indicative and subject to assumptions made)

DEMAND REDUCTION

- Chillers and HVAC
- Fabric Insulation
- Heat Distribution and Boilers
- LED Lighting
- Variable Speed Drives
- Voltage Optimisation
- Water Efficiency
- Behavioural Management
- Building Management Systems
- Contract & Performance Assurance



DEMAND REDUCTION

Chillers and HVAC

KEY FEATURES

- HVAC systems, including chillers, typically account for 15-35% of total hospital electricity energy use
- Many older systems may now be running below optimum efficiency
- Evidence shows scope for over 30% energy reduction
- A wide range of solutions can be applied to improve efficiency and make energy savings
- Benchmarking existing energy usage is an essential starting point.

1. Introduction

HVAC systems, including chiller energy, typically account for between 15 and 35% of total hospital electricity energy use and around 80 to 90% of gas utilisation.

Gas use in HVAC systems is heavily influenced by heat generation plant, such as boilers and (where applicable) CHP, covered elsewhere in this guide.

Heat energy at point of use, however, is influenced by the HVAC system type and its control (e.g. radiators with local hot water control valves, or mechanical supply and extract ventilation to achieve required air-change rates).

General areas of the hospital and areas of specialised clinical use will require different levels and configurations of HVAC, depending on the demand for heating, cooling, dehumidifying/humidifying and provision of fresh air ventilation needed. Heat may be used alongside cooling to deliver a closely controlled environment (such as an operating theatre or laboratory) either as part of a full air-conditioning system, or separately - for example by localised radiators or local fan-coil units.

Cooling provisions are usually integral to air-conditioning systems, which may work with heating and humidification plant to provide close control; whereas separate split air-conditioning units may be installed to provide localised comfort cooling for patients and staff.

HVAC systems have usually evolved alongside estate development, often resulting in dispersed application (numerous localised plant-rooms or packaged external units), or a range of different systems serving different areas. These systems may have been progressively augmented or adapted to meet changing requirements over the years, with (unintended) compromises in operation and maintenance.

As a result, many elements of hospital HVAC systems may not be operating as originally intended. They may have received limited re-investment beyond minimum maintenance upkeep and thus may not be as efficient in energy utilisation as they could be.

2. Key HVAC issues

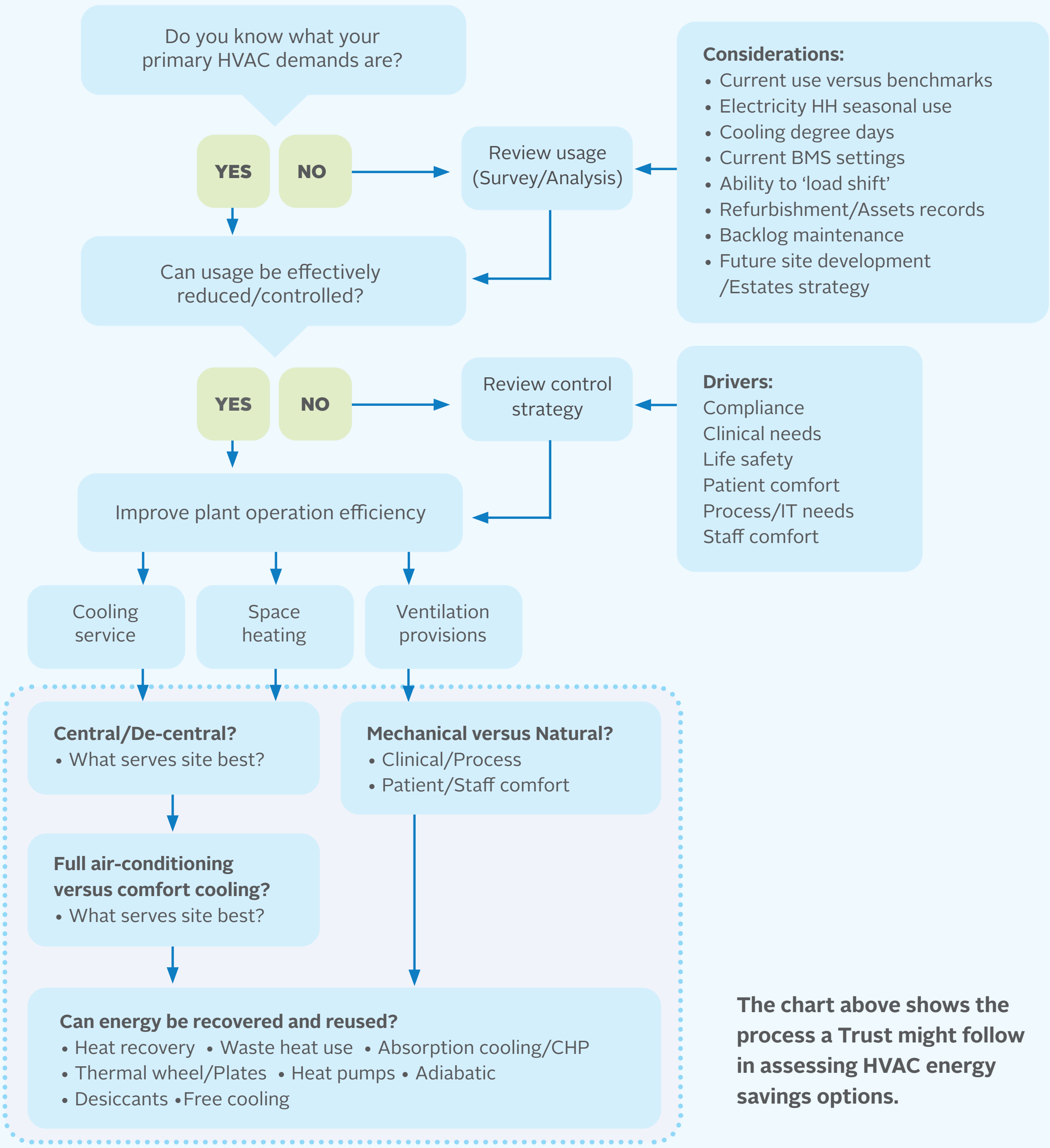
Typically, the primary issues that drive hospital HVAC solutions are:

- Compliance with NHS and hospital operational policy, usually driven by Health Technical Memoranda (HTMs).
- Specific environmental requirements to satisfy clinical processes and achieve internal space environments that do not compromise life, safety or patient well- being (for example, operating theatre activities or emergency spread of fire/smoke control).
- Environments where patient care and comfort can be maintained consistently throughout the day and during each season of the year (for example avoidance of over-heating in the summer, adequate warmth in the winter).
- Environments where more specialised process needs can be carried out (for example pharmacy, storage and IT server operations).
- General staff and visitor comfort (for example in rest, changing and waiting areas).

More recently, as a result of the SARS-CoV-2 (COVID-19) pandemic, there has been a focus on the ability of HVAC systems to maintain adequate ventilation within wards and clinical spaces to help mitigate the potential for virus transfer and to provide enhanced cooling for staff having to wear PPE continuously within these areas.

Depending on the age of the hospital and arrangements within it, there may be some very simple HVAC solutions, deployed with limited use of air-conditioning. These areas may have less reliance on conditioning 'a sealed building' and rely more on utilisation of natural ventilation (for example opening windows). A 'mixed-mode' philosophy may be in place that makes use of natural ventilation for most of the year, or perhaps only at certain times of the day, to achieve ad-hoc cooling without using high-density HVAC plant, but with localised mechanical cooling provided to sensitive areas only.

3. Initial assessment for HVAC solutions



The chart above shows the process a Trust might follow in assessing HVAC energy savings options.

DEMAND REDUCTION

An initial feasibility assessment is likely to consider some of the following questions. The answers suggest typical approaches needed to answer them:

Q How do I know if my hospital is operating efficient HVAC systems?

A You can't manage what you don't know. Unless you have had a recent review, or carry out ongoing reviews of your HVAC systems, it will be difficult to answer this question in any detail. However, the notes below may form part of a more detailed review to help with an initial assessment.

Q How can I benchmark my hospital's HVAC energy use?

A This may be difficult to do accurately or completely for the whole estate; however, the following actions will provide valuable snapshots of key systems or areas.

- Compare your ERIC returns (gas and electricity use /m²) to those of other hospitals of similar category/ size. This may help to put into context the more detailed analysis work suggested below.
- Review energy use breakdowns from Display Energy Certificates and accompanying reports, which should provide some pointers on where consumption is highest.
- Track gas usage records over a whole year. Using publicly available heating degree-days, this will determine the relationship of gas use and need for heat. The clearer the relationship, the more likely that heating is being controlled well (i.e. when heating degree-days are low, your gas consumption will be low; it should rise proportionally with heating degree-days).
- Look at consumption of gas from invoices for each season and for the whole year. Relate this to the m2 of areas heated from the gas meter billed to establish the kWh/m² demand pattern. How do these compare with benchmarks?
- Track electricity use over the summer against published cooling degree-days to determine if there is a relationship between electricity consumption and need for cooling. This may not be as obvious as for heating, and ideally needs access to half-hour electricity meter data.

Q How do I establish where the biggest opportunities are?

A Identify and target the largest HVAC loads since those improvement projects are likely to harvest the largest savings impacts and most viable paybacks. Smaller systems can be considered once the big picture and main opportunities are understood.

- Check whether large plant are already being 'sub-metered' and sending consumption data to the BMS. Operation trends and load plots may be available.
- Analyse BMS logs for operational times and loads of main chiller plant, AHUs and pumps.
- Consider employing a specialist to fit BMS points data capture analysis software. This will facilitate a more detailed pull-out of existing operational performance and possible opportunities for correction of set points and optimisation.
- In most cases, sub-meter information may be non-existent and if general data is not already being captured, an overview 'walk-round' survey, noting significant pump, compressor and fan motor sizes, will help build a picture.
- Existing asset registers, PPM plans, air-conditioning inspection reports and refrigerant inventory lists may already identify useful information on plant capacity and the areas served.
- Try to capture findings in a manner that helps map where the biggest energy users are.

Q Is usage pattern important?

A Yes. Knowing what areas the main HVAC plant serves and the associated user needs, will help to develop an energy savings strategy that minimises unnecessary plant operation.

- From the initial assessment exercises above, a picture should have emerged of where and when the largest HVAC usage occurs. Review this alongside electricity invoices for opportunities to reduce plant demand during periods of daytime higher-rate tariffs, red tariff periods and Triad periods shown on the bills. This may not require full 'load shifting' or 'load shedding', but might mean relaxing set points during these periods to reduce demand gradually.

- Some clinically critical areas may be out of bounds in terms of adjustments to control HVAC plant and may call for realistic conversations with department managers to establish what is possible and acceptable at a practical level.

Q Is my HVAC plant too old to improve?

A O&M budget constraints may mean replacement of old and/or unreliable plant has been put off.

- Estates teams are usually experts in optimising operation of older machinery to maximise life expectancy. Nevertheless, it is useful periodically to review potential opportunities to replace old/unreliable plant with more efficient or alternative solutions.
- At the same time, consider recent increases in energy prices and the build-up of backlog maintenance, some of which may be considered as an 'avoided cost' to help build a business case for replacement.

Q Will energy savings impact on the need to meet compliance?

A Be clear on what level of solutions are needed to comply with regulation or best practice (HTMs,BS ENs).

- This is important when considering energy saving opportunities that may rely on optimising or reducing plant duty (typically variable speed fan controls, occupancy detection or control setback changes).
- Changes of area use over the years may mean existing plant is either no longer compliant, or no longer needed to operate as originally designed. The high-level review identified above, alongside consultation with end users, should capture this.

Q How do I deal with areas where thermal comfort is not being met?

A Patient wellbeing relies significantly on achievement of thermal comfort. Overheating in many hospitals during more frequent periods of heatwaves may become an issue in the medium to longer term.

- Take a holistic view on any significant areas where there are thermal comfort problems. Any HVAC energy reduction proposal needs to account for the potential influence from existing levels of fabric insulation, impact of unshaded solar gain in the summer and influence from casual gains, including lighting, equipment and people.

Q Do I need to consider the longer-term outlook?

A This may not be possible to assess with total confidence. However, an initial assessment should consider any known impact of the short, medium and long-term estates strategy on current main plant, capacity and primary plant locations.

- Are there plans to remove/change/introduce areas to the estate that may have significant impact to HVAC load (e.g. new clinical scanners, hydrotherapy pools, theatre upgrades, significant IT areas?).
- In short, are any areas scheduled to change that may impact existing systems or create new potential energy improvement opportunities?

4. HVAC procedures and benchmarks

Hospital operational procedures may vary to a degree, but key HTMs associated with HVAC provision include:

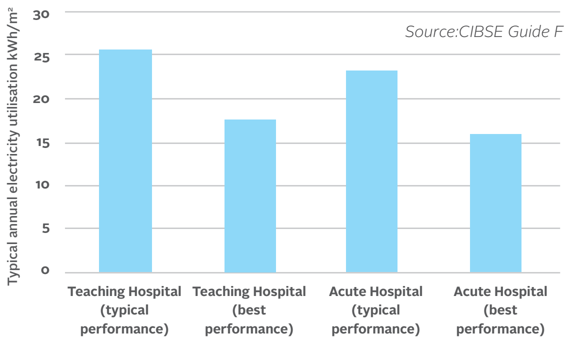
- HTM 03-01: *Specialised ventilation for healthcare premises,* which in various parts focuses on design and implementation aspects.
- HTM 07-02 Encode 2015 - *making energy work in healthcare,* which has a very useful and more detailed review of energy management aspects.
- Typical HVAC energy benchmarks for hospitals are published in CIBSE TM46 and in CIBSE Guide F Energy *Efficiency in Buildings.*

A review of the CIBSE benchmarks indicates a difference of c.30% between 'typical' and 'best practice' HVAC electricity energy use in acute and teaching hospitals, suggesting significant scope for HVAC energy reduction.

Caution is needed when isolating individual benchmarks from overall benchmarks, as other performance parameters may influence the HVAC benchmark and visa-versa. For example, reducing lighting energy should reduce heat gains for air-conditioning and comfort cooling, but may also increase winter heating demand.

DEMAND REDUCTION

Comparison of 'typical' verses 'good practice' HVAC electricity energy use



5. Cooling

Most hospital estates comprise a mixture of different building phases and a variety of cooling solutions may exist, depending on the age of the original estate and primary clinical usage of the area.

It is common for hospital sites to have a centralised boiler plant room with a distributed heating main, serving satellite HVAC plant rooms within various zones and buildings around the hospital site; it less common for cooling to be delivered in the same way.

A single centralised chilled water plant and chilled water distribution main is not always provided and it is common for cooling to be provided by more localised solutions. These may still encompass significant chilled water plant with localised chilled water distribution, but there is usually also a range of smaller cooling plant and systems that have been deployed to serve individual areas and retrofitted over time to suit specific use.

Therefore, cooling energy savings opportunities usually have different focuses relating to either centralised or dispersed plant, some of which are summarised below.

Opportunity	Centralised cooling	Dispersed cooling
Cooling load reduction	Plant size governed by resilience needs (usually N +1), connected site load diversity or load factor (ratio of average load to peak load), and longer-term site needs/ development plans. Review distribution chilled water set points. Is the chilled water flow temperature capable of being compensated or adjusted to suit demand? Is the system still distributing chilled water to buildings that no longer make significant use of it (i.e. have refits been applied to stand-alone systems instead)?	Plant size reduction governed more by flexibility of end users in the area directly served, plant space controllability, bespoke times of use, and set back opportunities. Look at potential for localised solar gain control. External brise soleil shading has greater impact than internal blinds, but more significant retrofit issues (visual impact to existing buildings; local authority planning may be needed). Look at more optimised location of electrical equipment (particularly IT servers); move away from zones more sensitive to solar overheating. Review the need for full close control in areas that do not have critical environmental control parameters. Small adjustments to space temperature and humidity (RH) set points can make significant impacts on consumption over time, and are usually no-cost to implement. Review plant operation times with end-users - are systems operating when there is no user requirement?
Cooling plant efficiency	Potential for good part-load efficiency if cooling circuits are adequately controlled. Use of thermal storage tank buffers is possible to reduce chiller compressor plant cycling. Heat rejection plant efficiency opportunities may be more practical to achieve, e.g. use of adiabatic air-cooled condensers. Consider compressor upgrades to enable VSD control,e.g. potential for 'Turbocor' oil-free compressor utilisation with integrated VSD to provide better part-load efficiency.	More dependent on zone controls, e.g. separate local plant or capacity control set up, to deal efficiently with external zones that are subject to more variant demand, versus internal zones in deep-plan buildings. Localised solar, equipment/casual gain control/management in the end use space may have a bigger energy savings impact. Avoid reheat operation on systems i.e. solutions that apply heating after dehumidification. If unavoidable on close control systems, consider utilising waste heat recovery.

Opportunity	Centralised cooling	Dispersed cooling
Cooling energy losses	Ensure chilled water distribution pipework thermal insulation is complete, including valve and fitting thermal covers. Avoid routing chilled water distribution through areas of significant heat gain e.g. boiler rooms, or near high temperature heat distribution pipework. Consider variable pumping control for primary chilled water distribution (VSD drives and 2-port valves at point of CHW usage).	Good local pipework thermal insulation is important. Avoid separated heating and cooling control systems, e.g. comfort cooling units operating with heating radiators active at the same time (simultaneous heating and cooling). Avoid comfort cooling units operating when the windows are open (uncontrolled ventilation).
Cooling energy storage	Consider larger chilled water buffer vessels if appropriate, to smooth out demand and reduce need to run chillers at peak capacity. The ability to do this will depend on diurnal load pattern. Consider phase change ice storage. Again, this is dependent on diurnal load pattern and any savings impact relies on significantly lower night rate electricity tariff and DUoS tariff band timings.	Consider night purging of buildings using cooler night air to pre-cool the building during the summer and delay the need to activate mechanical cooling the following day. Depends on the ‘thermal weight’ of the building and exposed ‘thermal mass.’ Difficult to retro-fit with existing deep-plan buildings that are occupied 24/7.
Cooling and cooling heat rejection energy recovery	Consider free cooling i.e. holding off refrigeration compressors and / or controlling heat rejection plant to take maximum advantage of lower ambient temperatures. Consider utilising waste heat from CHP to drive a thermal absorption chiller.	Local plant can also incorporate ‘free cooling’ and compressor VSD control, although replacement plant with built-in technology is more likely to be viable than retrofitting to individual systems. Consider enthalpy control on fresh air plant, to minimise the need to dehumidify fresh air in AHU cooling coils. Consider refrigerant-to-air heat pump technology and variable refrigerant flow units to maximise use of heat during condensing cycles. Consider thermal wheels on air-conditioning plant to transfer useful energy from extract air to supply air streams.
Cooling systems energy management and monitoring	Install electricity sub-meters on all major chiller plant and monitor half-hour usage to establish load patterns and opportunities to optimise operation and potentially load shed /manage. Meters on large chilled water distribution systems may also help in monitoring demand and optimising ongoing control between seasons.	Sub-metering local chillers and AHUs may be advantageous. Where possible, enable monitoring of remote systems via BMS and ensure out-of-range alarm values (i.e. temperature) are followed up. Effective energy management and savings will be achieved if feedback from monitoring is acted on.

6. Chillers

Conventional chiller energy utilisation comes primarily from the electric motors operating screw or centrifugal compressors to drive the refrigeration cycle. The efficiency of this process is largely governed by the ability to match compressor loading to prevailing cooling load.

Ideally, efficient chiller control avoids compressor operation until needed, and also prevents too many starts and stops to reduce occurrences of overshooting demand and 'hunting' around a control point, with associated mechanical compressor wear. The advent of cheaper variable speed drives and intelligent controls has made more dynamic compressor control possible. However, the mismatch of chiller capacity to actual cooling loads is still common. Significant energy savings may sometimes be made by installing an additional, small part-load / mid-season chiller, that can operate more efficiently than the original larger units outside peak load situations.

The ability to reject heat efficiently from the condensing cycle also has a significant bearing on overall chiller efficiency. Chillers used within hospitals are mainly of two types:

- **Water-cooled.** Having refrigerant condenser heat cooled by water (indirect or occasionally direct acting cooling tower)

Or;

- **Air-cooled.** Having refrigerant condenser heat cooled by external ambient air (radiator and fan).

There may be hybrids of these types, but essentially, they cover all refrigerant-based cooling solutions.

Water-cooled chillers are generally more efficient, as they use the latent heat from water evaporation to increase the efficiency of heat transfer from the refrigerant condenser to the air. However, because of concerns over Legionella risk, conventional cooling towers are not usually deployed in hospitals. Air-cooled chillers are used widely, although their efficiency drops off when the ambient air temperature is highest and closer to the temperature at which the refrigerant is condensing.

Chiller efficiency saving is usually considered in terms of ability to improve the seasonal energy efficiency ratio (SEER); that is the total cooling energy provided by the chiller, divided by the total energy delivered into the chiller over the course of a year. SEER will account for the ability to cool more efficiently when the external ambient temperatures are lower.

Annual seasonal efficiency ratios of more than 4 can be delivered using modern electric chillers that deploy variable speed compressors and system controls that enable good part-load efficiency, coupled with condenser designs which can make use of lower ambient external temperatures to reduce reliance on compressor operation.

Retrofitting improvements. It is worth considering possible retrofit improvements to existing machines where these units have a viable life expectancy, such as adiabatic cooling, which involves spraying water into the ambient air being drawn over an air-cooled condenser. This pre-cools the condenser and increases the efficiency of heat rejection, reducing the power needed from the refrigeration compressors. All the water sprayed onto the condenser coil is evaporated, so there is no recirculation. This 'total loss' system avoids the Legionella bacterial growth risk posed by conventional cooling towers. It is still advisable to assess risk and ensure there are no elements of standing water in connecting pipework and drains, and belt-and-braces solutions may also incorporate treatment with ultra-violet light.

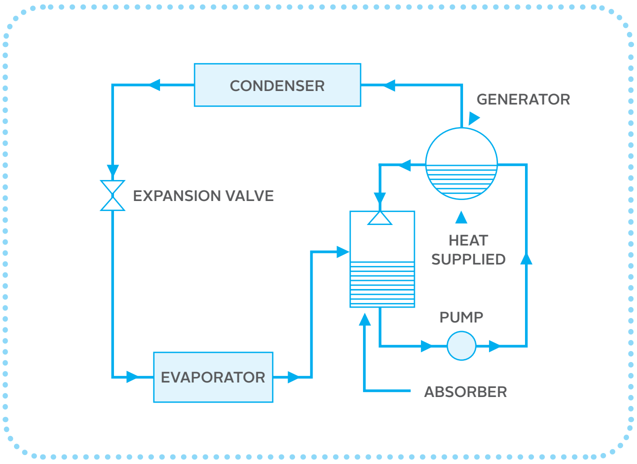
The Carbon Trust Guide "*How to add adiabatic cooling to your refrigeration plant*" suggests typical installation costs of c.£2000 for a 300 kW chiller with an anticipated payback of less than 2 years based on 1500 hours annual operation.

Refrigerant issues. Synthetic fluorinated greenhouse gas refrigerants are almost universally used in conventional electric chillers, packaged air-conditioning / split units and heat pumps. Since 2001, in Europe and the UK, traditional HVAC refrigerants like R22 which is a Hydrochlorofluorocarbon (HCFC) have been banned from use in new equipment and, since 2015, can no longer be used to top-up existing refrigeration plant. Consequently, most hospitals will now have replaced their old HCFC systems either with new plant using a hydrofluorocarbon (HFC) alternative synthetic blend or a drop-in replacement. While HFCs have zero ozone depleting potential, they still have high global warming potential. Although HFC refrigerants have generally replaced HCFCs, they are now the focus of the F-Gas Regulations which came into force in 2006 and were updated in 2014. These regulations require mandatory leak checks and repairs and automatic leak detection for systems above a certain threshold. They also dictate the need to keep records about air conditioning and heat pump equipment using HFC refrigerants, as well as the requirement to use qualified technicians for leak checking and refrigerant handling operations.

New replacement chillers should be checked for compliance with F-Gas and the use of natural refrigerants may also be considered as an alternative to HFCs where practical. Natural refrigerants such as Hydrocarbons (propane and butane), ammonia and CO2 are possible alternatives to HFCs, but each has its own practical implementation issues. Hospitals with a large base chiller load that are also considering applying Combined Heat and Power (CHP) technology may consider an absorption chiller as an alternative, which typically works on a process that encompasses natural refrigerants such as a water in a lithium bromide solution.

7. Absorption chiller economics

Absorption chillers use heat to drive a chemical refrigeration effect (as opposed to electricity used in conventional chillers to run mechanical gas compressors). If waste heat can be harnessed to drive a chemical absorption refrigeration process, and this supplants a conventional electric chiller operation, it may be possible to show significant energy savings.



Simplified schematic of an absorption refrigeration process

The thermodynamic efficiency of the absorption refrigeration process is poor compared to a conventional electric compressor chiller and is driven by the grade of heat applied in the 'generator'. Single-stage absorption chillers that use waste heat at around 80 deg C will have a typical efficiency ratio of around 0.6 to 0.7. This can double when double-stage absorption chillers are used, but to achieve this they require high-grade heat inputs above 140 deg C (typically from waste steam, or recovered heat from CHP exhaust gas).

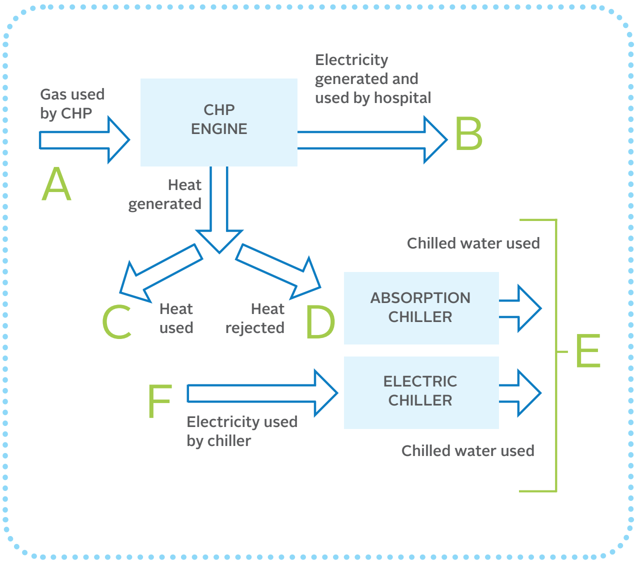
In common with electric water-cooled chillers, absorption chillers need water to carry away heat from the condenser using cooling towers, dry or adiabatic coolers, but the cooling water temperature must be kept above 20 deg C to avoid lithium bromide solution crystallisation. The viability for absorption cooling rests on:

- Access to high-grade waste heat - i.e. heat that is truly a by-product of another beneficial process such as CHP (in certain circumstances).
- Access to as large a base cooling load as possible - absorption chillers are generally not widely available at small scale and tend to operate best when subject to a relatively consistent demand.

An ideal scenario would be one where there is an existing centralised chilled water system and a CHP that can provide waste heat to drive an absorption chiller (connected to the chilled water distribution) during the cooling season. This improves CHP operational efficiency by reducing the amount of heat that may have otherwise been 'dumped' because of reduced summer heat demand, by extending the annual CHP hours, or by enabling a larger CHP to be considered, to generate greater savings.

A typical absorption chiller energy savings model is based on the inputs and outputs shown below. This model can be used to compare the absorption chiller CHP with existing hospital chiller efficiency, as well the potential for new high-efficiency electric chiller replacement.

DEMAND REDUCTION



The values of 'A' (gas used by CHP), 'B' (electricity generated by CHP in place of grid supply), 'C' (heat used for space heating or hot water) and 'D' (heat not required and rejected from the CHP) will depend on the type and size of CHP and prevailing base demands.

'D' may be high-grade or low-grade waste heat or a combination of both; the choice would depend on type of CHP utilised and will dictate the SEER of the absorption chiller achieved.

The model compares the total cost of energy to operate a CHP with absorption cooling to the equivalent cost for operating electric chillers. The amount of cooling delivered (E) is the same in each case. The electrical energy input (F) is based on the electric chiller SEER.

The table below shows the inputs and outputs for a modest 1.2 MWe reciprocating natural gas CHP, with and without absorption cooling, together with a comparison of the equivalent cooling output being generated by the hospital's existing electric chiller:

Element	CHP without absorption chiller	CHP with absorption chiller
Total annual gas used by CHP (A)	25,814,844 kWh	25,814,844 kWh
Total annual gas cost for CHP (£=A x gas tariff)	£771,864	£771,864
Total electricity generated by CHP used by hospital (B)	9,181,253 kWh	9,181,253 kWh
Total value of electricity generated by CHP used by hospital (£=B x elec tariffs)	£922,815	£922,815
Total heat recovered from CHP used by hospital (C)	7,672,074	7,672,074
Seasonal efficiency of existing hospital gas boilers (n1)	75%	75%
Equivalent annual existing hospital boiler gas saved (=C/n1)	10,229,432	10,229,432
Total value of existing hospital boiler gas saved (£= C x gas tariff)	£327,444	£327,444
Total heat rejected from CHP used for absorption chiller (D)	0 kWh	660,085 kWh
Seasonal efficiency of absorption chiller (n2)	0.00	1.00
Total cooling generated by absorption chiller (E=D x n2)	0 kWh	660,085 kWh
Cooling delivered by electric chiller (=E for comparison)	660,085 kWh	0 kWh
Seasonal efficiency of electric chiller (n3)	3.0	0.0
Equivalent electric chiller annual electricity (F=E/n3)	220,028 kWh	0 kWh
Total cost of chiller energy input (£=F x elec tariffs)	£23,004	£0
Total CHP + cooling solution energy operating cost (£B + £C - £A - £F)	£455,392	£478,396
Total saving compared to CHP without absorption cooling	**£0**	**£23,004**
Total carbon emissions from CHP excld. absorption chiller (=G)	-541 tCO2e	-541 tCO2e
Cooling carbon saved (=H)	-557 tCO2e	557 tCO2e
Total net carbon saved CHP + Cooling (=G+H)	-1098 tCO2e	16 tCO2e

On the face of it, there is a modest energy savings benefit in providing absorption cooling. However, this saving is very sensitive to the following variables:

- The amount of true CHP waste heat available. More absorption cooling could be provided, but may come at the cost of using CHP heat that would otherwise have been used to offset hospital space heating and DHW gas boiler use, rather than just the CHP waste heat that would have been 'thrown away'. The boiler efficiency that the CHP heat is offsetting may therefore also impact the amount of absorption chiller capacity that is most viable to use.
- The size of CHP in relation to site electricity load; for example, if the CHP is sized to follow base electricity load, a significant reduction in electric chiller operation may require reduced CHP output to avoid export to grid. This may significantly impact the overall savings achieved.
- The SEER of the electric chiller that the absorption chiller CHP is being compared against. The higher the electric chiller SEER achievable, the lower the CHP absorption chiller savings advantage.
- The CHP spark gap (difference between electricity price displaced by CHP and cost of gas to fuel the CHP).

Probably the most influential factor, however, is implementation cost, which is very site-specific. Absorption chillers are only marginally more expensive than an equivalent packaged electric chiller, but viability depends on optimisation to suit a CHP waste heat source and integration into an existing site chilled water system. This in turn will depend upon how centralised the site cooling load is, and the availability of additional plant space. These issues can significantly affect implementation costs and what can be achievable on site. It is difficult to demonstrate the viability of CHP with absorption chiller retrofits, and they are uncommon.

The ability of a CHP heat powered absorption chiller to save carbon compared to operating an electric chiller without CHP may be increasingly reduced. This is because grid electricity carbon content is reducing year on year and the alternative, that would consider a modern all electric vapour compression electric chiller, can now deliver much higher levels of COP. However, the idea of linking a CHP to an absorption chiller is to increase the utilisation of heat take from CHP to make it more efficient.

A CHP that is able to deliver more heat utilisation in the summer by sending it to an absorption chiller is likely to increase its summer carbon savings between 5% and 20% compared to the same CHP operating and throwing the heat away. The overall annual carbon saving will depend on how well the CHP recovers all of its heat, not just heat used in the absorption process and what you are comparing the absorption chiller-CHP operation with, in terms of alternative electric vapour compression chiller operation.

If the CHP is generally operating at a poor level of efficiency, then, while the carbon saving impact from operation with an absorption chiller is improved, the impact of operating the CHP may well still have a negative carbon saving impact compared to not having a CHP.

8. Heat recovery

HVAC systems involve exchange of energy, and once used within a heating or cooling process there may still be useful residue that can be re-used to benefit another (usually adjacent) systems rather than just throwing it away. Generally, the lower the grade of residual waste energy, the less viable it is to recover.

The Carbon Trust Guide: "*Heat recovery - A guide to key systems and applications*" provides useful details of HVAC heat recovery applications. Typical examples of potential within hospital environments are summarised in the following table.

Opportunity	Typical location	Typical viability
Low-grade heat recovery from chiller condensers	Main air conditioning chillers	• Only viable if simultaneous heating demand while cooling. • Not widely practised in hospitals.
Thermal wheel	Principal air handling units (AHUs)	• Difficult to retrofit, due to significant space requirement and impact on existing plant. • Cross-contamination of air streams may be a risk in clinical areas. • Heat transfer typically between 65% and 75% efficient.
Plate heat exchanger	Principal AHUs	• Difficult to retrofit, due to significant space requirement and impact on existing plant. • Heat transfer typically between 55% and 65% efficient.
Run-around-coil	Most supply and extract AHUs	• Usually possible to retrofit • Heat transfer typically only between 45% and 50% efficient.
Heat pumps (also see heat pumps section)	Unitary packaged basis room by room, or more centralised systems.	• Air-to-air heat pumps most common. See below for other heat pump types.
Heat pipes and heat pump coils (also see heat pumps section)	Principle AHUs	• Heat pump coils remove heat or cooling energy from one location to another i.e. between two separate air streams. They need to be in close proximity. Typical heat transfer between 50% and 65% efficient. • Heat pipes only used where the supply and extract air streams are contained in the same AHU. Typical heat transfer between 50% to 55% on horizontal pipes and up to 75% on vertical pipes. Limited ability to control.
Flue gas economisers	Most boilers > 100 kW	• Usually viable if space available. • Consider replacement with condensing boilers if existing boiler < 150 kW. • Typical net thermal efficiency improvement up to 5% using. • A non-condensing gas-to-water economiser or by up to 15% if condensing.
Pre-heat combustion air	Large boilers	• Pre-heating combustion air to the burner by using a flue economiser or drawing warm air from the top of the energy centre or boiler shell. • Typical boiler efficiency saving 1% to 2% by raising the combustion air temperature by 20°C.
Blowdown on steam boilers	Steam boilers	• Recover flash steam and residual heat from the blowdown process through a flash vessel. • Typical blowdown energy loss savings up to 50%, achieving energy saving of 0.5% to 3.5% of boiler heat input. • Typical payback in 2 years.

Because of the recent global SARS-CoV-2 (COVID-19) pandemic, HVAC systems that use heat recovery that involves mixing return air from occupied spaces with fresh air have been identified as high risk and the CIBSE has published general guidance on their website associated with ventilation system operation [https://www.cibse.org/coronavirus-covid-19/coronavirus-covid-19-and-hvac-systems]. Guidance consensus suggests that *"the potential benefit to public health at this time outweighs the reduction in energy efficiency caused by not recirculating air"*. The guidance also suggests that *"any ventilation or air conditioning system that normally runs with a recirculation mode should now be set up to run on full outside air where this is possible".*

9. Ventilation

New hospital building designs might incorporate ultra-low energy natural or mixed-mode ventilation solutions to areas not requiring close control, through careful design of building fabric, form and orientation.

Savings opportunities in existing facilities are likely to come from upgrading components and optimising the control of existing mechanical ventilation systems that may be quite old and inefficient. Typical opportunities are listed below. The potential savings, practical viability and resulting paybacks for these measures will vary considerably, depending upon the scope and scale of application, but the following measures are ordered in a typical hierarchy for consideration (starting with the generally low-cost measures first):

- Make sure filters in AHUs are changed regularly as part of PPM and that any excessively dirty filters are always changed even if this is before normal scheduled replacement.
- Retrofit low pressure drop filters in AHUs.
- Minimise duct air leakage - ensure duct access panels are properly fitted and any commissioning holes used for pitot tubes properly plugged.
- Ensure supply ducts and return air ducts (where air is recirculated) are thermally insulated or insulation repaired and upgraded where damaged.
- Replace existing v-belts and pulleys with cogged/synchronous belts.
- Provide effectively controlled free cooling wherever possible, particularly those controlling outside air supplied for heating and cooling in AHUs. Ensure dampers are not stuck, or incorrectly controlled. Consider review of operation so that only the minimum amount of outside air is cooled or heated.
- Retrofit low energy motors - electronically commutated or direct current may be possible.
- Retrofit VSD to existing motors.
- Retrofit low energy plug fans.

This is not an exhaustive list, and these measures would be considered alongside some of the controls and energy recovery measures mentioned elsewhere.

Some of the impacts to HVAC system design and operation following the recent SARS-CoV-2 (COVID-19) pandemic has been previously identified, and the guidance published by CIBSE highlighted. Designers of ventilation systems will need to refer to this alongside REHVA (Federation of European Heating, Ventilation and Air Conditioning Associations) COVID-19 guidance [**https://www.rehva.eu/activities/covid-19-guidance?no_cache=1**] as well as the most contemporary and emerging advice from NHS England & NHS Improvement.

10. HVAC controls

Controls for HVAC are linked to improvements in BMS which is detailed in the BMS section of this guide. In general, efficient HVAC controls rely on the following factors:

- Appropriate Zoning - ensuring areas have as local a control as possible. Ensure that AHU, duct and room control sensors are located in representative positions for the services being controlled.
- Optimising start and stop - ensuring systems can be switched off or set-back to back-ground operation when areas are not in use and that they can be activated in good time to achieve comfort conditions following setback or periods of deactivation.
- Avoiding simultaneous heating and cooling - avoiding the possibility of two separate systems heating and cooling the same space at the same time.
- Controlling ventilation - uncontrolled ventilation from draughts through poor fabric, or in appropriate

opening of windows and doors will affect efficiency of both heating and cooling controls within a space.

References

- ***HTM 03-01: Specialised ventilation for healthcare premises***
- ***HTM 07-02 Encode 2015 - making energy work in healthcare***
- ***CIBSE Guide F - Energy Efficiency in Buildings***
- ***Carbon Trust Guide "How to add adiabatic cooling to your refrigeration plant"***
- ***Carbon Trust Guide "Heat recovery - A guide to key systems and applications"***

Fabric Insulation

KEY FEATURES

- ➤ Enables the Trust to reduce energy costs and increase safety
- ➤ Reduces capacity of heat generation required
- ➤ Increases staff and patient comfort levels.
- ➤ Reduces burn/scalding risk of bare pipework
- ➤ Reduces plantroom and pipe duct temperatures
- ➤ Increases lifetime of other plantroom equipment through reduced temperatures.

1. Introduction

Many types of fabric insulation will exist in a hospital. This guide focuses specifically on:

- building fabric insulation, which is used to achieve thermal separation between inside and outside spaces, and includes wall, floor and roof insulation.
- plant and pipework insulation, which refers to the insulation of heating and cooling systems with appropriate materials.

Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare refers to a fabric-first approach to energy efficiency. This helps to improve the effectiveness of energy-efficient refurbishments, increases energy savings and improves thermal comfort. It can also reduce the size, and therefore cost, of new heat generation equipment. For building fabric, typical economic retrofit upgrades are loft insulation and cavity wall insulation. In general, all easily accessible uninsulated building elements or plant/pipework are worthy of detailed assessment. For heating or cooling systems, all uninsulated plant or pipework should be considered for insulation.

2. Initial assessment

Buildings typically conform to the building standards/regulations required at the time of their construction. Therefore, unless there is evidence to the contrary, the minimum thermal insulation levels required at that time should be assumed. Building fabric thermal insulation upgrades will require careful planning and consideration to ensure compliance with building regulations, smooth installation and no detrimental effects.

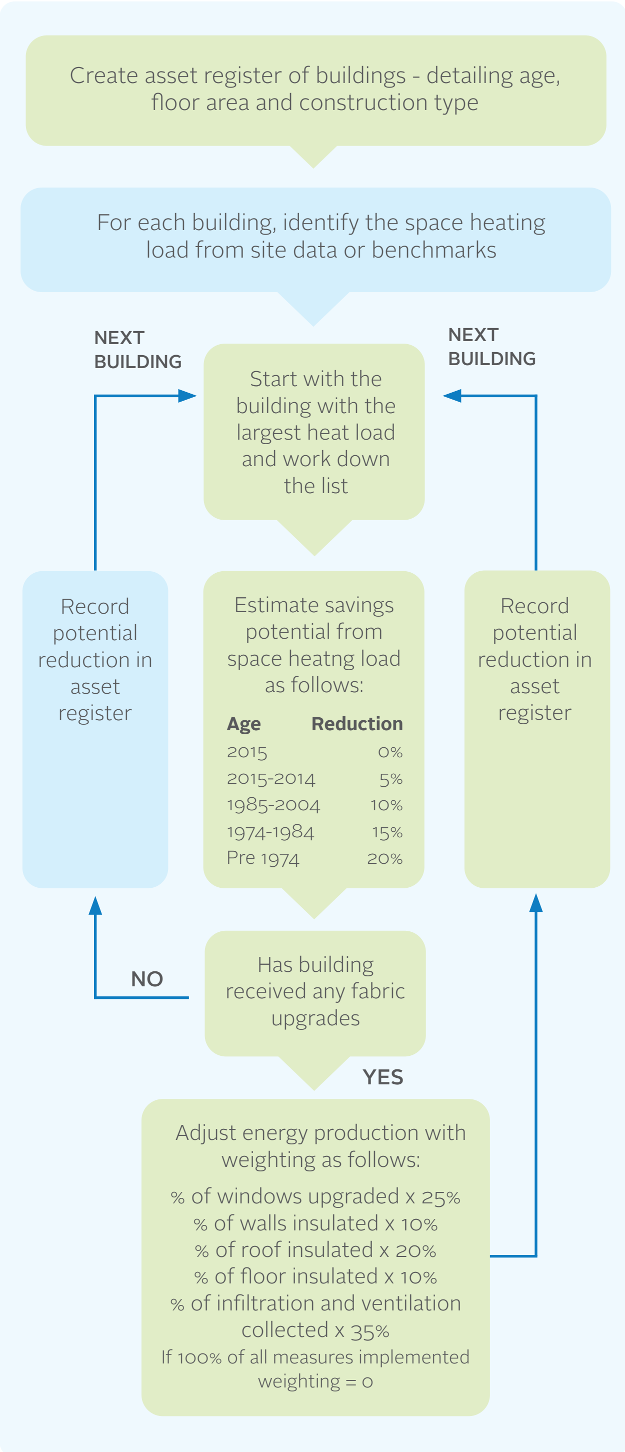
There are several factors that can influence the thermal performance of a building as follows:

- **Building age.** Building regulations and construction standards have changed significantly over time. Although some buildings may have been retrofitted there are likely to be elements that are difficult or not cost-effective to upgrade. An initial assessment of the building age will give an indication of the original thermal insulation levels.
- **Construction type.** An assessment of the construction types can give an indication of insulation upgrade potential. For example, a cavity wall constructed before 1985 is unlikely to have been insulated during construction.
- **Improvement works already undertaken.** This may or may not be obvious from visual inspection, so it is always best to consult the relevant person or department about upgrade works that might have already been undertaken to improve insulation levels. For example: cavity walls may have been filled. An indication of this would be holes drilled at regular intervals across the whole wall. Alternatively, internal or external wall insulation may have been installed. If any flat roofs have been replaced or overlaid, they may also have incorporated insulation.

Establishing existing insulation levels. It will not usually be possible to confirm insulation levels from visual inspection (except for loft insulation). Sources of information include:

- building construction information.
- inspection during other works, such as viewing wall constructions during window replacement.
- thermal imaging cameras, which may be useful in identifying poorly insulated or uninsulated areas.
- endoscope surveys of enclosed spaces such as cavities and flat roof structures.

Building fabric assessment. The chart below shows a process a Trust might follow to quickly assess whether a detailed feasibility study of building fabric insulation is worthwhile. The method shown below provides a rough estimate to enable the Trust to decide which buildings should be prioritised for more detailed follow up.



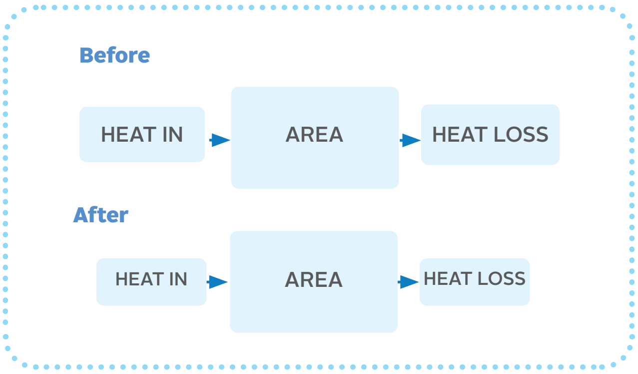
In addition to energy saving, the benefits of building fabric insulation can include improved comfort levels for staff and patients.

3. Detailed feasibility

Detailed feasibility is generally only required for building fabric measures, to ensure the correct specification and design of insulation systems. When progressing to detailed feasibility stage, it is important to engage with accredited insulation installers, who should carry out detailed inspections before providing accurate quotations. They should also be able to provide a guarantee on the works. Care is required in some cases to avoid thermal bridging and condensation issues. As with all feasibility studies, the accuracy of the information will determine the accuracy of the result. If there is no accurate information regarding current building construction, and this cannot be determined through other methods, then the results can only be based on best estimates.

4. Calculating savings

The financial savings associated with building fabric insulation are based on the reduction in heat losses, using the cost per unit of heat generated as shown in the diagrams below. There will also be associated carbon savings.



A worked example of the cost and carbon savings is shown below.

Cost savings	**Before insulation**	**After insulation**
Heat loss (kWh)	1,000,000	150,000
Boiler efficiency	70%	70%
Heat loss associated gas consumption (kWh)	1,428,571	214,286
Unit cost of gas (p/kWh)	2.3	2.3
Total cost of gas	£32,857	£4,928
Total cost saving	**£27,929**	

Cost savings	**Before insulation**	**After insulation**
Heat loss associated gas consumption (kWh)	1,428,571	214,286
Carbon factor for gas (kg/kWh)	0.18387	0.18387
Total carbon emitted (tonnes)	263	39
Carbon saved	223	
Capital cost	**£100,000**	
Simple payback (years)	4.1	

References

- ***Health Technical Memorandum 07-02: EnCO2de 2015 - making energy work in healthcare***
- ***FEB08 Economic Thickness of Insulation for Hot Pipes 1993 rep 1996***
- ***Carbon Trust Guide ctl176 - how to implement cavity wall insulation***
- ***Carbon Trust Guide ctl178 - how to implement roof insulation***

Heat Distribution and Boilers

KEY FEATURES

- Replacement of life expired plant can improve resilience and generate cost savings
- System upgrades can generate significant increases in efficiency
- Older steam systems can in some cases be upgraded and retained
- Gas costs can typically reduce by up to 10%
- Carbon savings can be typically around 10%
- Alignment to energy strategy is essential to maximise opportunities.

1. Introduction

Heating systems in hospitals, whilst following the same key principles, are implemented in a wide variety of configurations across the NHS. Unlike the other sections of this document, heating systems apply in some form or another in almost all hospital buildings. It is simply essential to have a firm grasp of the current design of the heating system when determining a new energy scheme for a hospital. There are three main types of primary heat distribution as follows:

- **Decentralised plant.** This is where each building is heated by its own boiler(s). In such configurations, it is not unusual for the LTHW generated by the boiler to be directly used in heating circuits within the hospital (i.e. a single hydraulic system). Decentralised heat generation is almost always at LTHW level. Decentralised plant makes for simple extensions of the estate but requires significant maintenance of assets spread across a wide area. For example, a medium sized decentralised hospital site can have around 100 separate boilers. It is also challenging to provide site resilience since to achieve N+1 for fuel supply the site would need to provide two fuels to each boiler (typically gas and oil) and this can prove problematic to implement at individual building level. Decentralised plant also cannot easily integrate with site wide efficient generation technologies such as CHP or low carbon technologies such as biomass. However, in some instances a decentralised heat pump solution might be well suited. It wouldn't require the capital cost of recentralising, whilst still providing resilience through backup generation. However, consideration would be required to increase the capacity of backup generation to meet the additional power requirements.

  In addition to wet heating systems, some buildings can have independent electric heating with either storage heaters or heat pumps (see separate section on heat pumps). This is common for temporary buildings, although some temporary buildings can end up becoming permanent site features. Storage heaters in particular can be very expensive to operate since, at the current time, electricity is typically 4-5 times more expensive than gas.

- **Centralised plant, Hot Water.** Centralised Low Temperature Hot Water (LTHW), Medium Temperature Hot Water (MTHW), and High Temperature Hot Water (HTHW) are all systems that generate hot water in boilers that is then pumped to site. The systems have flow and return pipework and use pumps to circulate the water. The water produced in the boilers is distributed in primary circulation pipework to plate heat exchangers that heat water in secondary circuits, usually at LTHW. The secondary circuits then route hot water to radiators, fan coil units, DHW systems, etc.

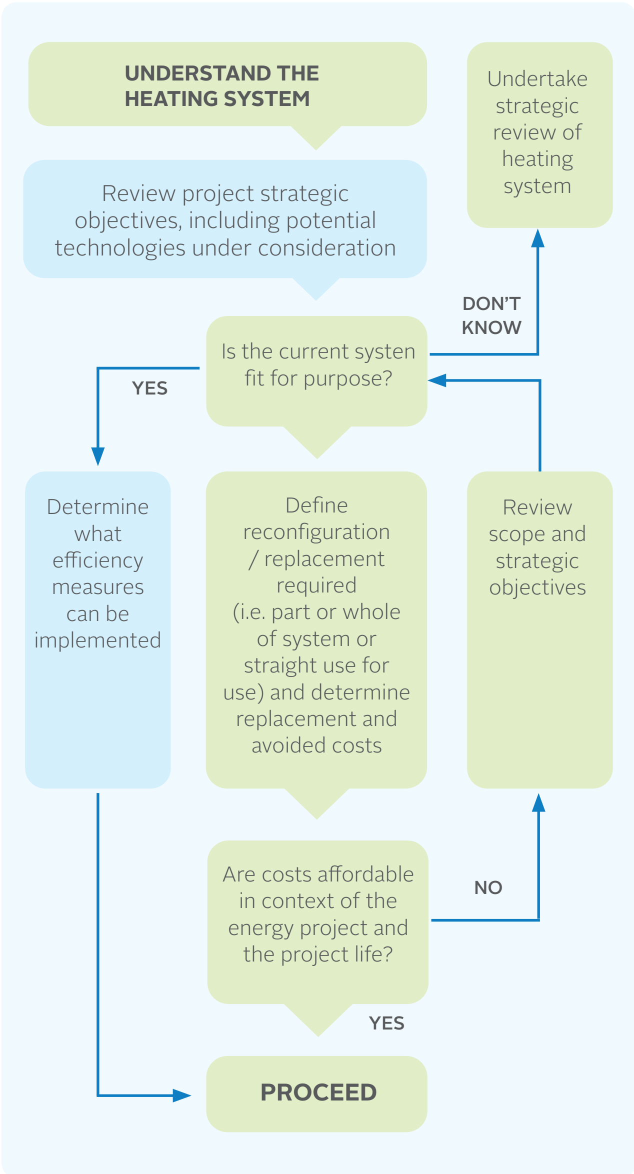
  Some hospitals use secondary hot water for air handling units, although some use water direct from the primary heating circuits. MTHW and HTHW both fall within the Pressure Systems Safety Regulations, 2000 and are subject to the required periodic inspection. They therefore have higher running costs than LTHW, although they operate at higher temperature differentials so generally require smaller pipework and heat exchangers. Due to oversizing of pipework and plant, it is possible that some MTHW systems maybe converted to LTHW without the investment of a wholesale replacement, while in other cases conversion may potentially increase pipe flowrates and lead to increased pumping energy. Generally, there should still be an overall energy and cost reduction, compared to operating at MTHW. Furthermore, reducing the operating temperature to LTHW will then make the system suitable for integration with future low carbon technologies along with delivering immediate reduction in energy losses.

- **Centralised plant, Steam.** Steam systems generate steam in boilers that is distributed to calorifiers or plate heat exchangers, which convert it to secondary LTHW for radiators, fan-coil units and DHW systems. It is less usual for air-handling units to have steam heater batteries, with most tending to use LTHW batteries fed from secondary circuits. Steam can also be used for processes such as sterilisation or laundries. Like MTHW and HTHW, Steam falls within PSSR, 2000.

  In practice sites might have a mix of two or all three of the above. LTHW or MTHW sites might have some steam generation for processes (such as CSSD or humidification), or a steam site might have some buildings that were developed later with their own independent boilers. The NHS provides a rich and diverse mix of heating infrastructure across its estate, which has evolved over many decades of progressive development and expansion. However, in looking to the future it is important to consider that the ultra-efficient low carbon technologies of tomorrow will more than likely require integration with low temperature systems. It is therefore important to take this into account when looking to make significant investment in heat distribution infrastructure.

2. Initial assessment

The first step is to establish what buildings are supplied in what way, what the volumes of fuel and heat demand are for each area served by a heat source and how efficiently each area is operating. Attention should then turn to the strategic direction of the project and the energy technologies being considered, since this could affect the future design of the heating system; and the current design of the heating system could affect the type of energy project possible today. However, when applying a staged approach to achieving net-zero, it maybe that particular energy-generation technologies are selected to maximise savings that are simultaneously invested in preparing the distribution for future low temperature technologies. If the current system meets the requirements of the project today and in the future, then the focus should be to review where efficiency improvements can be implemented. If the system does not meet the project requirements, then the necessary changes need to be identified and costed. This could be as simple as needing to replace certain assets on a like-for-like basis, where they have reached end of life, or a more significant reconfiguration. Costs should not only include capital but also seek to identify avoided costs. Once costed they need to be evaluated in the project costs and benefit analysis to establish if the changes required still generate the outputs desired over the life of the project. If they do, then the project can proceed. This is summarised in the process flow chart below.



Some key questions to ask at this stage are shown in the table below.

How old are the components of the system and what is their remaining economic life?	If a system is over 25 years old and past the end of its economic life, consideration should be given to either full or partial replacement. General inspection of the system will give some indication of its state of repair and highlight areas that give cause for concern. Testing pipework thickness can indicate the level of wear and which pipe runs need replacing.
What is the efficiency of the system?	An assessment of boiler seasonal efficiency will give an indication of how well boilers have been maintained. Visual inspection of the distribution system pipework will, together with records of maintenance and operation, give an indication of the efficiency of the distribution system. It is also worth checking gas consumption against degree-days to get an understanding of how closely demand follows gas consumption. Combustion efficiency test sheets in maintenance records can also provide supporting evidence. However, the best method is to heat meters which can also aid energy management and ongoing performance measurement.
How well does the system match the heat demand requirements of the site?	During the life of a heat distribution system, a Trust site can undergo many changes. For example, demand on the energy centre and associated systems may be reduced if laundry facilities are outsourced, or changes made to the site footprint. This can result in plant being significantly oversized, with a very low seasonal efficiency. Alternatively, the site may have expanded and therefore the requirement for resilience may be compromised.

Some scenarios

Below are some sample scenarios, drawn from experience on NHS sites. They are not exhaustive, but aim to give some examples of the permutations that Trusts might find.

- A site with a new building with its own boilers could benefit from being brought onto an existing LTHW network to take advantage of heat from new low carbon heat generation.
- A site with an existing steam system could benefit from de-steaming one or two major plant rooms to create demand for low-grade heat from a new heat led carbon efficient CHP system or other low temperature carbon efficient heat generation.
- A steam site at end of life could be considered for conversion to LTHW. However, all the air handling units have steam heater batteries so conversion to LTHW requires changing all the AHUs, which is expensive. However, there are extensive costs in maintaining the AHUs and when factoring these into the business case along with the replacement cost of the AHU plant, which is also at end of life, so it presents an excellent opportunity to convert to LTHW.
- A steam site is at end of life (mains, condensate return, calorifiers, traps and boilers). It only supplies four major plant rooms along a central corridor and from those plant rooms heat is circulated as LTHW. It is therefore cost effective to convert to LTHW and integrate CHP.
- A decentralised site has over 100 individual gas boilers that are approaching end of life. They are costly to maintain and do not have N+1 resilience for fuel. They are also old and inefficient. The key strategic driver is to improve resilience. The site used to have an MTHW network and has a network of empty underground ducts. It is therefore cost effective to reinstate as an LTHW system using the existing ductwork.
- A site was designed with steam heat distribution in the 1970's. The system has been well maintained but is not very efficient. The system can be upgraded with modern controls and flue gas economisers to enhance efficiency, along with upgrades to insulation. However, whilst this will drive improvements today that only require minimal capital investment, the site is likely to need to consider more extensive system replacement in future years.
- A hospital was built in three phases, each with its own energy centre. Each energy centre provides LTHW and

now the heat generating plant is approaching end of life. Energy efficient heat generating technologies have proven difficult to implement as each energy centre is too small to provide sufficient heat load. This presents an opportunity to couple all three phases together to improve resilience and enable energy efficient heat generating technologies to be included.

3. Steam distribution systems

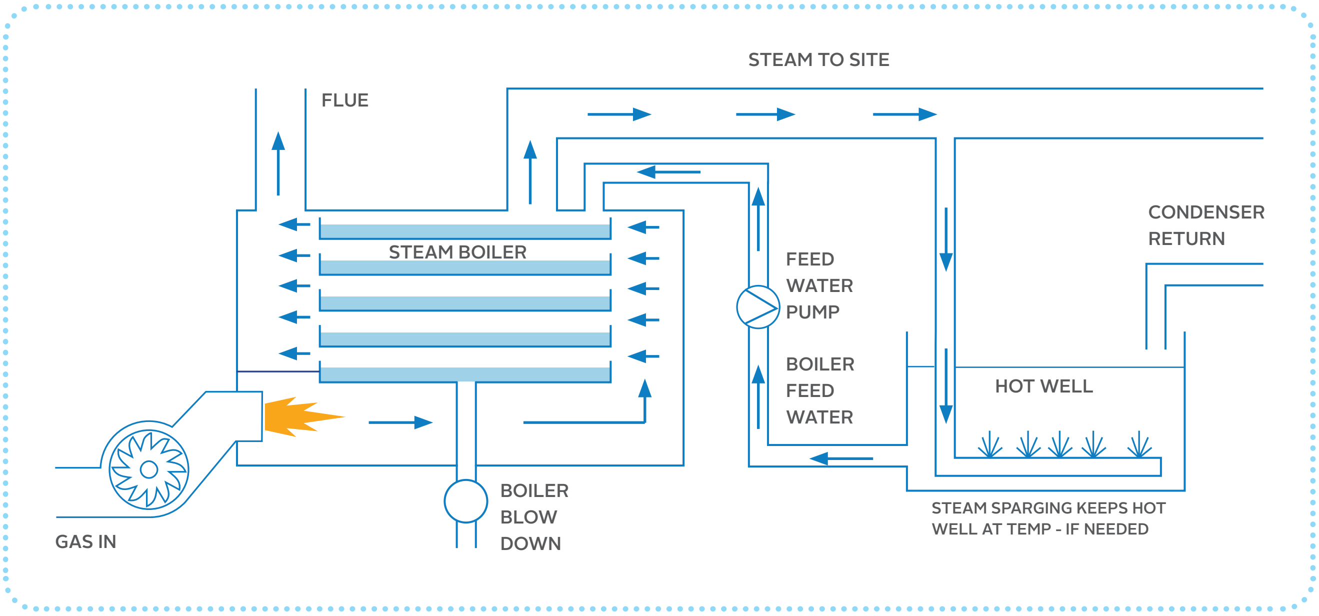
Steam systems form an integral part of many hospitals; distributing heat energy for space heating, hot water and processes such as laundries and sterilisers. Heat distribution with steam is a well-established process and, when properly maintained and operated, provides a reasonably efficient means of heat distribution across a healthcare estate. New hospital sites now tend to be designed with either Low or Medium temperature distribution systems; the former having higher net efficiency combined with lower operation and maintenance costs. However, replacement of a hospital's entire steam system can be very invasive, disruptive and costly and the risks of losing service during the works need to be managed carefully. However, there are many examples where hospitals have successfully converted from steam to LTHW. In some scenarios it maybe cost effective to upgrade and improve the existing system; it all depends on the condition of the current equipment and complexity of the installation.

The typical life expectancy of steam infrastructure for a hospital is 25 years, although there are many examples of systems which are still operating effectively, long past the expected life. There are also examples of systems that are in such poor condition that it might be more expensive to repair and upgrade than to replace. Investigation is required as to whether the hospital would benefit from infrastructure upgrade, in whole or in part.

How does a steam system work?

On first inspection, steam systems can appear more complex than low temperature hot water systems, and in some respects, they are; however, they can be broken down into a series of simple stages. It is important to note that steam systems operate at high pressure, usually between 5barg and 10 barg (barg is short for bar gauge, the measure of pressure shown on the pressure gauge, accounting for atmospheric pressure at 1 bar). Steam systems therefore fall within the Pressure Systems Safety Regulations, 2000. The following diagram below gives a simple schematic of a natural gas fired steam system.

Steam systems are generally considered to be closed loop, i.e. all the steam generated by the energy centre returns to the energy centre as hot condensate stored in the feed water storage tank (commonly referred to as a hotwell) until returning to the boiler to be converted back to steam. Systems are never perfectly efficient and there will be some losses and leaks. In some instances, process equipment might consume steam without providing a condensate return; however, these cases are less common.



The hotwell must be maintained at an appropriate temperature (~85degC to 90degC), which is regulated by injecting steam to maintain temperature. Hotwell level is maintained through returning condensate and top up, where required, from cold top-up water. The design of hotwells is in fact more complex than described here, as it is also a critical part of the process for managing water quality and oxygen content, however that is not covered in this guide. For detailed information on hotwells see links in the reference section at the end of this chapter.

Requirement for steam is determined by measuring the pressure of steam in the steam main. As the site demands steam, through condensation in calorifiers and plate heat exchangers, the steam pressure reduces and the boiler control system will turn on and regulate one or more boilers to ensure the pressure level is maintained within specified set-points.

Increasing steam boiler efficiency
A steam boiler is essentially a large pressure vessel containing a body of water. The water is heated by combustion gases from the boiler passing through the tubes within the body of water, that transfers heat from the flue gases into the water. There are several operating parameters of the boiler that need to be considered, all of which have an impact on its efficiency. These are as follows.

- **Level control.** The level of water in the boiler must be maintained between pre-determined high and low levels. If the level becomes too low, the heating surfaces could become exposed and the boiler over heat; if the level becomes too high, hot water could be carried over into the steam main, causing poor steam quality and early deterioration of downstream equipment. There are two types of level control for steam boilers, on/off control and modulating control. On/off control systems use level switches to determine the point at which the feedwater pump turns on and when it turns off. This means the boiler will evaporate a volume of water to a set level at which the pump will turn on and supply water to the boiler. The pump will continue to operate until a set water level is reached, when it will turn off. Even with feedwater at 90 degC, filling the boiler with a batch of cooler water disrupts the boilers equilibrium and its efficiency (in a similar way to topping up an already boiled kettle with a cup of cold water).

  A modulating system uses a level sensor coupled to a variable speed feed pump. The boiler is fed feed-water on a continual basis, in proportion to the steam demand. This helps the boiler maintain an equilibrium and increase the efficiency.

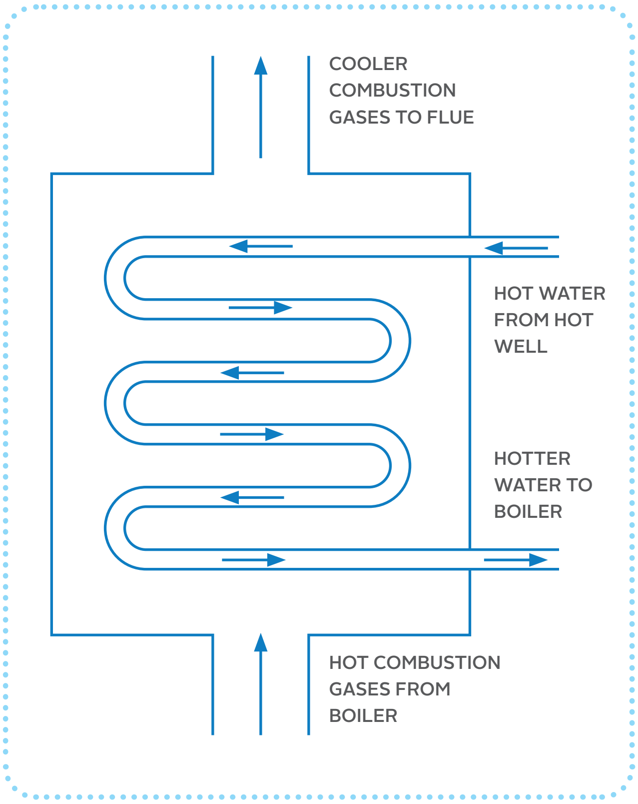
- **Water quality.** Steam boilers must maintain the total dissolved solids (TDS) content of the water in the boiler, to a given tolerance. Just like in a kettle, as water boils and turns to steam it leaves deposits behind in the water that 'fur up' the kettle or boiler. Even treated water used in steam systems contains a small amount of TDS and, if left unchecked, results in build up within the boiler causing inefficiency in heat transfer and premature aging of the plant. Traditional TDS control involves periodic opening of the blow-down valve on the bottom of the boiler for a given time to let out some of the water. This allows new clean water to enter the steam system but also causes a loss of heat energy in the form of hot-water that is discharged to the drain. A key issue of this method is that the boiler might be blown-down when the TDS level is acceptable or blown-down for too long. An automated TDS and blow-down control system monitors the TDS level and opens the valve automatically when necessary to maintain the TDS within a specified tolerance. Furthermore, heat recovery equipment can be installed to recover energy in the blow-down water and return it to the hotwell.

  Make up water that is supplied to the hotwell must be suitably treated to ensure it meets exacting standards and does not introduce impurities into the steam system that would otherwise cause deterioration of the steam plant and subsequent loss of efficiency. Water softeners and reverse osmosis water treatment plant are typically employed for this purpose. Regular testing of the water quality is therefore important along with any corrective measures to ensure a long life of steam energy assets. Water quality should be compliant with BS EN 12953 Part 10.

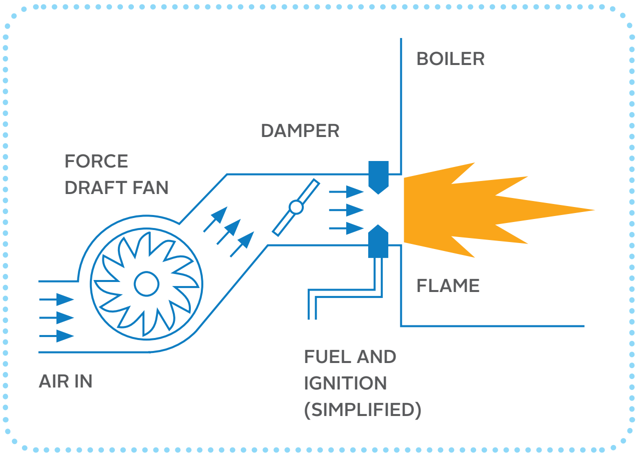
- **Combustion quality.** It is essential that the boiler burner is controlled such that all the fuel consumed is fully combusted to gain the maximum conversion efficiency from input fuel. Older systems rely on pre-set air/fuel ratio for different firing levels which are set at commissioning and subsequent service intervals. However, gas quality and calorific value can change throughout the year, meaning such settings may not represent the optimum in efficiency. Systems can be upgraded to continually monitor the oxygen content of the flue gases with a sensor known as a lambda sensor and associated combustion controls. The system monitors the oxygen content and automatically regulates the air/fuel ratio to ensure that combustion is continually optimised.

There are also some other measures that can be implemented on steam boilers as follows:

- **Flue gas economiser.** A flue gas economiser captures some of the heat present in the exhaust gases from the boiler and uses them to raise the temperature of the boiler feed water. A flue gas economiser can usually achieve efficiency gains of around 4%, depending on the temperature of the water from the hotwell. The diagram below shows a simple schematic of operation of a flue gas economiser.



- **Variable speed force draft (FD) fan.** The force draft (FD) fan provides combustion air to the boiler. On older boilers, fans tend to operate a single speed with an actuator-controlled damper regulating the flow of air into the boiler. This means that as the requirement for air reduces, the fan works against a progressively closing plate. The relationship between a fans speed and power is the cube law. This means that a 20% reduction in speed equates to a 51% reduction in power. Therefore, removing the damper and fitting a variable speed drive (provided the boiler controls can accommodate it) produces significant savings in fan power consumption.

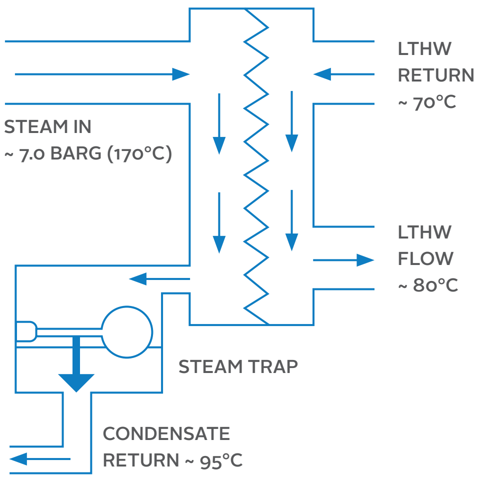


Increasing steam distribution efficiency. There is a variety of down-stream steam equipment used in hospitals. The main items include steam and condensate return pipework, heat-exchangers such as a calorifiers or plate heat exchangers, steam traps and condensate return equipment including condensate receivers and pumps.

Steam mains and condensate return pipes. Steam pipe work can often appear to be in poor condition, particularly if it is an older installation. It is not uncommon for contractors or site engineers to overlook reinstallation of insulation after a repair and for ducts to have evidence of leaks and high temperatures that reinforce suspicion of leaking pipes and degrading pipe lagging. However, evidence suggests that steam mains, even at 30 or 40 years old, can still be in good serviceable condition and pipe condition can be established through non-destructive testing techniques. Condensate return systems and steam traps usually tend to be more problematic; however, it can still be cost effective to replace insulation and refresh the condensate return system, resulting in a system that is fit for purpose for years to come and generating utility cost savings.

Heat exchangers. There are three main types of steam heat exchanger used in hospitals; storage calorifiers, non-storage calorifiers and plate heat exchangers. The principle of heat transfer is broadly the same in all types. Steam entering the primary side of the heat exchanger will condense on the cooler internal heat transfer surfaces, transferring energy to the secondary side medium, usually LTHW. The condensate is then collected at the bottom in the steam trap and returned to the energy centre. The incoming secondary LTHW is heated by the transfer of steam energy and leaves the heat exchanger at a higher temperature. For storage calorifiers' the heat transferred is used to heat a stored volume of water, which is drawn off as required. These are more commonly deployed for domestic-hot-water supply.

STEAM TO LTHW PLATE HEAT EXCHANGER



All steam heat exchangers require annual inspection under the PSSR 2000. Good quality water treatment is essential to ensure the heat transfer surfaces remain in good condition with optimum efficiency in heat transfer. Lagging of all heat exchangers is essential to minimise losses.

Steam traps. Steam traps are a common point of failure and subsequent inefficiency in steam systems. The steam trap is a valve that allows condensate to pass, but not steam. Should steam pass the trap then the steam energy is lost and mechanical damage can occur to condensate return equipment beyond the trap; this results in poor reliability and potentially costly repairs. There are several types of steam traps but all are mechanical devices, so can be prone to failure.

Regular checking of all steam traps is essential to identify and resolve problems promptly. One method to establish if steam traps are working correctly is with an ultrasonic probe. There are companies who provide a steam trap survey service or alternatively the Trust could purchase their own test equipment (around £2,600) and undertake the testing in-house. Alternatively, there are real-time testing solutions that clamp to the steam trap's condensate outlet. These systems connect wirelessly and highlight issues as soon as they arise. Finally, good water treatment is essential to reliable performance of steam traps.

Condensate receivers and pumps. Condensate from steam traps is usually fed to condensate receivers in convenient locations across site from where it is then pumped back to the energy centre. Ensuring condensate receiver systems are kept in good working order with suitable lagging will minimise unnecessary energy loss. Also, regular steam trap inspection and maintenance will help extend the efficient operation of this plant.

4. Hot water distribution systems

Heat distribution with hot water is likely to be present in all hospitals in some form or another, even if it is just on the secondary distribution system. There are three types of hot-water distribution:

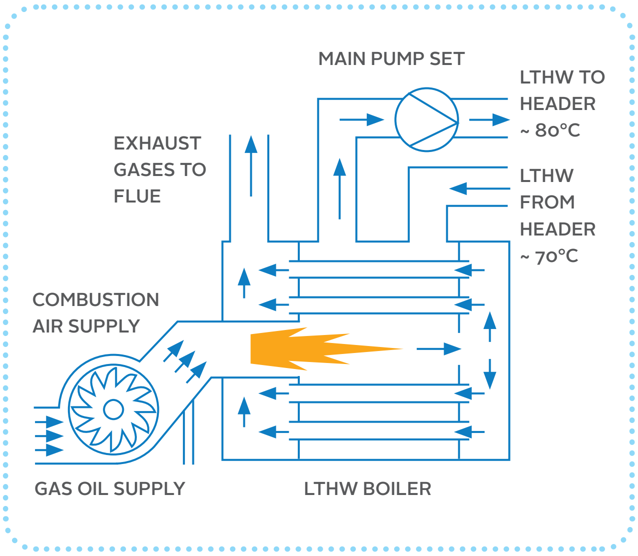
- Low Temperature Hot Water (LTHW) - ~80degC flow /70 degC return.
- Medium Temperature Hot Water (MTHW) ~120degC flow/90 degC return.
- High Temperature Hot Water (HTHW) ~ > 170 degC flow.

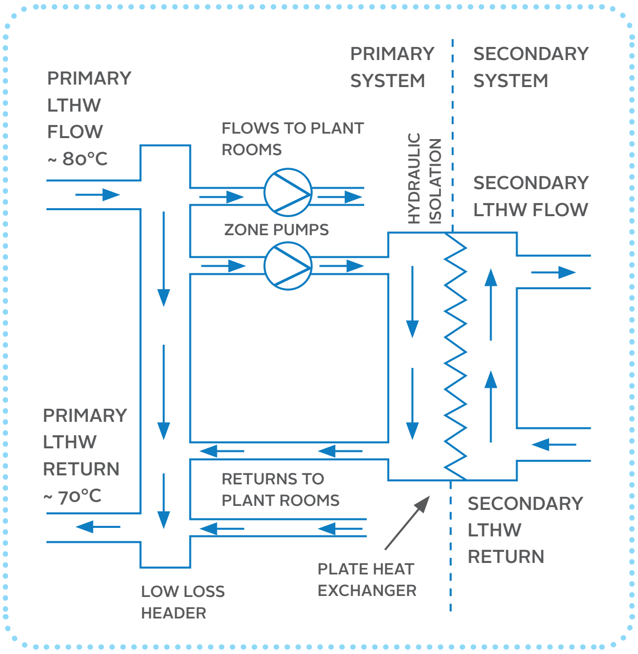
Hot water distribution systems are, in general, simpler than steam systems, especially LTHW that operates at low pressure and therefore not covered by the PSSR 2000 and its associated requirements. This guide does not cover HTHW systems as, although they are present in a few hospitals, they are rare and require specialist consideration due to the very high operating pressures.

As the absolute temperature, the temperature differential and therefore the pressure all reduce, the energy contained within the body of water also reduces. This means that to distribute the same quantum of energy, a lower temperature differential system requires larger distribution infrastructure.

For example, 10kg of saturated steam at 7 barg contains around 5.6 kWh of useful heat energy, whereas 10kg of hot water flowing at 80 deg C and returning at 70 deg C contains 0.11kWh of useful heat energy. Therefore, an LTHW system needs to circulate much larger quantities of water to achieve the same heat transfer and as such pipework and equipment is larger. However, a key benefit of an LTHW system is that the lower temperature results in lower losses and higher overall system efficiency. LTHW systems can also be operated at even lower temperatures than the traditional 80/70degC that make them particularly well suited to low carbon heat generation from technologies such as heat pumps.

How do hot water primary systems work? The key components in most hot water primary distribution system are the boilers, circulation pumps and headers. The diagram below shows a simple schematic of a boiler system. Most boilers follow the shell and tube design, with hot combustion gases passing through tubes. Return water flows over the outside of the tubes picking up heat which is then returned to distribution system. The burner, mounted on the front of the boiler is usually dual fuel (gas and oil) to provide fuel resilience. A boiler control system is provided to regulate combustion and temperatures. A boiler circulation pump-set circulates water to the main header, where it combines with hot water from other boilers and is distributed to site. A boiler sequencer or BMS system will oversee the distribution system demands and determine which boilers should be firing to meet the load. A high-level schematic is shown below.





The Non-Domestic Building Services Compliance Guide recommends the following minimum efficiency standards for boilers. Increased seasonal efficiencies of new boilers mean that when Trusts replace an ageing boiler, they will secure cost and energy reductions as well as improved resilience.

Thermal efficiency is the ratio of heat output to fuel input, shown as a percentage. Seasonal efficiency is the weighted average of efficiency for a given boiler provided by the manufacturer, and described in CIBSE Commissioning Code B. This is different from actual thermal efficiency. To measure actual boiler efficiency, Trusts should measure heat output and fuel input over at least a year or, if not possible, at least a month, at half-hourly frequency.

Low loss headers are now commonplace in hot water heat distribution systems and enable the correct flow rates to be maintained through boiler plant while not affecting the flow requirements of secondary systems.

The diagram shows a high-level arrangement of a low loss header with primary flow and return from the boiler plant with zone pumps providing supply to a plate heat exchanger. The heat exchanger provides hydraulic separation for secondary side circuits. Plate heat exchangers generally have an approach temperature of around 5 deg C. For example, if it is supplied with hot water on the primary side at 85 degC, the highest temperature produced on the secondary side will be around 80 degC.

Recommended minimum energy efficiency standards for building services

Gas, oil and biomass-fired boilers: new buildings		**Seasonal efficiency** (gross)	
Natural gas	Single-boiler system ≤ 2MW output	91%	
	Single-boiler system > 2MW output	86%	
	Multiple-boiler system	82% for any individual boiler	
		86% for overall multi-boiler system	
LPG	Single-boiler system ≤ 2MW output	93%	
	Single-boiler system > 2MW output	87%	
	Multiple-boiler system	82% for any individual boiler	
		87% for overall multi-boiler system	
Oil	Single-boiler system ≤ 2MW output	84%	
	Multiple-boiler system	82% for any individual boiler	
		84% for overall multi-boiler system	
Biomass - independent, automatic, pellet/woodchip		75%	
Gas, oil and biomass-fired boilers:		**Seasonal efficiency** (gross)	
existing buildings		**Actual**	**Effective**
Natural Gas		82%	84%
LPG		83%	85%
Oil		84%	86%
Biomass - independent, automatic, pellet/woodchip			75%

Increasing hot water boiler efficiency Hot water boilers do not have the inherent complexity of steam boilers and there are fewer opportunities for efficiency gains. For boilers approaching end of life it may be prudent to consider complete replacement, since the evidence suggests increases of ~20% in seasonal efficiency are achievable when replacing with the latest boiler technology. Interim measures that are worth considering where the core of an existing boiler is still in good condition are:

- Boiler lagging to reduce thermal losses from the casing.
- Replacement burners for modern efficient units.
- Variable speed boiler circulation pumps to reduce flow when boilers are at part load or switched off.
- Flue dampers to stop air flow through the boiler heat exchanger when it is not firing.
- Ensure air vents work properly and the system is properly vented to make sure heat circulation is not compromised and reduce risk of cavitation at pumps.

Increasing hot water distribution efficiency

Controls. The plate heat exchanger diagram above shows a simple illustration of a hot water distribution system. Systems, whilst following similar principles to that shown above, contain many actuators, controls, sensors, valves and pumps that ensure heat is delivered to the right place at the right time and the system is operated within the defined set-points. Systems are usually controlled by the site Building Management System (see chapter on BMS). The optimisation of the BMS system can realise significant savings through efficient control of the heat distribution system. For example, a site might have a very low temperature differential and consequent high pump flow rates. This consumes unnecessarily high quantities of electricity for pumping and the higher flow rate causes premature aging of the distribution plant. Reducing the flow rate through intelligent control can reduce energy consumption, improve reliability and equipment life.

Lagging. All equipment, such as valves, heat exchanger and pipework should be lagged to minimise heat loss. It is not uncommon to find lagging has not been replaced following system repair or maintenance activities and this can generate costly losses. Also leaks within pipework will cause the insulation to become ineffective and as such leaks should be repaired promptly, even if only small, since the heat loss arising from wet insulation around the pipe can be significant.

Water treatment. As with steam systems, effective water quality and treatment is essential to maintain hot water boilers and heat distribution systems at their optimum efficiency. Poor water quality results in build-up of deposits on the heat transfer surfaces that reduce performance and increases operating costs.

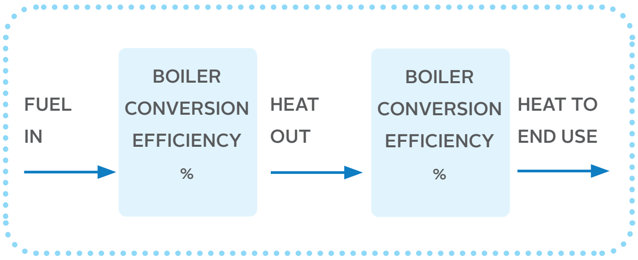
5. Considerations for de-steaming

Moving from steam to LTHW or MTHW can appear an attractive option for many Trusts, particularly those with older, inefficient plant considering co-generation projects or low-temperature technologies such as heat pumps. The table below summarises some of the criteria worth considering during evaluation.

Identified solution	Items considered
Remain with steam	• There is a significant steam process load on the site, e.g. laundry, sterilisation, kitchens. • The steam main is in relatively good condition with just some sections needing repair. • Steam is embedded deeper than just at calorifier rooms for each building, e.g. serves multiple air handling units.
Partial de-steam	• There is limited process load on site, which could be provided by smaller packaged steam boilers. • A centralised steam energy centre is maintained, but parts of the steam distribution system in poor condition are changed to LTHW or MTHW. • The change from steam to LTHW is in major plant rooms within the hospital.
Full de-steam	• Steam main is in a very poor condition and full replacement is required. • There are a limited number of plantrooms where calorifiers or heat exchangers need to be replaced, e.g. steam is not supplied to multiple air handling units. • Calorifiers or heat exchangers for steam to LTHW are in poor condition and need upgrading. • Ability to retain qualified personnel

6. Calculating savings

The economic and carbon benefits of steam systems replacement are shown below.



Calculating boiler efficiency improvements - The financial savings associated with improving boiler efficiency are based on a comparison between the difference in cost of running the old boiler and that of the new boiler. A worked example of the cost and carbon savings is shown below.

Cost savings	Old boilers	New boilers
Site heat demand (kWh)	20,000,000	20,000,000
Gas boiler efficiency	70%	86%
Annual gas consumption (kWh)	28,571,429	23,255,814
Unit cost of gas (p/kWh)	2.3	2.3
Total cost of gas	£657,143	£534,883
Total cost saving	**£122,260**	

Carbon savings	Old boilers	New boilers
Total gas consumed (kWh)	28,571,429	23,255,814
Carbon factor for gas (kg/kWh)	0.18387	0.18387
Total carbon emitted	5,253	4,276
Carbon saved	977	
Total cost saving	**18.60%**	

Calculating distribution efficiency improvement. The financial savings associated with improving distribution efficiency are therefore based on the difference in cost of running gas boilers to provide the same heat at different levels of system loss. A worked example of the cost and carbon savings is shown opposite.

7. Other considerations

To maximise seasonal boiler efficiency and minimise energy centre consumption, consideration should be given, during the detailed design phase, to:

- Metering requirements - effective metering can help identify any deterioration in boiler performance.
- Ensuring that all relevant pipework in the energy centre is insulated, particularly where existing pipework remains.
- Where the systems are LTHW or MTHW, investigating variable speed drives on circulation pumps, so that the pumps only have to deliver the volume of hot water around the site required to deliver heat.
- Specify comprehensive controls of the boilers, to prevent unnecessary firing or heat loss.

The Trust may also want to consider energy centre automation. BG01 is a joint publication by the Health and Safety Executive, the Combustion Engineering Association and the Safety Assessment Federation. It applies to boilers with working pressure between 0.5 and 32 barg and working temperature between 110 deg C and 400 deg C. It therefore covers both steam and MTHW systems.

Of note is the guidance relating to unmanned operation. BG01 sets out typical arrangements for boiler control equipment and the appropriate level of attendance. BG01 Typical Arrangement 3 represents the highest level of automation and sets out how a boiler control system can be implemented that enables the boilers to be visited and checked by a boiler operator once every three days. This can be relevant to Trusts considering third party operation of an energy centre or redeploying existing staff to other tasks.

Cost savings	**Old distribution system**	**Upgraded distribution system**
Site heat demand Including some distribution losses (kWh)	20,000,000	20,000,000
Distribution Losses that can be removed (kWh)	2,222,222	0
Total Heat Input to System (kWh)	22,222,222	20,000,000
Boiler Efficiency	70%	70%
Annual Gas Consumption (kWh)	31,746,032	£28,571,429
Unit cost of gas (p/kWh)	2.3	2.3
Total cost of gas	£730,158	£657,143
Total cost saving	**£73,015**	

Cost savings	**Old distribution system**	**Upgraded distribution system**
Total gas consumed (kWh)	31,746,032	28,571,429
Carbon factor for gas (kg/kWh)	0.18387	0.18387
Total carbon emitted (tonnes)	5,837	5,253
Carbon saved	584	
Carbon saved	**10.00%**	

References

- ***CIBSE Guide M*** *- http://www.cibse.org*
- ***Non-Domestic Building Services Compliance Guide*** *- https://www.gov.uk*
- ***CTV052 - Carbon Trust, Steam and high temperature hot water boilers*** *https://www.carbontrust.com*
- ***Steam Boiler Feedwater Storage Technology White Paper*** *http://www.spiraxsarco.com*
- ***BG01 - Guidance on Safe Operation of Boilers*** *http://www.cea.org.uk*
- ***Steam Tables*** *- http://www.spiraxsarco.com*
- ***Steam Boilers - The Inside Story: Part 1 - Introduction*** *https://youtu.be/azDyYDGWxbo*

DEMAND REDUCTION

LED Lighting

KEY FEATURES

- Swapping from conventional to LED lighting could save 5-20% of a Trust's electricity energy use
- Anticipated carbon savings of up to 45%. Almost all existing lamp types can be replaced or retrofitted
- Enhanced controls can save 2-5% of electricity energy used
- Payback periods typically 5-7 years but can be less.

1. Introduction

Lighting typically accounts for between 22% and 33% of total hospital electricity use. Swapping from conventional fluorescent lighting to LED could save from 24% to 62% on these loads. Advances in LED technology are rapid and the opportunities are likely to increase as the efficiency of LED improves. Hospital operational procedures may vary to a degree, but key lighting issues are:

- complying with NHS and hospital operational policy (usually driven by HTMs).
- maintaining specific environmental requirements to satisfy clinical processes and to achieve internal light levels that do not compromise life, safety or patient well-being.
- maintaining light levels for patient care and comfort, consistently throughout the day and night.
- ensuring that light levels enable both general and more specialised task processes to be carried out.

Another aspect to be considered is creating an environment that is visually satisfying and emotionally supportive. Good lighting can also help to promote a sense of quality and competence within a hospital. Three main components contribute to establishing the energy efficiency of lighting systems:

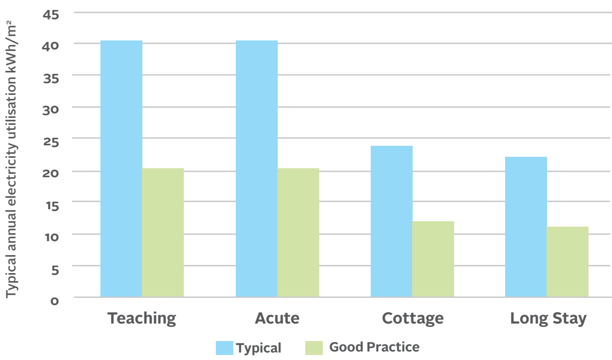
- lamp type, for which the rating is known or can be estimated.
- lighting levels required compared to achieved.
- type of controls.

Light level requirements. Guidance documents associated with hospital lighting include CIBSE Lighting Guide 2: Hospitals and health care buildings. CIBSE LG02 Table 1 & 2 general light schedule provides recommendations for the illuminance, switching and emergency lighting requirements for the many different departments and rooms in hospital and health care buildings. Light level requirements can vary significantly across a hospital building, as can the lighting levels achieved. This is illustrated from the typical measured illuminance levels for sample areas taken as part of the CEF measurement and verification process:

- Corridor: 100-300 lux.
- Consulting room: 2-1,000 lux.
- Operating room general: 1-2,000 lux.

Benchmarks. Typical lighting energy benchmarks for hospitals are published by CIBSE in TM46 and in CIBSE Guide F *Energy Efficiency in Buildings*. The graph below uses this CIBSE data to show the difference between 'typical' and 'best practice' lighting energy use in different types of hospital. The graph below uses this CIBSE data to show the difference between 'typical' and 'best practice' lighting energy use in different types of hospital.

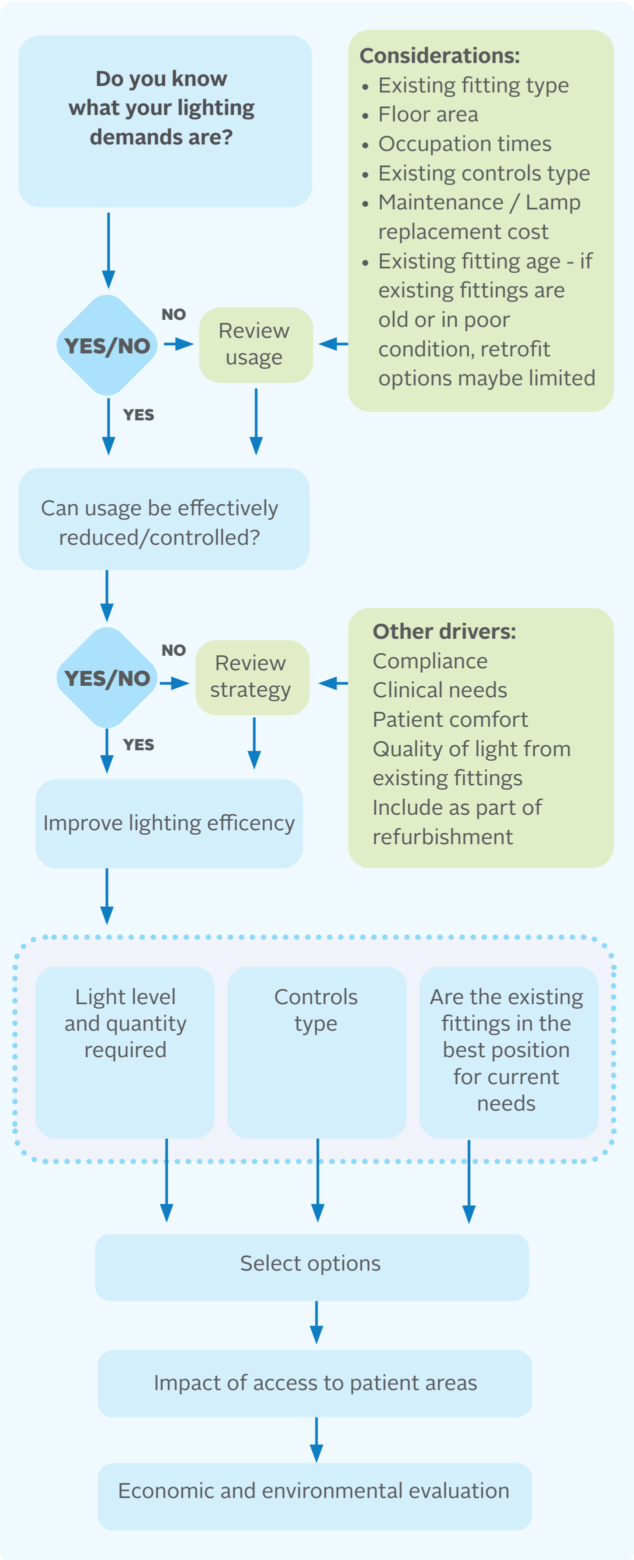
Comparison of 'typical' verses 'good practice' lighting electricity energy use



Source:CIBSE Guide F

2. Initial assessment

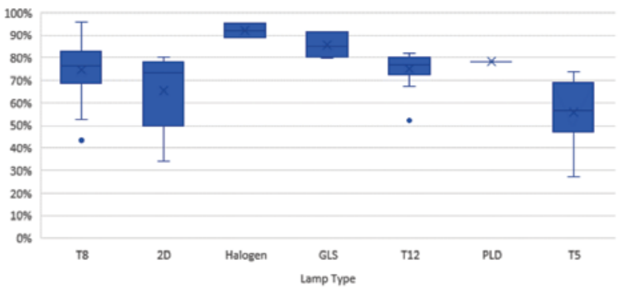
Before getting into a detailed feasibility study, an initial assessment should be carried out to establish the scale of opportunity for LED lighting upgrade. The chart below shows the process a Trust might follow in assessing energy savings options.



3. Savings potential based on lamp type

LED technology has become a reasonably established technology in recent years and it would be unusual now for a Trust not to have undertaken some conversion to LED lamps; although it is also likely that there will still be plenty of scope for further work. It is likely that someone in the estates team will know if LEDs have already been installed, and where. To calculate savings, a detailed assessment of existing fittings will need to be carried out. The main lighting types found in hospitals are described below. The range of lighting power savings achieved and confirmed through power testing for some sample CEF projects is shown in the chart below.

Range of savings achieved based on lamp type



Source: Carbon and Energy Fund

Fluorescent tube fittings. Most of hospital lights will be fluorescent tube fittings. They come in varying lengths, typically 2ft, 5ft or 6ft. Fittings can hold up to four tubes. The "T" value of a tube represents its diameter as a proportion of an eighth of an inch. Thus, a T12 fitting has diameter of 1.5inches, T8 has a diameter of 1 inch and a T5 has a diameter of 5/8 inch. Typically, the smaller the diameter, the more efficient the lamp. Using the following rules of thumb, the potential savings achieved by replacing fluorescent tubes with LED will be 62% for T12 tubes, 45% for T8 tubes, and 24% for T5 tubes.

Lighting consumption can be calculated using the benchmarks shown in the section introduction. If the building is predominantly lit by T5 fluorescent tubes, use the 'good practice' benchmark. For predominantly T8 fittings use the 'typical' benchmark.

Installation costs will vary considerably, but can be estimated using a payback period of 5 to 7 years.

Compact fluorescent lights (CFL). CFLs can be used in many different fittings. However, they are commonly used as corridor spot lights/downlights. These can be cost-effectively retrofitted with LED equivalents, saving between 50% and 70% of the energy consumed. In most instances, typical payback periods are less than 3 years.

Halogen spot lights. Halogen lamps are quite inefficient and can be retrofitted with LED equivalents, saving up to 80% and often providing payback periods of less than 1 year. The transformers of low voltage lamps may need replaced if converted to LED.

High-intensity discharge lamp. High-intensity discharge (HID) lamps are a type of electrical gas-discharge lamp that produces light by means of an electric arc between tungsten electrodes, housed inside a translucent or transparent fused quartz or fused alumina arc tube.

Various types of chemistry are used in the arc tubes of HID lamps, depending on the desired characteristics of light intensity, correlated colour temperature, colour rendering index (CRI), energy efficiency, and lifespan. Varieties of HID lamp include:

- Mercury-vapor lamps.
- Metal-halide (MH) lamps (SON).
- Sodium-vapor lamps (Low pressure/ High Pressure).

While HID lamps are generally very efficient they can have poor colour rendering and they do not work well with automatic controls, as they have long strike times. In many cases, these lamps can be retrofitted with LED equivalents without changing the fitting. This can save between 35% and 65% in energy consumption. When upgrading to LED, there may be opportunities to improve controls, for example introducing presence detection for car park lighting. The cost to retrofit depends on the location and whether access equipment is needed; even considering the cost of access equipment, payback periods can be within 5 years.

Halogen floodlights. Often used for security and car park lighting, halogen floodlights are inefficient. However, there is no LED retrofit option; the whole unit needs to be replaced. As with other exterior lights, the cost is affected by the location and whether access equipment is needed. However, savings of 80% in energy consumption can be achieved and, even considering the cost of access equipment, payback periods can be within 5 years.

Electromagnet ballast. Fluorescent tube fittings with electromagnet ballast (also known as switch starters) still exist on many hospital sites. These types of ballast consume more energy than modern, high frequency ballast. These can be recognised by small starter cylinders in the fitting along with flickering of the lamp as it is turned on. A fitting hole where ballast might be expected to be has probably been retrofitted with high-frequency ballasts.

4. Replace or retrofit?

The decision to replace the whole fitting or just retrofit the tube with LED equivalent will depend on several constraints. Typically, replacing the fitting will cost more, take more time and is likely to cause more disruption. In most cases, retrofitting the tube means simply replacing it, without the need for specialist contractors. The general exception to this is retrofitting tubes with electromagnet ballast, as these need to be removed before the LED lamp can be fitted. The table below highlights some pros and cons of each approach.

	Pro	Con
Retrofit	Cheaper Less intrusive and takes less time to install	Existing fittings need to be in good condition. Does not provide the opportunity to incorporate controls. Does not provide an opportunity to improve the aesthetics or design to improve patient experience.
Replace	More flexibility of fitting type and output, generating more savings opportunity. Incorporate controls within the fitting. Can include smart fitting features - hours run, energy consumed etc. Can improve the quality of patient experience. Can include upgrade of emergency light system.	More expensive. More intrusive and time consuming. When using LED panels to replace multiple tubes, the whole panel will need to be replaced at the end of its working life.

5. Savings achievable through controls

Improving lighting controls can save energy and improve patient experience. There are many different methods.

- Manual switching.
- Daylight linking: the controls sense daylight levels and dim or turn off lamps when there is sufficient light from windows. Note: it is better to dim the lights as daylight level increases, rather than switching off lamps that are on full power, as this can distract occupants and reduce the quality of the lit space by creating a visual imbalance at different times of the day.
- Occupancy control: turns on lights only when a space is being used. A common use of this is in corridors that require to be accessed 24/7. The lights are kept at low level until they are activated by movement. Anecdotal evidence suggests this could save between 50-60%. Note: whenever occupancy control is deployed, there should always be a time delay built in to prevent excessive switching.
- Automatic controls: allow lights to be controlled by timers, and can also include daylight and occupancy sensing. The two main methods are standalone or centralised. Standalone controls are typically integrated into the fittings or link a small group of fittings. These can be quite cost-effective when replacing existing fittings. A centralised control system is intended to cover the whole building; all the fittings are on an addressable network and adjustments to schedules and settings can be set from a computer. Note: there should always be adequate local manual override switching in the case of emergency.

Understanding the impact of controls on systems can be difficult. In the CIBSE LG2 approach for assessing the design energy efficient rating (DEER), the following factors are used to assess reductions in lighting energy consumption through controls:

- Daylight control = 0.9.
- Absence control where manual switch on, but off when no presence detection = 0.9.
- Combination of above =0.85.
- None of the above = 1.0.

6. Other considerations

Emergency lighting. Escape route lighting will be required to cover all parts of a hospital or health care building. This should be in line with the requirements of BS 5266-1:2016. *Emergency lighting. Code of practice for the emergency lighting of premises*[ii]. Design guidance can also be obtained in the CIBSE SLL *Lighting Guide* LG12[iii].

Colour temperature. The colour of the light plays an important role in enhancing the healthcare environment. It can encourage visitors to feel positive about their experience and helps staff appreciate their workplace. A lighting upgrade therefore provides a real opportunity to improve the visual quality within the hospital. A well-designed scheme can also overcome potential problems of sensory deprivation that can be created by spending a long time in drab interiors.

Both the NHS publication *Lighting and colour for hospital design*[iv] and CIBSE SLL *Lighting Guide 2: Hospitals and Health Care Buildings*[iii] provide insight on colour in lighting for hospitals. It is worth noting that, when refurbishing an area, the colour scheme needs to be viewed under the same light source that will be installed.

Clinical needs. Section 10 of LG2 Construction and operation of luminaires provides an overview of how light fittings need to comply with existing safety and hygiene standards. It covers areas such as:

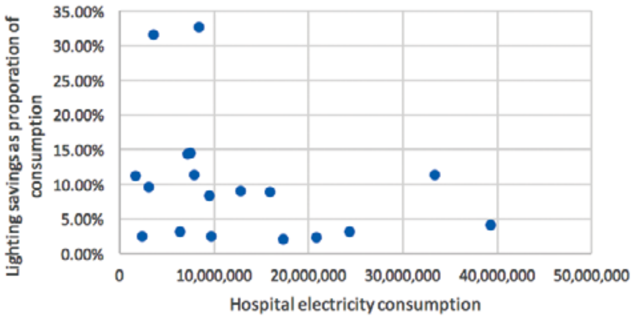
- fire integrity of recessed emergency luminaires.
- protection of ingress of moisture or dirt, referencing BS EN 60598-1.
- dust-borne infection.
- noise.
- electrical and mechanical safety (BS EN 60598-1, BS EN 60598-2-25).
- electromagnet compatibility (BS EN 61547:2009, BS EN 60601-1-11:2015).
- luminaire installation and maintenance.

LED reliability. One metric of reliability is lifetime. However, a manufacturer may present two different lifetimes, one based on lumen maintenance, which refers to the lifetime of the LED light source and the other on luminaire failure rate, which refers to the lifetime of the LED light source and driver.

As an example, an LED unit may have a Median useful life of L70 B50 at 50,000 hours, meaning around 50% of the units will have a light output of 70% of original at 50,000 hours. The LED unit (LED and Driver) may also have a specified failure rate of 7.5% per 50,000 hours. A Guide to the Specification of LED Lighting Products 2012- The Society of Light and Lighting provides an overview of LED quality standards.

The graph below demonstrates the lighting savings achieved across several actual NHS lighting projects as a percentage of electricity consumption.

Light savings



7. Detailed feasibility

When progressing to detailed feasibility studies, it important to engage with lighting designers that can provide not only the most energy efficiency solution, but also one that addresses all the issues raised above. This is particularly the case when considering replacing the existing fittings. Also, in addition to the energy and associated cost and carbon savings, the economic evaluation should include lifecycle costing and, where appropriate, opportunities to save on maintenance and material costs.

As with all feasibility studies, the accuracy of the information supplied will determine the accuracy of the result. Understanding the existing lighting assets and how they are operating is key to project viability. If there is no accurate asset schedule of existing fittings, a survey will need to be carried out. This can be assisted with as-built drawings, if they are available. The asset list should show the type of fittings, location and area activity (corridor, office, ward etc). If a centralised lighting control system is in place, this may also provide a list of assets. A potential supplier may be willing to carry out the survey and verify any information that already exists as part of the procurement process.

Once an asset list has been drawn up and the electrical ratings have been estimated, the next step is to calculate the annual consumption. This requires an estimate of lamp-run hours. If there is no central control system, these will have to be estimated based on their location and local knowledge of occupation. A pragmatic approach would be to allocate occupation profiles to different zones: for example, 24/7; 9am-5pm, 5 days a week; and 8am-8pm 7 days week. These can be applied to a site map and added to the asset list while it is being created.

8. Calculating savings

The following worked example shows cost and carbon savings for a typical acute hospital site.

Cost savings	Before	After
Lighting day consumption (kWh/year)	5,129,000	2,833,000
Lighting night consumption (kWh/year)	2,112,000	1,167,000
Unit cost of day electricity (p/kWh)	11.8	11.8
Unit cost of night electricity (p/kWh)	10.1	10.1
Total cost of electricity	£818,534	£452,161
Total cost saving/year	**£366,373**	

Cost savings	Before	After
Total electricity consumed (kWh/year)	7,241,000	4,000,000
Carbon factor for electricity (p/kWh)	0.25319	0.25319
Total carbon emitted (tonnes/year)	1,833	1,012
Carbon saved	821	
Carbon saved	44.76%	
Captial cost	**£2,228,000**	
Simple payback (years)	6.08	

References

- ***CIBSE LG2*** - *http://www.cibse.org*
- ***SLL Lighting Handbook*** - *http://www.cibse.org*
- ***CIBSE Guide F*** - *http://www.cibse.org*
- ***CIBSE TM46*** - *http://www.cibse.org*
- ***BS 5266-1:2016. Emergency lighting. Code of practice for the emergency lighting of premises***
- ***Lighting and colour for hospital design A Report on an NHS Estates Funded Research Project by: Hilary Dalke, Paul J Littlefair, David L Loe & N Camgöz. Published by TSO (The Stationery Office) 2004.***
- ***A Guide to the Specification of LED Lighting Products 2012 - The Society of Light and Lighting***
  https://www.voltimum.co.uk

DEMAND REDUCTION

Variable Speed Drives

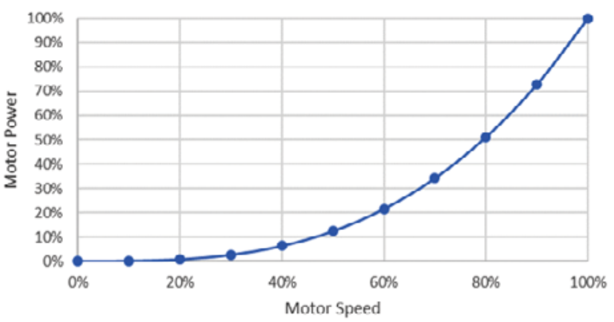
KEY FEATURES

- Primarily applicable to fan and pump applications for energy savings
- Large power savings for small reduction in speed
- Often straightforward to implement
- Can improve building environments through better control
- Different options to suit different site situations
- Lots of suppliers and installers to choose from.

1. Introduction

When considering energy savings in a hospital it is normal practice to look at the contribution of variable speed drives within existing HVAC and pumping systems. It is not uncommon for fans and pumps to be oversized for their application and the actual demand for flow of air or water is usually variable. Fan and pump applications are governed by a speed-power cube law, which means that a small reduction in speed equates to a far larger reduction in power consumption. Therefore, if the motor speed can be adjusted to meet the load requirements significant savings can be achieved. For example, a 20% reduction in speed equates to a 51% reduction in power, as shown in the graph below.

Speed - power cube law for fans and pumps



Traditional fans and pumps are powered by induction motors. Induction motors are simple electromechanical machines that spin at a speed dependent on the number of poles (windings) in the motor and the frequency of the mains electricity. Two and four pole motors are most common, with speeds of 3,000 rpm and 1,500 rpm respectively. Induction motors are simple, reliable and efficient; their main drawback is the fixed speed nature of the technology.

The most commonplace technology for controlling the speed of an induction motor is the variable speed drive (VSD). VSDs have been around for over 30 years. Early VSDs were very expensive and reserved for very high-power applications where the energy savings or control benefits would warrant investment. However, advances in power electronics and mass manufacturing have significantly reduced costs and VSDs are now affordable for most applications. In fact, some small zone pumps have built in VSD technology.

There are three types of variable speed drives:

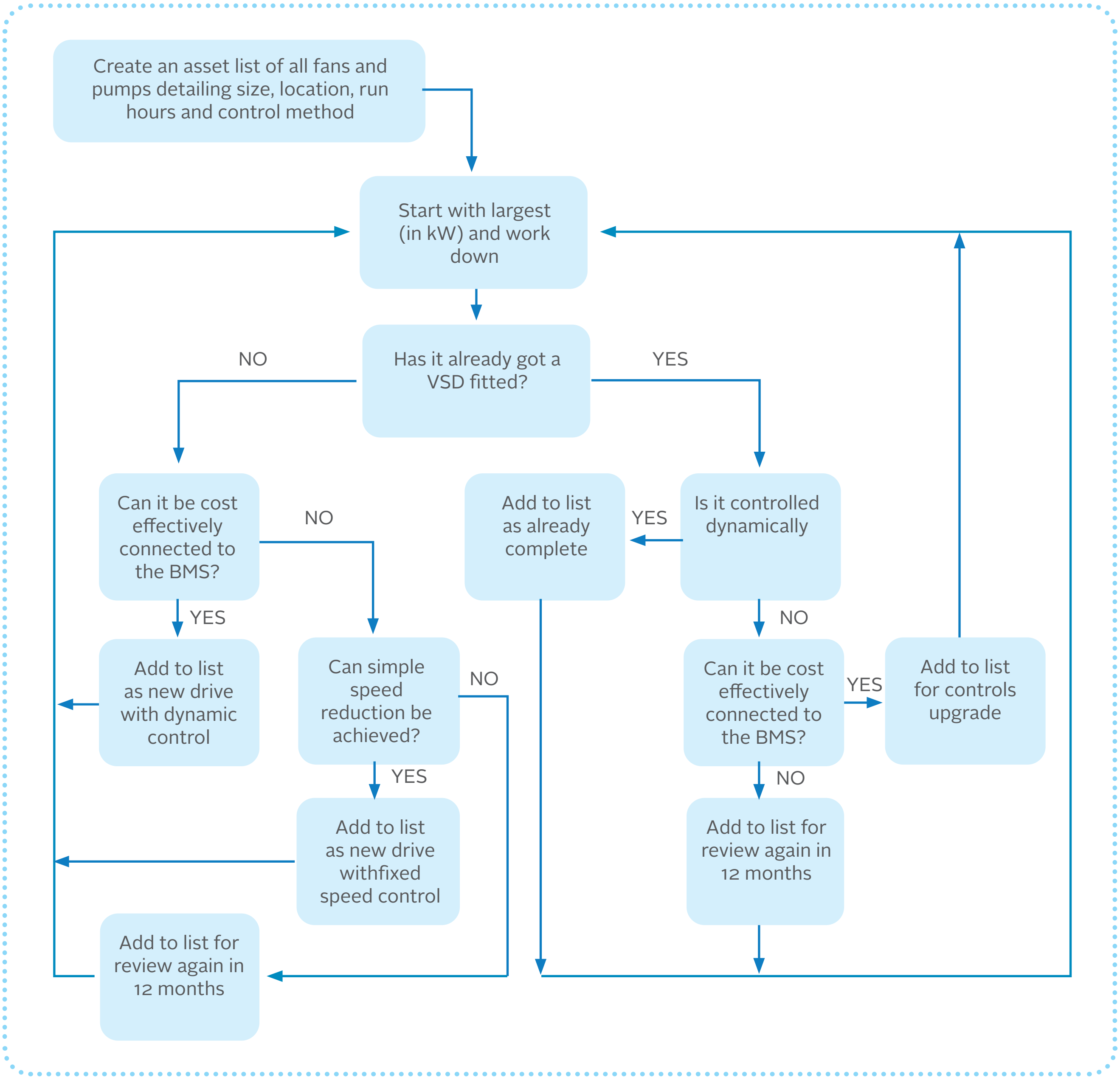
Simple variable speed drives. These drives can control motor speed, either through an external analogue control signal or by using a series of speed set points, triggered through digital inputs. These are the simplest and cheapest types of VSD. If the application simply requires a motor speed to be reduced to a fixed level or if the BMS will be undertaking PID control, then this could be a suitable option.

Fan and pump variable speed drives. These VSDs are optimised to work with fan and pump applications. HVAC is a major market for VSD suppliers so many have produced application-specific products. The key difference compared to a regular VSD is the inclusion of a PID control loop. A fan and pump drive can accept a signal from a temperature, pressure, or flow sensor, use a second input to receive a set-point from a control system, and regulate the output to the set-point. For example, a VSD could be connected to a pump regulating water flow. A flow meter measures the flow and feeds it to the VSD. The BMS sends the VSD a signal that tells it what flow rate is required. The VSD then automatically regulates the speed of the pump to maintain the desired flow rate.

Flux vector (open loop and closed loop) variable speed drives. These VSDs represent the best technology. They use intelligent monitoring of the motor flux currents to enable near 100% torque to be developed at zero speed. These VSDs are not normally used for fan and pump applications. In building applications, they are more commonly used in lifts as they can dramatically improve ride quality and accuracy of floor levels. However, lifts are a very specialised application and any considerations for VSD upgrades should be led by a specialist lift contractor. In addition, there are usually only minor savings from VSDs in lift applications, due to the nature of winding applications.

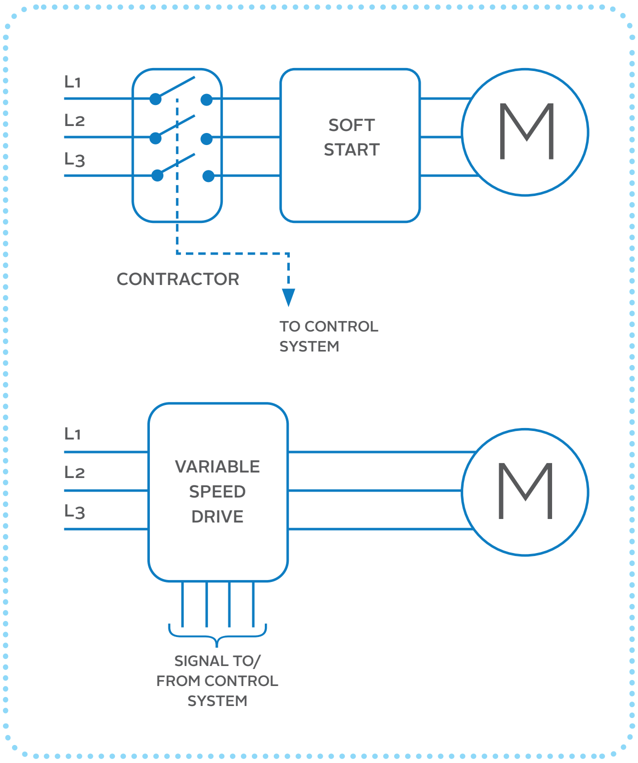
2. Initial assessment

When considering a variable speed drive project, it is first important to understand what fans and pumps are installed onsite. The focus should be to start with the largest ones, in kW of power demand. This is usually shown on the name plate of the motor. Creating a simple asset register is a good way to do this, if one does not already exist, and then identify how the motor is controlled and if a drive is already fitted. The process flow diagram below gives an example of how to conduct an initial assessment.



3. Implementation

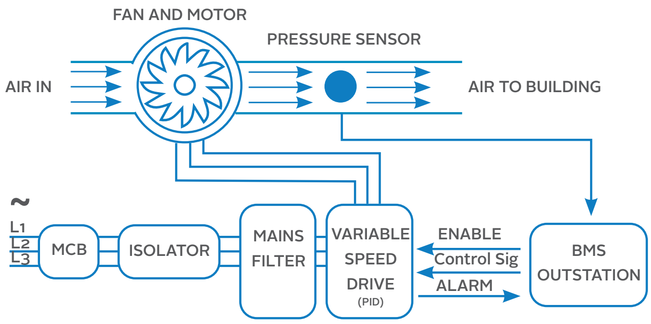
Variable Speed Drives are relatively straightforward to retrofit to existing motors. A direct-on-line (DOL) motor will be controlled by a contactor and in some instances a soft start device, that enables a gradual ramp up of the motor. When fitting a VSD the contactor and soft start can be removed and the VSD connected in its place, as shown in the diagram below.



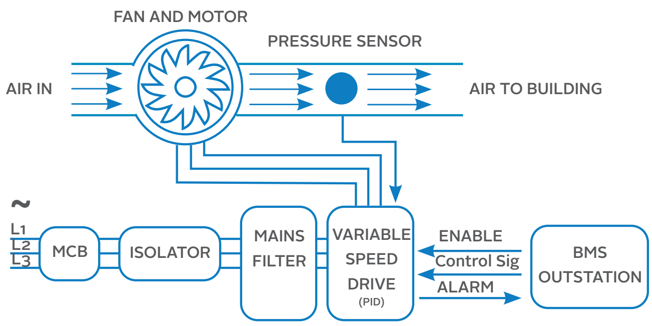
The key to success is implementing an appropriate control strategy. Simply installing a VSD as shown in the image above, turning it on and setting it to 50Hz will not make any reduction in energy consumption. In fact, it will consume marginally more electricity as some power is required to run the VSDs internal electronics. There are main three ways that a VSD can be implemented:

- **Simple speed reduction.** This option does not require any integration with control systems except for an external enable signal that would have previously been applied to the contactor. The drive is set up to work at a fixed speed but at a rate lower than 50Hz. This will only work if the system is known to be oversized and a reduction in pump or fan speed can be achieved without creating an adverse impact (such as heating not reaching temperature in certain areas). This is the cheapest option to implement and can be achieved with a simple low cost VSD.

- **Dynamic control, by the BMS.** In this scenario the BMS uses a sensor to track the required parameter and sends the VSD a control signal to adjust its speed. The BMS uses its internal PID loop to continually adjust the VSD control signal to meet the required demand. As other factors change in the system, the BMS can readjust the output in real time. This can create significant gains in efficiency, although it can be hard to measure precisely so it is worth taking power measurements before and after installation to verify the improvement. A specialist fan and pump VSD is not necessarily required but it does require a VSD that can accept a variable set-point control signal.



- **Dynamic control, by the drive.** Dynamic control, by the drive – In this scenario the VSD automatically regulates to a given parameter, using an external sensor and a control signal from the BMS. This can be advantageous in scenarios when the BMS is not able to provide a PID loop function to the drive or the drive is independent of the BMS. As with the previous option this can create significant gains in efficiency, although it can be hard to measure precisely so it is worth taking power measurements before and after installation to verify the improvement.



Variable speed drives are easy to select as they should be matched to the power rating of the motor. Motors are supplied in a series of standard sizes and VSD manufacturers provide sizes to match. There are also several ancillaries that should be considered:

- **Mains filter.** Variable Speed Drives create electrical noise, which can interfere with other equipment. It is therefore recommended that suitable mains filters are installed in the supply to the VSD. In some cases, VSDs will have filters built in. External filters should be sized to match the drive capacity.
- **Enclosures.** VSDs are usually available with options for different levels of protection, depending on the location. VSDs can be mounted on the wall in plant rooms if sufficient protection is provided. Some manufacturers' products already meet certain IP ratings and others provide options that improve IP ratings. However, VSD electronics are sensitive and if dust and dirt can enter the enclosure this is likely to shorten the life of the product.
- **Field bus.** Some drives have capability built in to communicate to BMS field bus, such as Modbus or DeviceNET. Others have options to provide this facility. Connecting a drive to the BMS field bus enables the BMS to access all the data in the VSD, such as speed, torque, alarms, etc. It can also use the field bus to send control messages and enable signals, dramatically reducing installation time.
- **Circuit Breakers.** Variable Speed Drives produce a high leakage current on start up. This is commonplace but it is important to install the VSD with D Type miniature circuit breakers (MCB) to ensure nuisance tripping of MCBs does not occur.

4. Calculating savings

Assessing the precise quantum of reduction can be challenging. The greatest savings will be achieved through dynamic system control, but knowing in advance how that will impact the energy consumption can be difficult. Some suppliers may consider providing a VSD on trial to enable savings to be proven, prior to purchase. To illustrate the savings calculation, consider the installation of a variable speed drive on a 50kW LTHW circulation pump that was initially oversized by 10% and runs continuously irrespective of demand. Assuming the average speed can be reduced by 20%, the annual savings, as shown in the table below, would be £25,350.

Pump motor power rating (kW)	50
Total run hours	8760
Cost of electricity in the day (p/kWh)	11.8
Cost of electricity at night (p/kWh)	10.1
Before VSD	
Total energy consumption (kWh)	438,000
Total cost of electricity	£49,512
After VSD	
Pump speed reduction	20%
Pump power reduction	49%
Average power consumption after VSD (kW)	24.4
Total energy consumption after VSD (kWh)	213,744
Total cost of electricity	£24,161
Annual saving from VSD	£25,350

References

- ***Carbon Trust - CTG070 – Variable Speed Drives*** *https://www.carbontrust.com*
- ***CIBSE Guide H - Building Control Systems***

DEMAND REDUCTION

Voltage Optimisation

KEY FEATURES

- ➤ Electrical equipment designed for EU uses more power than required in the UK
- ➤ 10% reduction in supply voltage produces 20% reduction in energy used (depending on types of site load)
- ➤ Can help to even out supply fluctuations. Savings of 10-20% typically achieved
- ➤ Need to consider in context of other energy saving strategies.

1. Introduction

The standard supply voltage in the UK is historically higher than in Europe (240V rather than 220V). This means that many electrical items take more power from the UK supply than they require, which in turn creates waste in the form of heat. The main issue with over-voltage is that magnetic circuits can suffer from saturation. The effect of saturation is increased iron losses, leading to heating and the introduction of poor power factor elements to the load, which in turn lead to further system losses.

Transformers, lights with ballasts and motors are especially vulnerable to this effect. However modern electronic equipment is generally immune to the problem, so the likelihood is that VO will be of diminishing importance as older equipment is replaced.

Voltage across the UK network is not only generally higher than required, but also suffers from significant supply and demand fluctuations, which can be further aggravated by high levels of local intermittent generation.

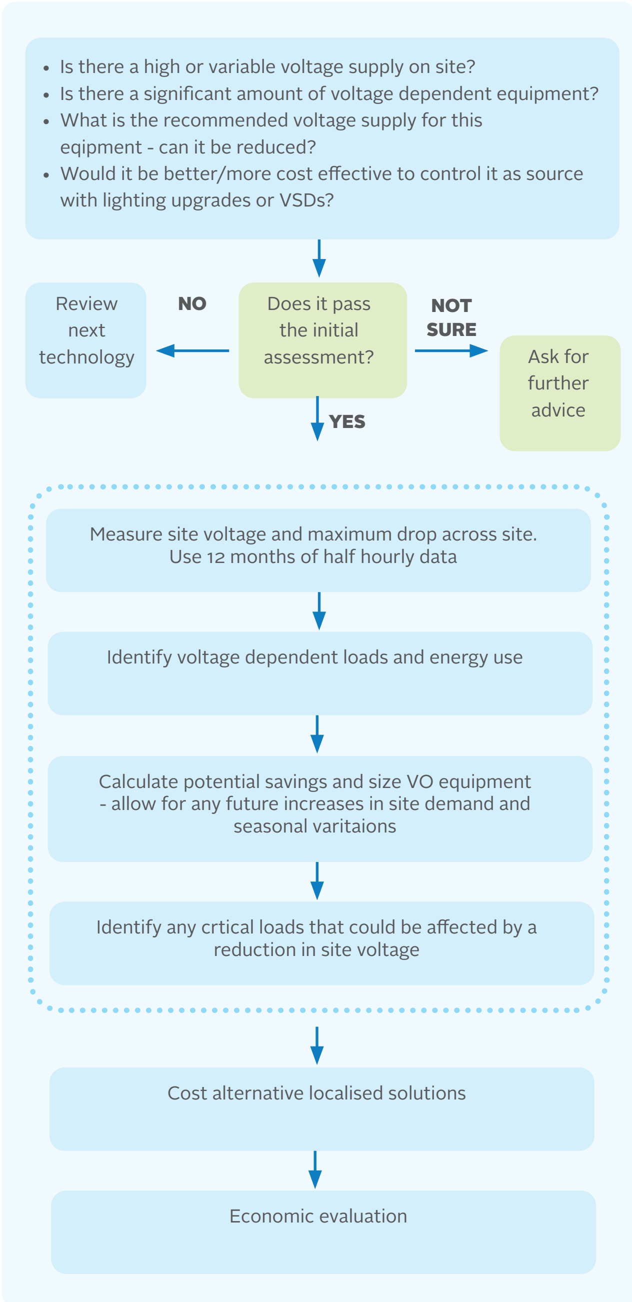
The aim of VO is to reduce and, in some instances, stabilise the voltage level supplied to electrical equipment. The power used is proportional to the square of the voltage:

$$\text{Power} = \frac{\text{Voltage}^2}{\text{Resistance}}$$

For a simple load, a 10% reduction in supply voltage will result in a 20% reduction in power used. Small reductions can therefore result in significant energy savings.

2. Initial assessment

Before deciding to invest in VO, Trusts need to consider several factors to determine that the savings available can be realised and maintained throughout the payback period.



The chart above shows the process of establishing whether the project is likely to be viable and if it is worth proceeding to a detailed feasibility study.

Assess site supply characteristics. The first thing to determine is the actual voltage level, whether it is subject to significant fluctuations and whether these characteristics are maintained over the long term. So, for example, a sudden drop in voltage on site could be due to high local demand (perhaps at the end of a popular television programme when everybody switches their kettles on), and not an indication of a longer-term problem. A site with high but steady voltage could be suitable for a tap-down of the main incomer transformer(s). This is a relatively low-cost and low-effort approach that simply reduces the overall voltage supplied to site. A site with fluctuating voltage, on the other hand, would also require some optimisation to prevent brown-outs or voltages dropping below functional levels.

Assess site equipment. VO will only work for items that offer a linear resistance, and not all electrical equipment does this. Electronic control equipment or high-frequency lighting, for example, are designed to give a fixed output regardless of the supply voltage. Such items are referred to as voltage independent. Even items controlled by something as simple as a thermostat, such as water heaters, are also, in effect, voltage independent. Water heating takes the same amount of energy whatever the voltage, but with a higher voltage will reach the desired temperature faster. Where enough voltage-dependent loads exist, VO can offer savings, provided these items are happy to run on reduced voltage. The primary targets for VO are fluorescent and incandescent lighting and motor drives for pumps and fans that have not been fitted with variable speed drives. On a site with a great many of these items, the savings can be significant.

3. Implementation

There are three main options for VO, the first two of which rely on having a high voltage supply to the site and therefore dedicated substations or transformers, as is often the case with hospitals and large healthcare sites.

Tapping down existing transformers. If there is a high voltage supply to the site, and the aim is simply to reduce the overall incoming voltage, it may be possible to tap down an existing transformer by adjusting the 'tap setting' (the ratio between input and output voltage). This is a relatively low-cost option, and can typically achieve up to 10% savings, but will not reduce fluctuations and, if the incoming supply drops, may cause excessively low voltage or brown-outs.

New transformers with voltage optimisation. If a transformer is to be replaced, it may be worth considering both the tap setting described above and also the choice of a model with, or that can be fitted with, VO. This solution will not only reduce high voltages but also smooth the voltage being fed to the site. There may be other potential savings from this route, by specifying more efficient transformers that waste less energy as heat. This approach is more expensive than the step-down transformer, but can achieve savings of 10-20%, and paybacks of under three years.

Local 3-phase voltage optimisation. On smaller sites that do not have a high voltage supply, or for local voltage regulation/optimisation to individual buildings, smaller low voltage three-phase, or even single-phase VO units are available.

4. Calculating savings

Obtain site voltage characteristics using a minimum of 12 month data (to allow for seasonal variations) and as granular as possible, ideally half hourly to gain understanding of fluctuations

Develop a power profile for site broken down into operating periods

Undertake survey of equipment operating during thses periods and assess suitability for reduced-voltage operation

Compare the measured maximum demand with site survey - they should be a close match

Calculate potential reduction in power used for each piece of equipment at lower voltage

Cost alternatives such as lighting upgrades or a localised low voltage solution

The following example applies to an installation where the transformers and VO have been shown to reduce the day electrical consumption by 1.42GWh and the night by 0.79GWh.

Power saved in the day (kWh)	1,420,000
Power saved at night (kWh)	790,000
Electricity day rate (p/kWh)	11.8
Electricity night rate (p/kWh)	10.1
Total saved (to nearest 000)	**£247,350**

5. Other considerations

Consider 'unexpected consequences'. Some equipment, especially older items, may not run as well, or at all, at a reduced voltage. It may be worth replacing such items or providing a localised solution for them. With lighting, the output (i.e. the light level) will be reduced. This may not be a problem, because many lighting schemes were designed with higher levels than needed, but it is important to recognise this at design stage.

Consider the future. If the intention is to replace equipment in the near future, VO savings may well not be worth the outlay. For example, if a large lighting retrofit is planned, this will usually involve lower energy lighting, including voltage-independent systems. Similarly, if motors and fans are soon to be replaced, the new versions are likely to be more efficient and better controlled, so benefits from VO will again be reduced. However, if it is unlikely the Trust can action these items quickly and there are many across the estate, VO may be a good investment with typical paybacks of around three years. It is also worth considering whether there may be changes to the grid locally, with local generators or energy users coming on or off line, or grid upgrades and engagement with the local DNO is recommended.

References

- ***Carbon Trust, Voltage Management***
  https://www.carbontrust.com
- ***CIBSE Carbon Bites, Voltage Optimisation***
  http://www.cibse.org

DEMAND REDUCTION

Water Efficiency

KEY FEATURES

- Financial savings of up to 20% achievable
- Often requires little or no capital investment
- Effective management measures possible in all estates
- Water-efficient technologies favoured for new build and upgrades.

1. Introduction

Many Trusts are charged for waste and sewage costs in proportion to metered water volume supplied, on the basis that the water drawn from the supply mains will ultimately be drained as waste water / sewage. Water and sewage costs have risen significantly in the last five years, and although the overall bill still usually represents a lower utility cost for a hospital than electricity or gas, it can still be substantial.

HTM 07-04: *Water Management and Water Efficiency – Best Practice Advice for the Healthcare Sector* states that significant quantities of water and waste water are utilised in the NHS and that savings of up to 20% may be possible from applying water saving and conservation measures.

The HTM cites examples of reductions in water consumption from addressing leaks, water-saving measures for taps, WCs, steam boiler feedwater and recycling waste water. It also notes the requirement to prioritise patient health and well-being.

Water conservation is often ignored due to real concerns about legionella and infection control. Obviously, both those clinical matters are a high priority, but no savings measure comes without some careful design and thought and it should be possible to make significant water savings whilst maintaining cleanliness and legionella compliance. In fact, if legionella can only be controlled through heavy and continuous flushing, then the energy project should include measures to address the high legionella risk in other ways, through perhaps reducing dead legs, reducing the unintended heating of cold water pipes, and even considering proactive water cleaning systems. HTM 04-01 *Parts A, B and C: Safe water in healthcare premises* provides guidance on the approaches to be considered in managing legionella and infection control.

2. Implementation

The usual starting point for improving water conservation measures is to carry out an audit of all water fixtures, to identify where the largest proportions are consumed. HTM 07-04 suggests typical percentages of total annual consumption from the range of hospital uses including WCs, urinals, taps and boiler use. It suggests unattended leaks alone may be as much as 30% of annual consumption.

Uncontrolled and unintended usage from leakage has the potential to represent a significant proportion of water consumption. If 15% of a hospital's annual water utilisation of 130,000 cubic metres were attributable to uncontrolled leakage, and the leaks were all fully repaired, this could save around £35,000 per annum.

It may be impossible to determine the true extent of leakage on a large hospital estate, but it will be easier to spot out-of-the-ordinary events, or changes in trends, through a thorough and systematic process of inspection, sub-metering, bill analysis and benchmarking. Some of the events might then be traceable back to known changes to the estate, or new clinical facilities. Where events do not support the change in consumption trend data, this may suggest potential leakage.

Rolling out a renewal programme for estate-wide water outlets and fixtures will introduce standardisation, which in turn should reduce maintenance and spares costs. Typical improvements might include the following.

WCs and urinals. Replacing older larger volume (>9 litre flush) WC cisterns with new low-volume units (<4.5 litre per flush). If complete WC cistern replacement is not viable, retrofitting dual flush valves (halving flush volume) may be more practical. Even more cost-effective might be installing a water volume reducer in the WC cistern, minimising the water available to flush the toilet. This measure usually requires no maintenance.

Flushing cisterns serving urinals can also be considered for potential water savings. If they are always triggered to flush by a float valve once the cistern has been filled, significant amounts of water will be wasted during periods of non-occupancy. Solutions range from retrofitting flush valves operated by electronic passive infrared sensor (PIR)/occupancy detectors to isolating the urinal water connection and going completely waterless. HTMs recommend that the hospital's infection control team is consulted before installing waterless urinals, which still require regular manual disinfection using chemicals. In most instances, PIR-controlled urinal flushing will satisfy infection control requirements, whether automatically triggering the flush operation after user detection (with a defined delay), or flushing at pre-determined times. Auto PIR solutions are now able to avoid flush repeats during periods of heavy use.

Other water outlets. Most sinks in public areas will almost certainly already have push taps fitted. There may still be further scope for retrofitting new low-flow push or PIR-activated taps, and possibly tap aerators or flow restriction devices, in non-public areas where these would not compromise clinical utilisation or patient needs. Regular adjustment and cleaning of percussive taps is usually necessary to avoid them sticking.

Other outlets, including showers, may benefit from retrofitting aerated low-flow heads, to reduce the water used while giving the appearance of a much higher flow being delivered.

It should be noted that water conservation measures adopted on hot water outlets will achieve heat energy savings as well as water savings. The energy saved will depend on the form and efficiency of heat being provided.

Steam boilers. For steam boilers, water make-up can be greater than necessary if most of the steam condensate is not returned to the energy centre hotwell, or if unnecessary boiler blow-downs occur. On old or very dispersed installations, it is not uncommon for only 50% of condensation to be returned, requiring more make-up water and heat energy to replace that lost by leaking steam traps or local venting. It may require significant capital expenditure to improve these situations, so condensate recovery savings could be considered as part of a wider benefit when addressing boiler replacements or de-steaming a site (see Heat Distribution and Boilers section for more information).

Waste water from processes. Waste water from reverse osmosis plant, boiler feed pre-treatment and general raw water softening systems is normally sent to drain. Unnecessary regeneration and draining cycles can often be reduced by carrying out regeneration processes only when needed and adjusting trigger levels for regeneration through more detailed monitoring of the throughput and water condition.

Grey water recovery and rain water harvesting. Grey water recovery from sinks and ablution fittings or reverse osmosis drains will require fairly major alterations to existing waste water drainage, and rain water harvesting will need to be integrated with external surface water drainage. Additional investment in water disinfection is usually needed, and the level of treatment depends on the usage and location of water draw-offs. The most common utilisation for grey and rainwater harvest is in non-clinically sensitive areas, such as landscape watering or, in certain circumstances, toilet and urinal flushing. Again, infection control will need to be involved in any scheme proposed. This type of solution will need water storage and pumping in addition to water treatment, so will not usually pay back very quickly. Investment returns may be improved when solutions are encompassed in new development or refurbishment and can contribute to BREEAM scoring and sustainability planning strategy.

Water supply bore holes. Given the costs associated with supplying water to hospitals from utility companies, some hospitals have made significant savings from utilising private supply boreholes to harvest underground aquifers.

Health Building Note 00-07 "*Resilience planning for the healthcare estate*" also suggests that a second water supply either from a different mains water network or a private bore hole might be worth investigating.

Private boreholes are typically 75mm to 250mm diameter and can be as deep as 200 meters. Some boreholes in the NHS are long established, having been in use for a number of years. They usually require an abstraction licence, to be periodically renewed by the Environment Agency. If the bore hole serves water for domestic purposes (drinking, food preparation and washing, by staff, patients and visitors) then it will also be regulated under the Water Industry Act 1991 by the Local Authority, who will usually need to carry out a risk assessment to satisfy itself that the private supply is safe, and meets all regulatory requirements.

If there is no existing water supply borehole on site, then specialist consultants or companies should be called in to carry out feasibility on any proposed new well. The first step would be to look at the location of the site in relation to published ground water maps and to determine whether there are existing or planned future ground water users already abstracting or planning to abstract water that may affect the potential yield.

It is usually necessary to refer to the Local Authority to check records of current, historic or disused landfill sites within a radius of a number miles around any proposed site for a new borehole, because their presence may impose additional contamination risk management.

A trial borehole is usually needed that will firm up any initial viability established. This will also enable a basic borehole water quality test to be conducted to determine the water treatment requirements such as chlorination, pH correction and UV disinfection. Chemicals used need to be approved for use with drinking water and UV treatment systems need to be validated and approved by independent third-party testing.

Sometimes water abstraction is limited to non-domestic uses such as WC flushing and HVAC cooling solutions, in order to limit the higher risk management imposed on potable supply use. Boreholes can be in the range of £70 to £150 per metre depth, depending on the local geology and the procurement method. Because of this, initial specialist consultation is usually needed to be sure of scheme viability before expensive drilling commences.

If the risks can be managed, the potential for significant savings may be expected. Given that some sites have significant water use, paybacks within just a few years are potentially possible.

Most hospitals, however, will not rely on private water boreholes 100 % of the time, and resilience planning dictates the need to retain mains water connections.

3. Calculating savings

The amount of water saved by implementing the measures identified will vary from site to site depending on the actual scope possible and any work that has already been carried out to existing fittings and systems. The model hospital has an equivalent water consumption of 1.74 m3/m2 of occupied area, which is typical of a large acute hospital benchmark that can be derived from HTM 07-04.

The following table summarises typical savings that might be applied as consumption levels fall towards ‘best practice’ benchmarks through water conservation measures. It also shows cost benefits and simple pay-backs when set against the model hospital baseline.

Measure	Annual water saving m³	Water cost saving	Cap-ex (excludes on costs)	Op-ex issues	Simple payback
Potential uncontrolled water leaks eradication	circa 3,500-20,000	circa £6,000 £35,000	Dependant on leak issue	Good level of on-going management and consumption trend analysis	Usually low, depending on leak issues
Retrofit dual flush valves to 50% of WC cisterns (assumes remaining already done)	circa 4,500	circa £8,000	circa £18,000	No additional	Typical 2 years (less if cistern volume reducers used)
Convert 50% of urinals to waterless or fit water saving controls (assumes remaining already have controls)	circa 3,000	circa £5,500	circa £7,500	Should be similar to existing, waterless needs disinfection program	Typical 1.5 - 2 years
Apply flow restrictions, non-concussive self-closing taps to 30% of fittings (assumes remaining done or not possible)	circa 2,000	circa £1,850	circa £7,000	Should be similar to existing	Typical 3 - 4 years
Improve condensate recovery per MW of base heating demand	circa 1,750	circa £3,000	Dependant on trap issues	No additional, poss. Additional savings from lower steam -trap system	Typical 2 - 4 years

Existing water consumption baseline m³/year	129,292
Existing m³/m² occupied floor area	1.74
Total saving m³	**23,000**
Total water consumption after savings m³/year	106,292
Total water consumption after savings m³/m² occupied floor area	**1.45**

References

- ***Department of Health, HTM 07-04*** - *https://www.gov.uk*
- ***Department of Health, HBN 00-07*** - *https://www.gov.uk*
- ***Department of Health, HTM 04-01 Part A: design, installation and commissioning, Part B: operational management, Part C: Pseudomonas aeruginosa – advice for augmented care units*** *https://www.gov.uk*

DEMAND REDUCTION

Behavioural Management

KEY FEATURES

- Staff and patient behaviour can save energy and carbon
- Culture change initiatives are effective and low-cost
- Starts with a full understanding of where and how energy is consumed
- Requires commitment and embedding in Trust policies.

1. Introduction

The way a hospital's staff and patients interact with and utilise its buildings and facilities impacts on site energy consumption and carbon emissions. Trusts can promote and facilitate a workplace culture that minimises energy and water consumption and encourages greater use of sustainable transport. Managing this behavioural change will deliver energy and carbon savings for a relatively low investment.

Behaviour in the workplace comes from the attitudes, reactions, activities and mindsets of staff. These behaviours can be influenced by campaigns that, for example, might encourage facility users to turn off lighting and equipment when not in use, or to adopt good housekeeping habits such as closing doors and windows.

2. Implementation

Many campaigns will focus directly on achieving energy, carbon, operational and maintenance savings for the Trust. However, end-users may identify more readily with, and be motivated by, other benefits, such as making a positive contribution to improving patient experience, privacy and comfort.

No single approach to changing behaviour and culture will be appropriate for every hospital. What works well in one organisation or department may not necessarily be right for another. However, general guidance and behavioural change examples specific to the NHS are published in Health Technical Memorandum 07-02: EnCO2de 2015 – *making energy work in healthcare Environment and sustainability*".

More generally, an organisation will probably have management policies in place to recognise, actively promote and continually review beneficial behavioural change if it follows best practice energy and environmental management standards, including those covered in *ISO 14001:2015 Environmental management systems* and *ISO 50001:2011 Energy Management*. The standards identify model approaches that can be adopted by Trusts.

The foundation for all successful campaigns is a clear understanding of where most energy is consumed and what activities have the biggest impact on carbon emissions, operational efficiency, and patient wellbeing. This makes behavioural change one of the first lines of attack for energy savings.

It is important to be clear on aims and objectives from the start and to understand:

- the baseline from which the behavioural change programme is working.
- how the campaign will be enacted.
- what motivations are needed and will be effective.
- what resources will be required.
- how the impact of the campaign will be measured.

It may be effective to start by targeting specific areas of the estate, or organisational departments. This enables detailed observation and assessment of impacts, including metered or calculated savings. These pilots can then be rolled out across the site with a more realistic understanding of the benefits that can be achieved.

This will also ensure that significant investment of staff time and money - for example, investment in training or marketing materials - is directed to where it will generate greatest impact. For larger initiatives, a business case may be needed and an initial small-scale pilot may help to show how the return on investment can be scaled up across the organisation. Once achieved, behavioural changes will need to be embedded within the hospital operational policies, in particular as part of the organisational energy and sustainability strategy, to ensure that they are sustained.

3. Calculating savings

Carbon Trust figures indicate that an investment of between 1-2% of energy spend in an effective employee engagement campaign may enable some organisations to save up to 10% on energy. Based on typical acute hospital energy costs, an investment of c.£20k would be required to deliver between £50 and £100k energy saving. Other sources suggest a much higher level of investment might be needed to effect similar levels of savings. In general, the larger the site and more complex the organisation and its activities, the greater the investment needed to deliver the same level of saving.

In any event, it may be difficult to sustain this level of saving (and possibly investment) year-on-year over the long term. The true effectiveness of behavioural change campaigns may be variable and difficult to define accurately. Their outcomes are often influenced by wider organisational actions that also contribute to energy performance.

4. Maintaining savings

In the longer term, many other factors may affect the ability to demonstrate a beneficial legacy. These could include ad-hoc campaigns outside the main strategy, inconsistent access to resources, varying support from management, staff movements, organisational and operational changes or re-purposing of hospital estates and facilities. Behavioural management therefore needs to adapt to these changes with continual reinforcement, development and funding to maintain its effectiveness.

To ensure that behavioural management initiatives are successful, fully understood and appreciated, they should be delivered in the context of a 'plan, do, check, act' strategy with the same emphasis on establishing a before-and-after verification as other more physical plant and energy infrastructure improvements.

References

- ***Department of Health, EnCode*** - *https://www.gov.uk*
- ***Carbon Trust, Low Carbon Behaviour Change***
  https://www.carbontrust.com
- ***ISO14001, Environmental Management*** - *https://www.iso.org*
- ***ISO50001, Energy Management*** - *https://www.iso.org*

Building Management Systems

KEY FEATURES

- Traditionally used for control of heating, ventilation, air conditioning and hot water
- Advancing technology means that high levels of systems integration are now possible
- Can play a significant role in energy usage monitoring and control
- Up to 30% energy reduction may be possible
- Can serve as a diagnostic tool to identify if and why a building's energy performance has changed
- Can start with a single outstation and expand to system-wide capabilities
- User training and commitment are essential to maximise benefits of the BMS

1. Introduction

The term building management system (BMS) refers to electronic control systems that are used to control building services. They can be applied equally to new and existing buildings. In healthcare premises, they have been used primarily to monitor and control environmental conditions, particularly in critical areas such as operating departments, intensive care units, isolation suites, pharmacies and sterile supply departments.

The traditional focus of the BMS is heating, ventilation, air conditioning, and hot water services. Recent technological innovations have enabled the BMS to branch out to a variety of integrated engineering controls covering the whole or various parts of the building. These include:

- Power - including energy usage monitoring and flow control.
- Climate control - including heat, ventilation, air conditioning, and air circulation.
- Water - pumping to the various floors.
- Lifts - including control, surveillance, and access to the cars.
- Lights - providing automated activation/deactivation and power conservation of fixtures.
- Critical component monitoring.
- Access control - including door monitoring and access, intrusion sensor monitoring and alarms.

Intelligent technologies are key to effective healthcare building management. For example, where a department in a hospital only operates on weekdays, the BMS traditionally turned off or reduced the air conditioning in those areas through 'time of day' scheduling. With an integrated smart system, the lighting can also be turned off, the security access restricted and the lifts controlled in a manner where they operate as efficiently as possible (for example only a certain number of lifts running in a bank, proportionate to the volume of people using them). All the energy savings can be calculated automatically using smart metering, which is also integrated into the system.

There is also a need to monitor critical components such as fridges, cold rooms, UPS / IPS systems, sump pumps etc. remotely, to ascertain any issues before they happen. Whilst traditional BMS still provides clear benefits to the building services departments, an integrated approach with a site-wide view enables a much higher degree of control, monitoring, energy savings, and operational savings. This holds the key to resolving many hospital managers' dilemma - how to do more, with fewer resources.

The main benefit of a well implemented BMS is the easy and convenient monitoring of the individual building control systems and the ease with which adjustments can be made. A BMS can also serve as a diagnostic tool to identify if and why a building's energy performance has changed. Specific benefits include the following.

Energy management

- Effective monitoring and targeting of energy consumption.
- Reviewing performance of individual building services.
- Tuning and optimising systems at a common interface.
- Reducing energy costs through Integrated energy saving control functions.

Comfort

- Minimised intervention by staff in daily operations.
- Good control of internal conditions, providing more comfort for building occupants
- Possibility of individual room control.
- Effective response to HVAC-related complaints.

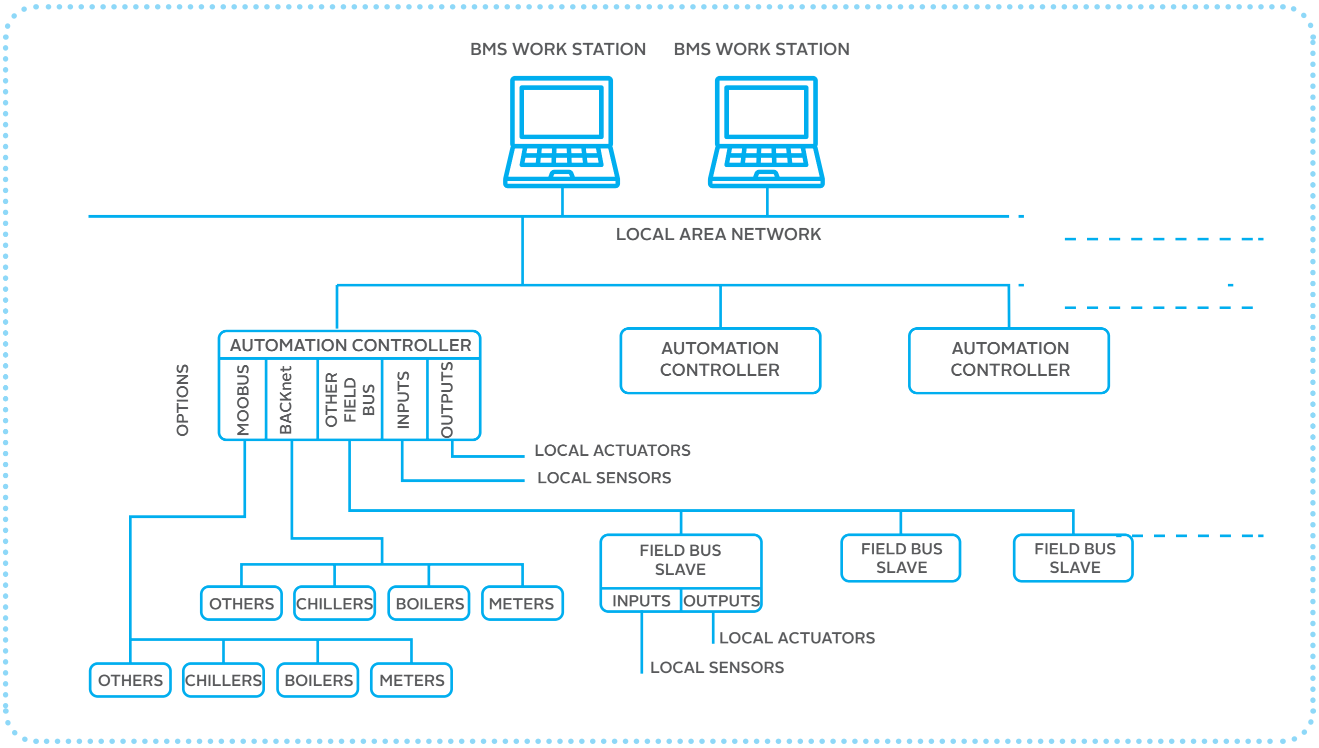
Maintenance

- Ease of information availability.
- Monitoring specific parameters for condition-based maintenance.
- Identification of regular and reactive maintenance requirements by recording the number of hours motors have run or identifying equipment faults or failure.

Monitoring

- Monitoring and collecting building performance data for analysis.
- Logging and archiving data for compliance requirements, for example monitoring and logging hot water temperature data for legionella management.

2. How BMS works



The BMS works by using field-level, intelligent, standalone controllers (or outstations) to control different systems. In a hospital, for example, it may be used to control air handling units (AHUs), boilers, pumps and lights. The controllers are usually programmed to respond to changing environmental conditions such as temperature, time and light levels.

The field-level controllers comprise both digital and analogue inputs and outputs, such as temperature and humidity sensors, room control devices, etc. Using these inputs and outputs, the BMS engineer or programmer develops a control logic with feedback, based on environmental conditions, to control the system.

The field-level controllers usually connect through a gateway or automation-level controller into a common communication network, normally through Ethernet / IP protocol. Both input and output data is picked up through a server and transmitted to an end device, which can be in the form of a workstation, tablet, phone, web browser etc. The workstation and server act as a management tool, enabling all outstations to be monitored and adjusted from a central control point.

A BMS can begin with a single outstation, which can be expanded at any time by adding further outstations and linking them into a common communications network. The ability to add to and expand a BMS gives it vast capabilities, restricted only by cost and the Trust's commitment to control. User commitment is essential to get the best out of a BMS; without it, the system will just be an under-used facility.

3. Integrating control systems

There has been a shift in the current generation of BMS systems to be open-protocol and web-enabled, allowing integration of systems from multiple vendors, accessed from anywhere in the world. The characteristics of an open-protocol systems are published and they may be used by anyone, either freely or with a licence.

There are many different open protocols for BMS controllers, including both wired, such as BACnet and Modbus, and wireless, such EnOcean and Zigbee. Increasingly, service users are demanding that all captured data is capable of being integrated. This is in line with the increasing use of technological devices through the internet of things (IoT). The BMS industry is following the same pattern.

For example, different systems communicate with a wide variety of devices, from temperature sensors and occupancy detection to engineering plant equipment such as boilers, air handlers and chillers. Whatever the originating field controller, its data may be forwarded to the cloud and used on monitoring dashboards displaying real-time visualisations of energy performance and issues. These will be widely available to the local estates office, theatre managers or other users. In all instances, suitable security measures must be implemented to prevent unauthorised access.

Assessing which building controls should be integrated into the BMS may, initially, be a question of cost. Not all systems have to be integrated at once, and systems can be added or excluded over time. Further enhancements to building performance and energy savings can be made in the future. However, if a new system is capable of being integrated into existing systems, they must be able to communicate with each other. An open-protocol system used by many suppliers will allow for future expansion and scope. It is also important to choose a supplier that is able to match solutions to your building-specific challenges.

4. Implementation

Not all healthcare buildings or departments require the same type and complexity of control. A complex BMS is particularly cost-effective for large buildings with extensive electrical and HVAC systems and high energy bills. One of the key benefits of a BMS is being able to monitor and control costs more accurately.

It is important to determine the economic and environmental targets that could be achieved before installing a new system. Trusts need to investigate whether, where and how much energy could potentially be saved, by monitoring the hospital's energy consumption. Other considerations include deciding which systems to integrate, for example lighting control or access control, and the analysis of potential benefits against costs.

Benchmarking and logging energy data before changes are implemented will enable the Trust to calculate payback periods and achieve guaranteed savings. It is often useful to implement a smart metering strategy, linked to the BMS, before proceeding with a new Building Management System.

A design brief should be produced to ensure that the controls will minimise energy consumption and provide information and trend analysis to support overall energy management. The control design should integrate all relevant systems to maximise convenience and energy performance, whilst being reliable and responsive.

5. BMS opportunities

Energy savings and enhancements to existing HVAC BMS. Most NHS healthcare sites have some degree of BMS within their buildings, most commonly used to control heating, ventilation plants, air handling units, motors, pumps, and hot water systems. Within these areas there are opportunities for reduced energy consumption, in some cases amounting to as much as 30% energy reduction in addition to maintenance savings.

Time of day rescheduling. HVAC equipment runtimes may not reflect the actual occupancy of the spaces they serve, as changes occur over the lifetime of a building. For example, an area once occupied 24/7 may now only be used on weekdays. There will be complaints by service users if the air conditioning in an area is not working, but it is rare for anyone to tell the estates department if the area is unoccupied. To establish actual usage patterns, other building management systems (such as access controls) can be used, or departments simply asked to provide data. By utilising the scheduling capabilities of an existing or proposed control system, equipment runtime can be reduced, producing electrical, heating, and cooling savings.

Occupancy (passive infrared sensor) control. In some areas of a hospital, space usage may be intermittent but requires certain environmental conditions when in use. For example, operating theatres may be used outside normal working hours in emergencies. Occupancy sensors can be installed to the theatre and preparation rooms to initiate control and operation of the associated supply and extract fans. Where the theatre is unoccupied over a length of time, the motor speeds can be reduced through variable speed drives, and temperature control relaxed to reduce heat and power consumption. It is important to explain to theatre managers, service users and infection control staff how occupancy sensors work and ensure that these user groups understand the operating protocols and are included in the development of any operational changes. Any changes must be in line with the requirements of the relevant Healthcare Technical Memorandum and other best practice guidance.

Hydronic loop optimisation. The basic principles behind Hydronic Loop Optimisation are:

- Shutting off variable temperature (VT) zone loop pumps to heating systems when space heating is not required.
- Utilising 3-way valves to reduce VT zone loop supply water temperatures according to demand.
- Slowing variable speed drive supply pump speeds to maintain pressure at only the furthest heating element.

Electrical savings are made through reduced pump runtimes and speeds, and heating savings by reducing the heating demand from each space and ultimately the loading on the boilers and primary loops.

To optimise the heating contribution of each VT loop, programming should account for both outside and inside air temperature. The outside air temperature is used as a variable in a supply water temperature reset schedule, since it is an inherent indication of the amount of heating skin loss to expect. Outside air temperature also forms the basis of the VT loop lock-out, shutting off flow when outside temperatures rise above a pre- determined set point. The internal space temperature is used to determine whether flow to convectors is required. When the space temperature is above the set point, the pump serving that loop is disabled until the set point is no longer maintained. Dead bands are used to ensure that 'hunting' and therefore inefficiency doesn't occur in the heat generating plant.

Plant temperature control recommissioning and reprogramming. As part of the technical analysis, the control strategies on the BMS should be examined. Common issues include:

- Unnecessary heating and cooling. For example, a single duct air handling unit may pre-heat, cool and re-heat the air unnecessarily, where, if properly set, it would have heated once only, or cooled without heating.

- AHUs with hot and cold deck duct temperature set points can be rescheduled, depending on the heating and cooling demands of mixing boxes, with the following optional demand modes:

  - mixing box heating demands rescheduled against outside air temperature.

  - average mixing box heating and cooling demands.

  - maximum mixing box heating and cooling demands.

The choice can be left up to the service user, but this ensures that plant runs as efficiently as possible.

6. Guaranteed savings and maintenance

The methodology provided by the supplier for both energy and maintenance savings should be as cost-effective and robust as possible. To put it simply, the savings achieved in year 1 should be like the savings achieved a few years later. Performance monitoring and exception reporting through the BMS itself is a good way of keeping track of how the installation is performing, and whether the savings are being achieved.

End users, including estates managers and the maintenance team, need to be trained how to use the system. Introducing a BMS is a process which will require regular review as conditions and needs in the building change.

The BMS is only as good as the downstream sensors and actuators to which it is connected. Maintenance is therefore, essential and should include calibration and fine-tuning of sensors and regular check and repair of valves and actuators to ensure that the system performs optimally.

7. Considerations

There are several pitfalls that need to be avoided to maximise the performance and efficiency of the BMS.

It is important that the correct operation and maintenance is performed, so training and staff engagement are keys to the success of the BMS. Staff closely involved in its operation will have to be committed to its success and must be willing to incorporate it into their existing ways of working. There are often examples in healthcare BMS installations where staff have removed new BMS controls and reverted to manual adjustments simply because they did not understand how it worked, and the installers did not engage with them or provide the correct level of training.

It is also important to integrate exception reporting and performance monitoring as part of any BMS installation. This ensures that the system is kept to optimum parameters and any issues can be picked up quickly. There are times when maintenance staff make manual overrides on the system, for example such as manually adjusting the heating valve on an AHU to open 100% to alleviate an immediate issue or switching fans or pumps into manual on a control panel. This stops the BMS being able to control that item of plant and if left unchecked the plant will continue to operate inefficiently. An exception report, or a BMS software reset, can be initiated daily or weekly to reduce this risk of plant running inefficiently and to prevent this occurring continuously.

BMS systems are usually a form of logic controller and therefore not commonly suited to processing large volumes of data. There are now solutions available that can connect to the BMS network and automatically detect anomalies in operation across the site. With many hospital BMS having potentially thousands of sensors and actuators, these systems save time and enable rapid identification of faults so they can be rectified immediately.

References

- ***CIBSE Guide H – Building Control Systems***
  Analytics of building management systems for improved energy and plant performance - *http://www.cibse.org*
- ***Health Technical Memorandum 2005 - Building management systems - Management policy***
  http://www.wales.nhs.uk

Contract & Performance Assurance

KEY FEATURES

- Operates throughout project build and operational lifecycle.
- Establishes that an energy and carbon initiative is really saving what was planned.
- Ensures that project complications and issues do not impact on outcome.
- Demonstrates benefits to key stakeholders, at a consistent and auditable level.

1. Introduction

Before the creation of CEF, it was often following the construction and commissioning that energy schemes typically started to underperform. In the main, this was due to a lack of finance, contractual awareness, appropriate sector knowledge and resource. So once a scheme has reached completion, CEF automatically takes on the onus of Contract & Performance Assurance.

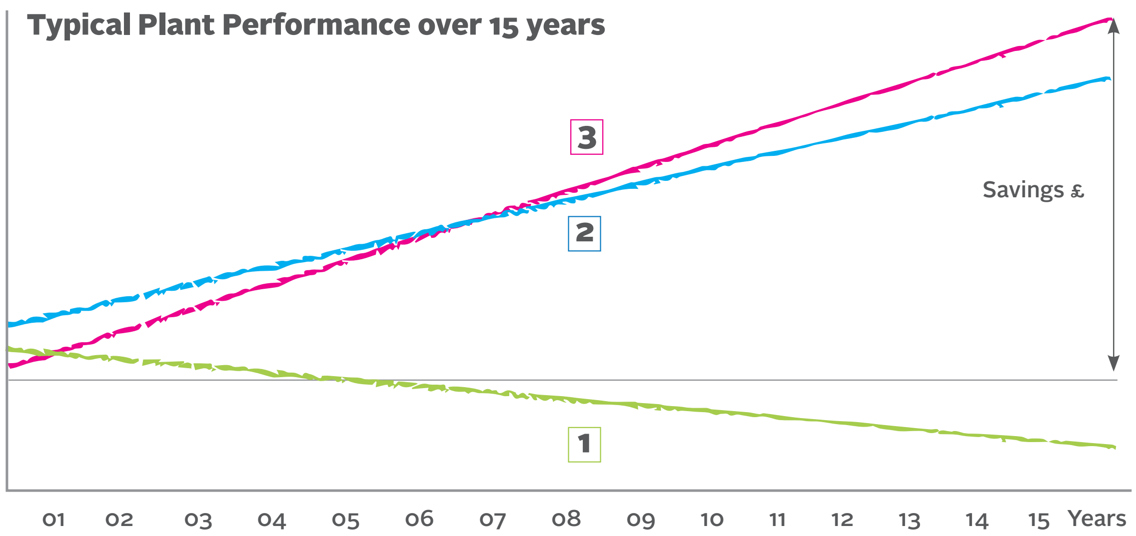
As projects are typically a minimum of 15 years, it's inevitable that things change - site size, personnel, technology and energy prices. Although the Contract caters for much of this, it's independent Performance Assurance through Monitoring and Verification (M&V) that truly safeguards the long term savings by drawing on the CEF in-house knowledge pool to steer a way through any potential uncertainties that can, and do, arise.

Our in-house team of consultants, legal, finance, contract management and M&V experts not only monitor and verify savings and performance on a regular basis, but check and double check any decisions and actions a contractor or Trust may want to implement in the event of any performance discrepancy or change in circumstances.

Although Capital constraints may make it difficult for some Trusts to justify 'platinum level' maintenance contracts, a 'belt and braces' approach is not the prudent option to take, as the Plant Performance illustration over the page demonstrates.

Contract & Performance Assurance not only pays for itself, but protects the Trust from poor outcomes, and through regular engagement with all parties involved, ensures fair and proper Contract enactment and the savings guarantee delivered.

Contract Guarantees +	Performance Verification =	Contract & Performance Assurance
• Robust and proven NHS contracts • The Trust receives continuous support from in-house: - *Qualified solicitors* - *RCIS quality commercial managers* - *Specialist EPC project managers* - *Chartered engineers to agree the design development*	• Independent M&V conforming to International Standards • Bespoke EPC software and client App • Quarterly and year end reconciliations • Daily independent data collection • EU ICP EPC assurer qualified • Continuous support from a team of in-house: - *Chartered engineers* - *Certified measurement & verification professionals (CMVP) / IPMVP specialists* - *Data quality managers* - *Specialist App and software developers*	• Contract & Performance Assurance has proven to deliver savings in excess of 50% greater than the NHS average • Proven achievement of positive outcomes for NHS Trusts during operational period of energy projects • Professional resource on tap covering potential change or disputes and promoting continuous improvement to maximise scheme benefits throughout the project term • Detailed knowledge of the Contract to ensure that performance is monitored and delivered



Without independent M&V. Scheme carried out directly by client	1
Average 62.2% plant availability*	
Incomings 1 year	£559,800
Outgoings 1 year	£300,000
Incomings 15 years	£8,379,000
Outgoings 15 years	£9,100,000
NET POSITION	**-£703,000**

Independent M&V using CEF Contract & Performance Assurance Internally funded	2
Average 92% plant availability**	
Incomings 1 year	£828,000
Outgoings 1 year	£306,000
Incomings 15 years	£12,420,000
Outgoings 15 years	£8,822,000
NET POSITION	**£3,598,000**

Independent M&V using CEF Contract & Performance Assurance Externally funded	3
Average 92% plant availability**	
Incomings 1 year	£828,000
Outgoings 1 year	£556,000
Incomings 15 years	£12,420,000
Outgoings 15 years	£8,527,000
NET POSITION	**£3,848,000**

**62.2 average availability calculated from ERIC returns for year ended April 2017.*
***92% average availability on the CEF scheme using Contract & Performance Assurance*

2. Implementation

Ideally, Contract & Performance Assurance should start as early as possible in the project lifecycle, certainly by business case approval stage, and continue throughout implementation and operational stages.

This will ensure that the project is established against a fully understood baseline, which has been adequately sensitivity-tested, meets internal organisational, clinical or site-specific operational parameters and, where appropriate, is normalised against external influences such as seasonal weather changes.

The Contract & Performance Assurance team should check and oversee the basis on which existing energy consumption information, utilities costs, existing plant efficiencies and wider lifecycle operational aspects are applied.

For a simple lighting replacement project, Contract & Performance Assurance may be limited to ensuring that a realistic baseline is established and that accurate before-and-after testing and measurements are conducted. For complex, larger-scale schemes, such as Combined Heat and Power (CHP), a defined set of key performance indicators (KPI's) on plant performance and availability will be required to ensure that real savings are achieved.

3. Measurement and verification

Verification is crucial to maintain long term confidence in an energy saving scheme, demonstrating that it delivers benefits consistently over time through any future estate changes. Any energy project should include a Measurement and Verification (M&V) Plan that establishes:

- how a project will be set up.
- how the baseline conditions will be established.
- how energy saving measures will be instigated.
- how it will be measured.
- what data is collected.
- how the savings will be demonstrated, verified and monitored during operation.

Basic M&V plan. The Contract & Performance Assurance team should oversee the development of this plan and subsequently make sure that all aspects of it are always correctly conducted, during both pre-and post-installation periods. They will also ensure that commissioning proving is properly documented and, if the project relies on local metering, that enough time is allowed for data proving before acceptance.

Specialist M&V expertise will be needed on the Contract & Performance Assurance team to ensure that recognised best practice is being followed and that there is proper auditability of project outcomes. Various recognised M&V standards, guidance and best practices have been developed over recent years, including:

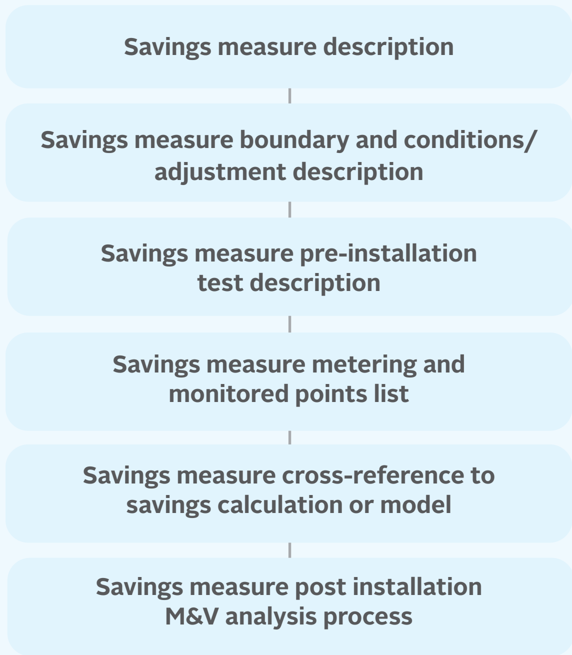
- International Performance Measurement and Verification Protocol (IPMVP) – the most widely applied standard.

- ISO 50015:2014 Energy management systems - Measurement and verification of energy performance of organizations - General principles and guidance.

- Investor Confidence Project (ICP) Quality Assurance program.

These are all aimed at establishing a common set of principles and guidelines, to promote the value of applying M&V processes correctly and consistently and increase the credibility of performance improvements.

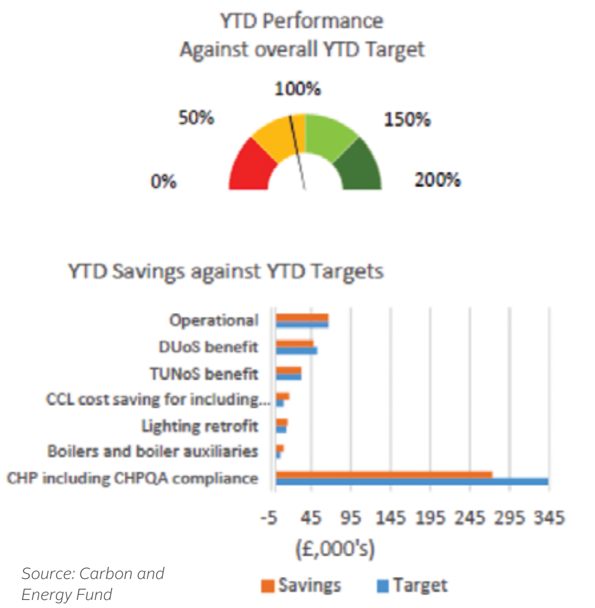
Published guidance, by necessity, is generic across sectors, and therefore it is important to try and procure expertise from practitioners with proven M&V application experience in the health sector.



Basic M&V Plan

4. Reporting

Depending on the scope and complexity of the energy scheme, regular operational stage reporting and auditing will be needed to maintain adequate oversight of the ongoing scheme performance and to promote communication between stakeholders. A typical CHP scheme is likely to require monthly liaison meetings between operators and estates personnel, with more formal quarterly auditing of performance involving the Contract & Performance Assurance team.



Source: Carbon and Energy Fund

5. Benefits, validation and costs

The intended benefits of Contract & Performance Assurance are the avoidance of uncertainty and assurances on the level and consistency of the energy savings being delivered. This may include fundamental evaluation of impact data, utility and operational cost savings; establishing changes in conditions that have affected those savings; monitoring KPI's; achievement of plant availability targets; and assisting with unexpected events.

Typically, M&V costs range between 5% and 10% of total project costs. A scheme overseen by a Contract & Performance Assurance team should deliver a very real benefit. Its value will be demonstrable in monetary terms by showing proven additional savings and avoiding savings or performance being misreported. *(Please refer to the Typical Plant Performance over 15 years illustration on Page 58).*

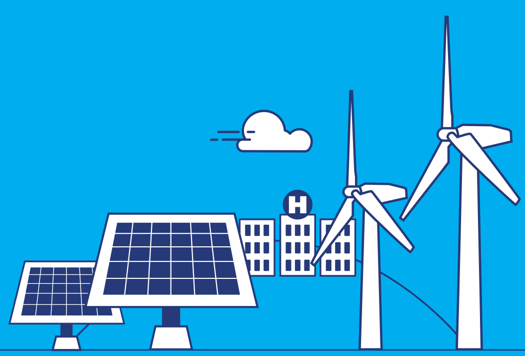
References

- ***International Performance Measurement and Verification Protocol*** - *https://eevs.co.uk*
- ***Investor Confidence Project*** - *http://www.eeperformance.org*
- ***ISO 50001 Energy Management*** - *https://www.iso.org*

ENERGY GENERATION

STAGE 1

- Biomass Boilers
- Combined Heat and Power



Biomass Boilers

KEY FEATURES

- Can provide steam, HTHW, MTHW or LTHW
- Well established, mature technology in use worldwide across many sectors
- Eligible for Renewable Heat Incentive payments
- Typical carbon saving potential up to 25%
- Plant life circa. 20 years.

1. Introduction

The term biomass refers to a broad range of fuels that are derived from matter that was once living, such as energy crops, sewage sludge, wood, straw and animal litter. The technology used to convert the fuel to useful heat varies significantly depending on the fuel itself. This guide focuses on the most popular biomass heating technologies that have been deployed on NHS sites, namely wood pellet and wood chip fired biomass boilers. It is also possible to operate standard boilers on biogas (bio-derived methane). This requires adjustment to the burner as the fuel typically has a different calorific value to standard natural gas. Biogas is also covered in the section on CHP.

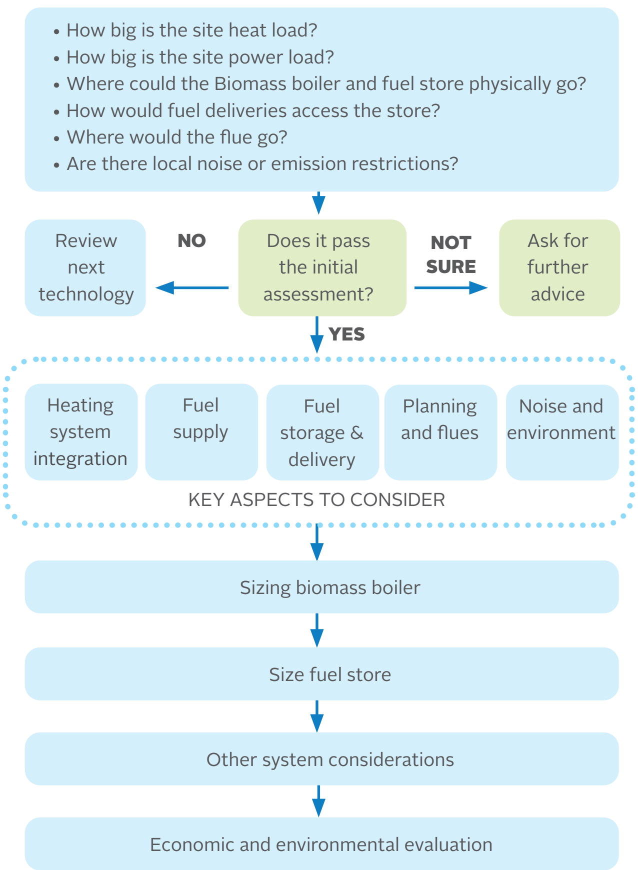
Biomass boilers use a well-established, mature technology, and have been deployed in other countries and sectors with great success. They are available in a range of sizes from a few kilowatts to several megawatts. There is a range of biomass installations in UK hospitals, although actual numbers of installations remain relatively low. Although 25 sites across the NHS are reporting use of renewable heat (2015/16 ERIC report), not all will be using biomass technologies.

Currently biomass is financially supported by the UK Government through the Renewable Heat Incentive (RHI), whereby operators are paid per kilowatt hour of useful heat produced. This mechanism helps to balance out the increased cost of biomass installations compared to gas, and the differential in fuel cost. The RHI payments are index-linked and guaranteed for 20 years from the date of accreditation.

Different types of wood chip and wood pellet boilers are available, depending on whether the site requires steam, HTHW, MTHW or LTHW. Biomass boilers can also significantly reduce site carbon emissions, even after accounting for the carbon footprint in fuel transport. Importantly, NHS experience has generally shown that biomass boilers, particularly larger installations, require more operator intervention than equivalent gas-fired plant. Biomass boilers also cannot rapidly adjust heat output like gas fired plant, so need be sized to the site heat baseload, with other heat generators providing the remainder. Some installations will benefit from the inclusion of thermal storage, although this needs to be considered on a case-by-case basis.

Engaging with fuel suppliers at the start of the project is essential, since the type and specification of available fuels and the vehicles available for fuel deliveries will set important engineering design criteria for the project. In this respect biomass is unusual, since the technical solution is determined by both site and fuel supplier requirements.

2. Initial assessment of feasibility



The chart above shows the process of establishing whether the project is likely to be viable and if it is worth proceeding to a detailed feasibility study. More details are provided in the table below.

Q How big is the available site heat load?

A Generally, biomass boilers will be used to supply heat for space heating or domestic hot water. Biomass boilers are available in a wide range of sizes, so can supply small heat loads, but multiple small biomass boilers could present operational challenges.

Q Where could the biomass boiler and fuel store be physically located?

A Smaller size units (circa 200kW) can be supplied packaged in a shipping container sized form that includes the boiler, thermal buffer and integrated fuel storage. Larger systems will require a plant room. A 1MW steam wood chip boiler would require a plant room around 7m x 4m x 4m (l,w,h) and a separate fuel store of around 150m^3. See section on fuel store types for typical arrangements.

Q How would fuel deliveries access the store?

A Fuels are delivered by either rigid or articulated lorry. Consideration needs to be given to how the vehicle could access the site, including any overhead obstacles. Bear in mind that, for convenience, the site might prefer deliveries outside of core hours.

Q Where would the flue go?

A A biomass boiler will need a flue, the height of which will depend on boiler size and local dispersion requirements. If possible, an existing chimney with a disused or spare flue is ideal.

Q Are there local noise or emission restrictions?

A Biomass plants, whilst significantly reducing carbon emissions, can be restricted or prevented in certain air quality management areas or smoke control zones. Before developing any project, it will save time and money to establish at an early stage whether it will achieve local authority planning approval.

3. Implementation: heating system integration

Biomass boilers are available in a range of sizes and heat outputs including Steam, HTHW, MTHW and LTHW. Heating system integration is therefore relatively straightforward.

For LTHW, MTHW and HTHW systems, boilers can be integrated into existing distribution headers to share loads with other heat plant. The boiler will need to be integrated into the existing boiler sequencing and BMS systems to ensure optimum efficiency.

For biomass steam boilers, consideration needs to be given to the interaction of the boiler with other steam-raising plant, to ensure the controls enable the biomass boiler not to be set back when working alongside much larger steam boilers. As with non-steam boilers, integration with boiler sequencers and BMS systems is essential to ensure effective and efficient operation of all plant.

4. Choice of fuel type

It is important to establish the availability of different fuels. The chosen fuel needs to be available from a range of suppliers and, as best as can be established, available for the life of the boiler operation (circa 20 years). Selecting a fuel only available from one supplier risks the hospital being held to ransom during later stages of the project, unless the price can be locked in.

The table below compares key features.

	Wood pellet	Wood chip
Consistency	Wood pellets are a very consistent fuel type available in 6-8mm diameter for smaller systems and 10-12mm diameter for larger systems. Fuels are covered by EU standard EN14961-2.	Wood chip is a more variable fuel source, particularly with sizing and moisture content. Care must be taken if purchasing by weight to systematically check fuel moisture content at point of delivery and for objects in the fuel that could jam feed mechanisms. Wood chip is normally supplied to a given particle size (G30, G50, G100) and a maximum moisture content (20%, 30%, 40%); the greater the moisture content the lower the energy density and the price, but more product is required to produce the same heat. Boilers will be designed to operate within a given range of fuel specifications.
Space required	The volumetric density of pellets is ~650kg/m3 and their energy density is ~4.8kWh/kg, so a 1MW boiler running at full output for three days would require a store of approximately 23m3, which could be configured as 2.5m x 2.5m x 3.7m (l, w, h).	Typical wood chip volumetric density is ~250kg/m^3 and energy density ~3.5kWh/kg (depending on moisture content), so a 1MW boiler running at full output for three days would require a store of approximately 82m^3, whjch could be configured as 3.5m x 3.5m x 6.7m (l, w, h). This is roughly 3.5 times the size of the equivalent pellet store.
Dust and aspergillus	Pellets can create dust, so this needs to be controlled during deliveries. Some delivery vehicles can extract and contain dust during delivery. Pellets are virtually dry, so are a lower aspergillus risk when compared to fuels with a higher moisture content.	Wood chip does not generally contain large quantities of dust. However, the comparatively high moisture content can present a risk of aspergillus and management methods for delivery and extraction must be considered, particularly if the installation is located close to critical care units. This could even include reviewing arrangements for AHU plant feeding nearby buildings.
Cost	Pellets are more expensive than chip. Prices observed in NHS hospitals in the last two years have been around 4.0 to 4.5p/kWh.	Wood chip is cheaper, in part due to the simpler production and greater variability in the fuel. Typical prices seen in NHS Trusts range from around 3.4 to 4.9p/kWh.

When the above points have been reviewed, it may still be possible that both fuel options can be included within detailed feasibility. It is worth noting that the cost of the fuel is not necessarily critical to the success of the project. Depending on the specific site requirements, it might be much simpler to install a wood pellet system, which saves significant capital cost and, compared to a more complex wood chip solution, may represent better value for money over the life of the project.

5. Fuel storage and delivery

There is a wide range of biomass fuel storage systems. System design depends on four main criteria:

- Type of fuel
- Site space constraints
- Delivery vehicle access and offloading
- Dust or aspergillus containment

The main systems that have been installed at UK hospital sites are as follows:

Blown pellet stores. The simplest storage system, in the form of simple silos, rooms, or prefabricated boxes. Pellets are blown into the store from equipment on board a delivery vehicle from up to 30 metres away, although to minimise fuel damage, a maximum distance of 20 metres is generally recommended. The boiler extracts the pellets from the store using a vacuum delivery system.

Wood chip silos. The wood chip silo can be constructed in a variety of forms. Fuels are typically delivered by tipper, hook-bin tipper, or walking floor articulated trailer. The simplest solution is for the silo to be located below the delivery point, but this is not often possible. More commonly, the wood chip will be tipped gradually into a hopper from which a variety of mechanisms such as augurs, bucket lifts and conveyors transfer the fuel to the silo. The mechanisms depend on the proximity of the offloading station to the silo and should be designed with simplicity in mind to ensure maximum reliability. Consideration must be given for the containment of aspergillus during delivery, where this is a site requirement. The bottom of the store will usually have a sweeping arm and an augur to transport the fuel from the silo to the boiler, usually via a small day storage bin.

Ro-ro hook bins. Roll-on, roll-off Hook Bins, typically 30m^3 to 35m^3 are used as a combined delivery and storage system. The bin is delivered onto a framework containing an augur. Once the bin is depleted it is removed and another delivered. The system has the advantage that the fuel remains in the container until it is required and therefore helps to minimise risks associated with dust or aspergillus. Where space permits, twin bins enable continuous operation and speed of delivery. If this is not possible, consideration needs to be given to loading and offloading space. This system is usually best suited to medium sized boilers (circa 500kW), as larger boilers will require high delivery frequencies. However, hook-bins have been coupled with larger silo systems on NHS sites.

Walking floor trailers. The fuel is delivered in a walking floor articulated trailer and the walking floor mechanism is connected to the boiler plant management system, which then controls the offloading. The trailer still offloads into a hopper, which usually transports the fuel to a day store, but there is none of the additional complexity seen with a silo system. Deliveries are faster, but space needs to be provided for trailer changeover. The system also usually requires a standing charge for the trailer hire.

Other storage and delivery considerations. A key requirement with any fuel storage system is the ability to remove the fuel back into a lorry, for example if a faulty load of fuel has been delivered, or boiler is shut down for an extended period (perhaps during the summer) and the store needs to be emptied.

Reliability issues with biomass are often associated with the fuel transport systems, so care in design is important to ensure that the system is robust and that it is simple to diagnose and remove blockages when they occur. Procedures for safe offloading of fuel must also be considered during design.

All biomass fuel transport systems must also be fitted with a system that prevents burn-back into the store from the boiler.

6. Planning considerations

Most hospital-scale biomass plants will exceed the permitted development criterion of 45kW. Key aspects for planning consent will be required flue height and dispersion and external features, such as stores or the entire biomass plant. Many trusts have ongoing communications with local planners, and early stage engagement when considering a biomass project will identify any specific constraints and enable these to be considered at feasibility stage.

7. Noise and environmental issues

Biomass plant are not particularly noisy, although consideration must be given to the proximity of delivery and fuel transportation mechanisms to other site activities and neighbours, as well as likely delivery times. The planning authority will also consider environmental impacts from biomass boilers, especially exhaust emissions. Where the proposed installation is within an air quality management area or smoke control zone, the local authority may impose certain requirements such as exhaust gas clean-up technologies such as cyclone particle removal.

8. Biomass boiler sizing

Biomass boilers cannot respond to rapid changes in demand, so are usually sized to meet heat base load requirements. However, as the summer heat load can be very low, it can sometimes be attractive to operate a biomass boiler only during the heating season (October to April) and this can still provide an attractive business case. This is because there are higher incentives in the RHI for the first 3,066 full load running hours.

A graph of the hourly heat demand over a 12-month period can be used to establish the heating base load. If this is not available, then scaling the site monthly demand to an hourly heating profile of a similar site can be effective. Data should be adjusted for degree days to ensure the analysis is robust.

Depending on the heating profile, it may be advantageous for LTHW biomass boilers to be fitted with a thermal store to enable the boiler to supply more of the heating load and enable it to operate a consistent rate.

9. Fuel store sizing

Fuel stores should be sized to suit operating regimes and frequency and size of fuel deliveries. Consideration should also be given to preventing fuel degradation and enabling fuel to be safely removed and transported from site if necessary. A sample calculation for an initial estimate of fuel store volume is:

Fuel store size = (((Boiler_Size x (Peak_Del * 24 * 1.25)) /Energy _Density)/Volumetric Density)

Where:

Boiler_size = Peak thermal output of the boiler.

Peak_del = Maximum permissible number of fuel deliveries per week in peak heating season.

Energy_density = Energy density of the fuel in kWh/kg.

Volumetric_density = Volumetric density of the fuel in kg/m^3.

Note: the 1.25 factor allows a 25% safety factor, which should be revised during detailed design.

For a pellet boiler of 1,000kWth with maximum permissible deliveries of three per week, this would equate to:

Fuel store size = (((1000 x (3 * 24 * 1.25))/4.8)/650)
Fuel store size = 28m^3

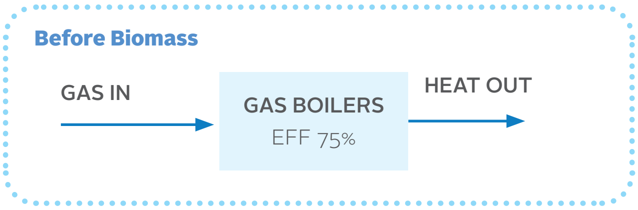
10. Other considerations

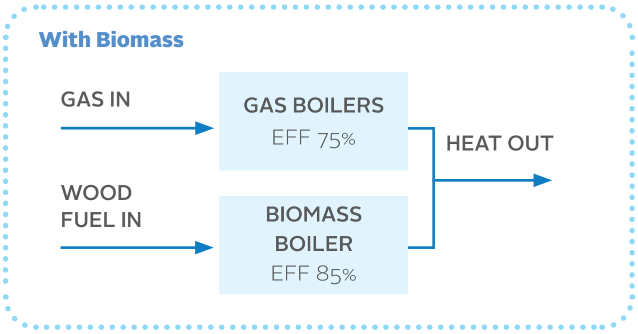
Boiler ignition systems vary between manufacturers, with some being powered by electricity and some by small natural gas burners. Consideration must be given to how suitable services can be made available to the boiler.

Biomass plant present specific aspects of health and safety that must be considered to ensure the plant is designed, constructed and operated in a safe manner. The Combustion Engineering Association has published guidance on biomass health and safety, details of which are noted in the reference section.

11. Economic and carbon evaluation

The financial case for biomass is usually made in comparison to the existing heat appliances it will offset and is shown in the diagrams below.





The financial savings associated with wood fuelled boiler plant are therefore based on a comparison between the operating cost of the gas boilers it offsets and the operating cost of the biomass boiler plus the income from the available incentives.

Renewable Heat Incentive (RHI). The Renewable Heat Incentive is a payment for qualifying renewable heat plant, with which wood chip and wood pellet usually are compliant. The scheme is administered by Ofgem and the current rates, at the time of publication, are shown in the table below. However, the rates are subject to regular review, so the latest rates should be confirmed on the UK Government website (see web address in the reference section, below).

Tariff name	Eligible technology	Eligible sizes	Tariffs
Small commercial biomass	Solid biomass including solid biomass contained in waste From 20 September 2017 the tiering threshold for small and medium biomass will change from 15% to 35% of heat load. From this date large biomass will move from a single, untiered tariff to a tiered tariff with the same 35% threshold.	Less than 200kWth Tier 1	2.96
		Less than 200kWth Tier 2	2.08
Medium commercial biomass		200kWth and above and less than 1MWth Tier 1	2.96
		200kWth and above and less than 1MWth Tier 2	2.08
Large commercial biomass		1MWth and above Tier 1	3.15
		1MWth and above Tier 1	2.21

Following changes on the 20th of September 2017, all biomass plants receive the same tariff level. Tier 1 covers the first 3,066 hours of operation and all further operation is paid at Tier 2. Once accredited, the RHI tariff is index-linked for 20 years. Biomass steam systems can be accredited through the RHI, but accreditation can be complex and early engagement with Ofgem is recommended.

12. Calculating savings

A worked example of the cost and carbon savings is shown below.

Cost savings	Without biomass	With biomass
Site heat demand (kWh)	20,000,000	20,000,000
Site heat provided by biomass (kWh)	-	5,000,000
Site heat provided by gas (kWh)	20,000,000	15,000,000
Gas boiler efficiency	75%	75%
Annual gas consumption (kWh)	26,666,667	20,000,000
Unit cost of gas (p/kWh)	2.30	2.30
Unit cost of biomass heat (p/kWh)	4.00	4.00
Total cost of gas	£613,333	£460,000
Total cost of biomass heat	£0	£200,000
Biomass boiler size (kWth)	-	990
RHI Tier 1 Revenue	£0	**£95,613**
RHI Tier 2 Revenue	£0	**£43,419**
Total cost	£613,333	**£558,468**
Total cost saving	**£54,866**	

Carbon savings	Without biomass	With biomass
Total gas consumed (kWh)	20,000,000	15,000,000
Total biomass heat consumed (kWh)	-	5,000,000
Carbon factor for gas (kg/kWh)	0.18387	0.18387
Carbon factor for biomass (kg/kWh)	0.0025	0.0025
Total carbon emitted (tonnes)	3,677	2,771
Carbon saved	**906.85**	
Carbon saved	**24.7%**	

References

- ***Planning Portal , Flues for Biomass and CHP Power Systems*** *https://www.planningportal.co.uk*
- ***Institute of Air Quality Management , Biomass and Air Quality Information for Developers*** - *http://www.iaqm.co.uk*
- ***Biomass Energy Centre*** - *www.biomassenergycentre.org.uk*
- ***Carbon Trust , CTG012 – Biomass Heating*** *www.biomassenergycentre.org.uk*
- ***Carbon Trust , Biomass Sizing Tool*** *https://www.carbontrust.com*
- ***Combustion Engineering Association, Health and Safety in Biomass Systems*** - *http://www.hetas.co.uk*

ENERGY GENERATION - STAGE 1

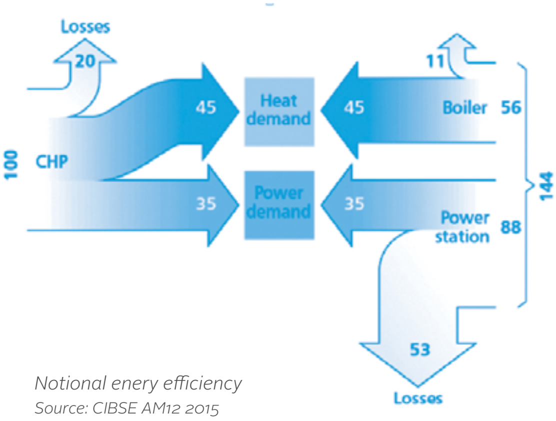
Combined Heat and Power

KEY FEATURES

- Converts gas to heat and power, displacing electricity from the grid
- Significant savings for medium and large hospital sites
- Heating infrastructure needs to be able to accept CHP heat
- Will require connection approval from the distribution network operator (DNO)
- Typical lead time of approximately 25 weeks
- 15-year life for well-maintained and operated reciprocating engines.

1. Introduction

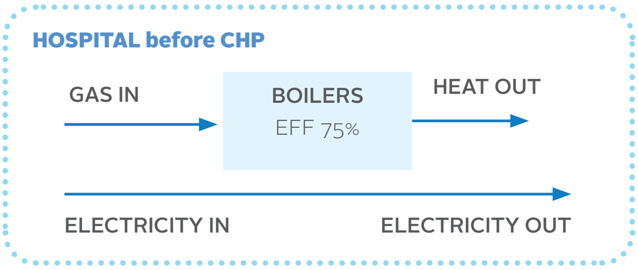
Combined Heat and Power (CHP) typically uses a single fuel to generate both electricity and heat. This is different from traditional, power station-generated electricity, which uses gas, coal, oil or nuclear to generate heat, which produces steam to power the turbines that produce electricity. Typically, the heat produced in the process must be rejected, since power stations are usually located in rural locations without access to heat consumers. CHP is more efficient and cost-effective, since both heat and power can be utilised on any site that has a suitable heat load and heating infrastructure. For acute hospitals, even small ones, it is one of the most economically attractive technologies to deploy, since it can generate some of the highest energy savings of any technology.

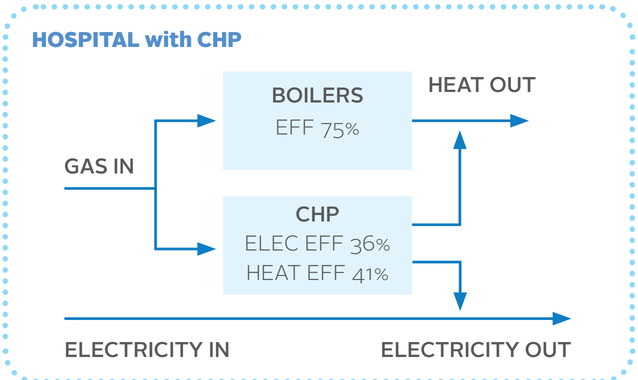


Notional enery efficiency
Source: CIBSE AM12 2015

CHP economics are therefore about changing how you supply your site with heat and power. The first diagram below shows the classic model of energy supply to a hospital site, using gas boilers and power from the grid. The second diagram shows the model with inclusion of CHP. The CHP contributes a significant proportion of the sites heat and power demand, although some heat ("top-up heat") will be required from boilers and the site will still bring in a small quantity of power from the grid.

Whilst CHP has and currently continues to be a significant revenue savings generator, particularly for acute hospital sites, it's impact on carbon reduction has been severely impacted by the rapid reduction in carbon intensity of grid electricity and relatively static carbon intensity of the gas grid. Decarbonisation of the electricity and gas supplies in the UK is essential to achieve the UK's goal of net-zero carbon. However, until the gas grid decarbonises too, most installations will see CHP as a net contributor of carbon in the medium term. More detail on this and how CHP installations can be lused to maximise carbon reduction and also maximise revenue savings to prepare for the future has been covered at the start of this guide in the section 'Roadmap to Net Zero'. It is also noted that all of the CHP technologies presented in this section have the potential to operate on biogas (zero carbon emissions) should a suitable local source be available.





2. How CHP works

There are four main types of Combined Heat and Power.

Reciprocating gas engines. This is the most common type of CHP found in the NHS. It operates in a very similar way to a petrol engine in a car, but is supplied with natural gas rather than petrol. For comparison, a typical car engine produces around 100kW of motive power, while a hospital CHP system produces electricity in the range of 500kW – 4,500kW.

Cooling water from the engine and heat from exhaust gases are used to heat the hospital, in conjunction with existing boiler plant. The cooling water (low grade heat, at about 80-85degC) accounts for about 50% of the heat produced by the engine. The remaining 50% (high grade heat) comes from the exhaust gases and can be converted to LTHW, MTHW, HTHW or Steam output.

1.2MWe Reciprocating Gas CHP at Cheltenham Hospital

The motive part of the engine is connected to an electricity generator, which, depending on the size of the engine, can produce electricity at Low Voltage (415Volts) or High Voltage (11kV).

Reciprocating engines can reduce output to about 50% of rated output, but can struggle to operate continuously at reduced loads for extended periods of time. Therefore, accurate system sizing and consideration of future site plans is essential to ensure successful operation.

Gas turbines. Gas turbines, as used in power stations, are more complex than reciprocating engines, and are more expensive for the equivalent size. Sizes range from 500kWe, although modular micro-turbines from 25-500 kWe have become available more recently.

There have been some installations in UK hospitals, with varying success. A gas turbine generally produces more heat for a given electrical output, but operates better at a continuous output. A key advantage is that all the heat is available at high temperatures to supply steam or hot water at any temperature. A key disadvantage is that electrical efficiency is impacted by the power required for fuel compression, so availability of a high-pressure natural gas supply is an important factor. It is also documented that electrical efficiency reduces notably at part load, and high ambient temperature also reduces efficiency.

Fuel cells. The fuel cell is a solid-state device that uses a chemical reaction to convert hydrogen and oxygen to heat for power and water. In commercial applications, hydrogen is produced for the fuel cell by including a steam methane reforming stage, prior to the fuel cell, that converts natural gas to hydrogen with carbon dioxide as a by-product.

Fuel cells have four major advantages: they can run continuously at part load for extended periods with only minor deviation in efficiency; they can produce all their heat as LTHW or MTHW; they have very low NOx output; and they are very low-vibration compared to reciprocating engines.

Fuel cell technology is only now becoming mainstream. There are several suppliers, and prices have reduced over recent years. Fuel cells have been deployed in hospitals in other countries, but at the time of writing it is understood they have not yet been implemented on a UK hospital site.

For hospitals with uncertainty over future loads, they represent a modular and flexible solution that can adapt to varying heat and power demands. They also have higher electrical efficiencies than reciprocating engines. More detail on fuel cell CHPs is provided in the Fuel Cells section of this guide.

Other technologies. Other technologies that can be deployed for CHP include Stirling Engines, Organic Rankine Cycle engines, liquid fuel biomass CHP, biomass CHP using gasification of wood, or gas from anaerobic digestion or other thermal treatment of waste. These technologies are more specialised, and except for Stirling Engines, have seen limited application in the NHS. Stirling Engine-based CHP is particularly suited to low-power applications and small buildings such as ambulance stations and small treatment clinics.

Biogas CHP is an alternative option for all of the types of CHP described above. Biogas is methane derived from organic matter and can be produced from a number of methods such as gasification or anaerobic digestion. Biogas, like natural gas, can be transported in pipes reasonably efficiently over a long distance so the biogas producing plant does not necessarily need to be on the hospital site. There are also some minor incentives available for biogas CHP plant through the Renewable Heat Incentive.

Hydrogen is considered to be the eventual carbon neutral combustion fuel that will eventually replace natural gas. It is possible to procure hydrogen fuel ready boilers today that currently operate on natural gas and can be easily change to hydrogen in the future when the fuel is anticipated to become widely available. It is also possible to run CHP from hydrogen, although the ability to viably convert existing natural gas CHP plant over to hydrogen without a major reconfiguration will depend very much on plant age and design. However, assuming hydrogen was available to utilise now, it is certainly possible to procure a purposed designed hydrogen fuelled CHP today.

3. Factors determining CHP installation

In the 2014/15 ERIC return there were 142 CHPs listed, There are several factors that affect the cost of CHP installation and, ultimately, whether the project is viable. **Available heat loads.** It is essential that a CHP system contributes as much to the heat load as possible with only minimal heat rejection if any. It can appear financially attractive to operate a CHP to maximise power generation (electricity led), however if operated on mains gas this strategy will undermine carbon reduction priorities. Many hospital sites have centralised heat distribution systems, which are ideal for integrating CHP. LTHW is the easiest to integrate, since the CHP low-grade heat will be directly compatible. For Steam, MTHW and HTHW systems, a source for the CHP low-grade heat needs to be found. Common ways to address this are by converting an existing plant room to LTHW or installing an absorption chiller. Also see the Chillers and HVAC section for further information.

For LTHW, MTHW and HTHW systems, there needs to be a flow and return temperature differential (Delta T) of at least 10 deg C. Where systems are operated below 10 deg C, changes will be needed to increase the Delta T to a level sufficient for the CHP to transfer generated heat.

Where sites have a decentralised approach to heat (i.e. multiple gas boilers located at separate locations across the site) a centralised heat network will be required. This can significantly increase the project capital cost, although it may solve several other issues that need to be factored into the business case. Most CHP engines do not deliver heat much higher than 92 degC, and most do not function at full efficiency if the return water temperature exceeds 77degC, so consideration as to the performance needs of the hospital and return temperatures form an important factor in designing CHP installations and reducing heat rejection.

Determining the right size of CHP. Once the annual heat and power loads have been established, they need to be analysed, using heat and power profiles. It is ideal to use actual site data, but if this not available, typical profiles from other sites can be used as a proxy. It is important that CHP sizing tools consider the real world operating parameters and constraints of CHP engines, along with other heat or power generating technologies on site, to ensure accurate sizing.

Connection to power loads. The CHP needs to be able to provide as much of the site power as possible, without rejecting excessive heat. This is normally achieved by connecting the CHP to the site HV network through an existing switch or new ring main unit. A key challenge can be the location of the HV network open point. These are often located so that each side of the network has around 50% of the total site demand, whereas CHP needs to access the full load. Back-generating through the Distribution Network Operator (DNO) substation requires DNO permission and changes to metering configuration. Alternative technical solutions include moving the open point, or installing different HV switchgear.

Available mains gas pressure. Available mains gas pressure. Finally, once a size and model of CHP has been determined a GT1 study might be required to establish the pressure available in the site gas main and assess if this is sufficient for the requirements of the engine and, if not, what additional infrastructure is required. It is important to note that most CHPs for hospital sites will need a medium pressure gas supply.

No	Item	Description
1	Saving from imported electricity	The CHP generates electricity for site so less is required to be imported from the grid. The offset is: **Total Elec Saving = {CHP Day Output (kWh) x Elec Day Rate (£/kWh)} + {CHP Night Output (kWh) x Elec Night Rate}**
2	Saving from gas for boilers	The CHP offsets heat that would have been produced by existing boilers. The offset is: **Saving from Boiler Gas = CHP Heat Output (kWh) / Unit Cost of Gas (p/kWh)**
3	Cost of Gas to CHP	The cost of the gas for the CHP is calculated as follows. Note that Climate Change Levy for gas does not apply provided the CHP is within the CHPQA. **Cost of gas = Total Gas Consumed by CHP (kWh) x Unit Cost of Gas (p/kWh)**
4	Climate Change Levy	The Climate Change Levy is a charged per unit of electricity imported and unit of gas imported. The rates are different for each fuel. **CCL Saving = Total Electricity Generated (kWh) x CCL Electricity Rate (p/kWh) } + { Total Gas Saved for Boilers (kWh) x CCL Gas Rate (p/kWh) }**

Triad and Demand Management

4. Calculating financial savings

Core savings formula. CHP Savings are calculated using the formula:

Total Saving = Total Electricity Saving + Total Saving from Gas Boilers + CCL Savings - Cost of CHP Gas

It is essential to use accurate energy costs, which can be found on energy bills. Using total cost per kWh averages is not appropriate, since the CHP will not impact standing charges.

5. Potential further economic considerations

There are potential savings to network charges that will further enhance the business case.

Distribution Use of Service (DUoS) is the Red, Amber and Green (RAG) charges that are levied by the local Distribution Network Operator for use of the local electricity network. The RAG charge rate is set for each half-hour period over a one-week period. Using CHP reduces the electricity imported and therefore reduces the quantum of RAG charges.

Transmission Use of Service (TNUoS) is the charge levied by the National Grid for use of the high-voltage transmission network. This was previously determined through the peak demand Triad system. The grid determines the three highest-demand half hours in the year and levies a charge based on the average power drawn from the network during these three periods. Using CHP (provided it is switched on during these periods) reduced the power demand and hence the charge. However, following the decision of Ofgem's Targeted Charging Review in November 2019 the Triad mechanism is to be discontinued from 2022. This means that TNUOS mitigation through operation of CHP during Triad periods no longer provides a benefit for CHP installations from 2022.

The UK electricity market is changing following the introduction of the Electricity Market Reform policy. This includes the Capacity Market Mechanism that rewards owners of embedded generators. For more information please refer to the Capacity Market section of this guide.

The Carbon Reduction Commitment- Energy Efficiency Scheme (CRC-EES) has now been discontinued by the UK Government and been replaced with higher Climate Change Levy (CCL) charges. The CCL is paid for every kWh of imported gas or electricity. The current rates are 0.811p/kWh for electricity and 0.406p/kWh for gas. This differential further supports the economic case for CHP.

Other Costs and Benefits. The operating costs of the CHP should also be considered. These will vary, but a typical average is around 1.5 p/kWh of generated electricity. Further savings can be achieved on some schemes through inclusion of boilers within the CHPQA boundary, which saves CCL charges on gas supplied to the existing boiler plant. Whilst the CHP produces electricity, it also consumes electricity in the form of pumps, fans, control systems, etc. This is referred to as parasitic electricity consumption and should be deducted from the total electricity produced. Parasitic losses vary between units, but as a guide are typically a continuous load ranging between 15 and 50 kW.

6. CHP Economics: an example

The example below is based on the following parameters:

- Medium sized hospital consuming 20GWh of gas and 10GWh of electricity per annum.
- 1,000 kWe CHP with availability of 90%, thermal efficiency of 41% and power efficiency of 36%.
- Hospital average energy costs of 1.9p/kWh for gas and 9.4p/kWh (bare rate) for electricity.
- CHP capital cost of £1.3million and maintenance costs of 1.58p/kWh of electricity produced.

	Before CHP (Business as usual)	After CHP (Reduced cost scenario)
Electricity from grid	£1,130,000	£239,108
Gas from grid	£460,000	£670,779
Energy costs	**£1,590,000**	**£909,887**
CHP Operational Costs	£0	£124,567
CHP Cost of external finance (15 year)	£0	£111,800
CHP Opex and Finance Costs	**£0**	**£236,367**
Total Costs	**£1,590,000**	**£1,146,254**
Annual Saving (Year 1)		**£443,746**
NPV (15 years @ 2.5% indexation)		**£7,957,216**

This model excludes additional benefits such as avoided DUoS charges, which would further enhance the business case by around £50,000 to £100,000/ annum depending on local DNO charges.

CHP capital costs vary depending on the complexity of the installation. The costs in the example above are based on a conservative £1,300/kWe.

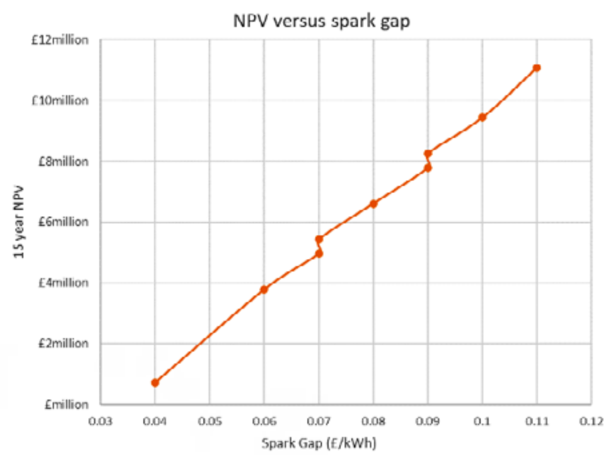
7. Economic sensitivities

Spark gap. CHP economics are particularly sensitive to the difference between the cost of gas and electricity, which is known as the spark gap: the closer gas and electricity prices get, the less economically attractive the project becomes. CHP efficiency doesn't change, so if the price of gas drops, so does the cost of the electricity produced by the CHP. If the cost of imported electricity rises, the differential between the cost of importing electricity and self-generation increases.

It is therefore important, when assessing the financial impact of CHPs, to review current energy costs and undertake sensitivity analysis to establish the strength of the business case. In the example above, if the cost of gas dropped by 0.5p/kWh and the price of electricity increased by 0.5p/kWh (i.e. a spark gap increase), the year 1 annual savings would increase to £306,915 and the NPV over 15 years would increase to £5.5million.

Gas price	Electricity price	Spark gap	Annual (1 year)	NPV
0.03	0.07	0.04	£41,000	£728,000
0.02	0.08	0.06	£211,000	£3,785,000
0.03	0.1	0.07	£277,000	£4,969,000
0.01	0.08	0.07	£303,000	£5,428,000
0.02	0.1	0.08	£369,000	£6,612,000
0.03	0.12	0.09	£435,000	£7,797,000
0.01	0.1	0.09	£460,000	£8,256,000
0.02	0.12	0.1	£526,000	£9,440,000
0.01	0.12	0.11	£618,000	£11,083,000

Note: The annual savings and NPV are rounded to the nearest '000.



Note: the small steps in the chart above show that the financial performance is also partly influenced by absolute tariff.

Exporting energy. For some schemes, it might viable to export electricity during times of surplus, where there is a demand for CHP heat but where the CHP will produce an excess of power. An agreement to export is required from the DNO, as is a contract with an energy supplier to purchase the exported units. Modifications might also be required to the site electricity meters. Export rates need to offset the costs of production and the value of the heat that is being used on site. The table below shows the export rate required to break even, using the rates from the example in section 7 and based on an export quantum of 10,000kWh.

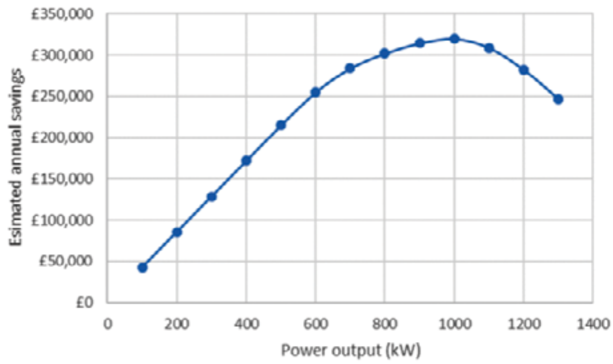
Excess power	10,000	kWh
CHP gas consumed to produce export	27,778	kWh
Heat used on site	11,389	kWh
Cost of CHP gas	£555.56	
Cost of boiler gas saved	£303.70	
Additional CHP maintenance costs	£150.00	
Export revenue	£401.85	
Export rate (to break even)	**0.0402**	**£/kWh**

In this case, a minimum price above 4.25p/kWh is required to produce additional revenue to the Trust.

Heat can also be exported, if there is a large heat consumer nearby such as a swimming pool or district heat network. However, arrangements for this are more contractually complex and should be considered on a case-by-case basis.

CHP size - bigger is not necessarily better. The chart to the right shows CHP sizes for a sample scheme. There is an optimum point in the CHP size, beyond which the economic benefit decreases. The primary reason for this is the inability of CHPs to reduce output below about 50% for extended periods of time. It is therefore prudent to select a size that leaves some headroom for reduction in site load that may result from further estate improvements over time.

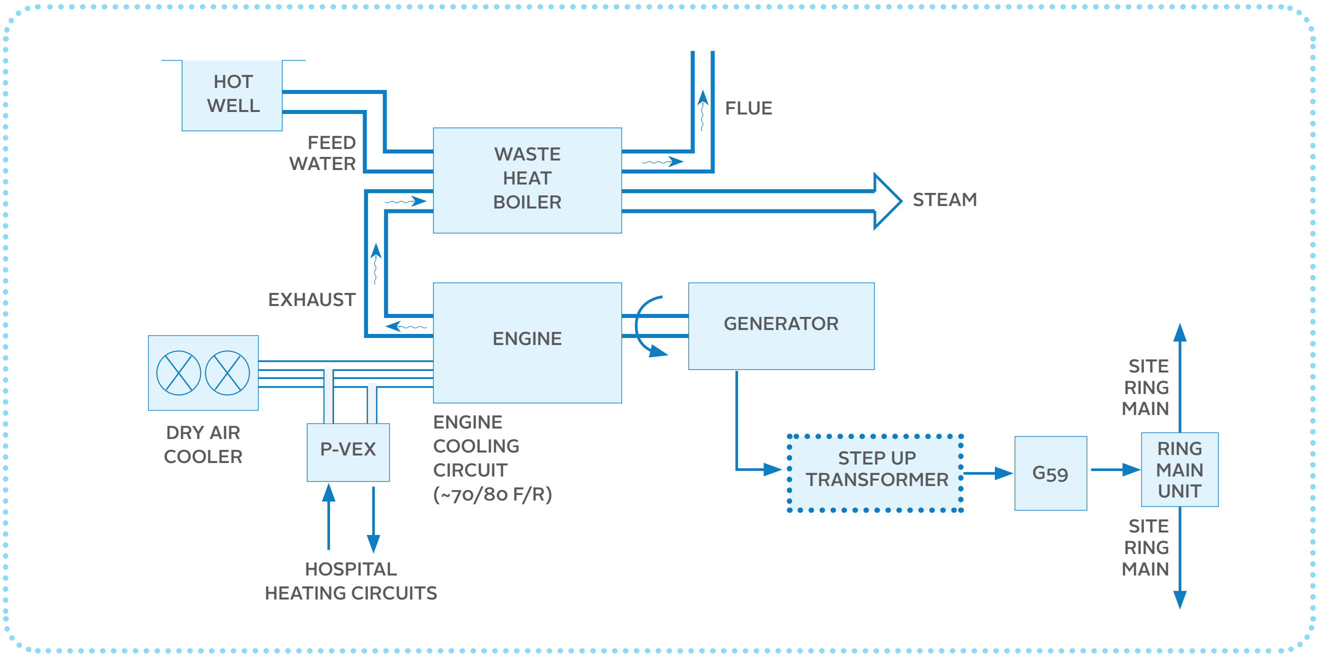
Capital costs. To a lesser extent, CHP projects are impacted by capital cost. The capital costs of engines generally increase in proportion with size. In addition, overall project costs depend on the complexity of the installation and the ancillary equipment that is, or is not, required for a project.



8. Ancillary plant

The CHP engine and generator are only part of the equipment required to implement a CHP project. Several ancillaries are required as shown in the following diagram and table.

ENERGY GENERATION - STAGE 1



Item	Description
Heat rejection	• All CHPs should be installed with a heat rejection radiator capable of rejecting all the low grade (engine jacket cooling) heat. • Also known as a Dry Air Cooler (DAC) or dump radiator. • Protects the engine by maintaining correct engine temperature in the event of failure of the system transmitting CHP heat to the building. • Allows maximum electrical output to be delivered during periods of low building heat requirement (where this is economically attractive).
Waste heat boiler	• Required for systems needing to produce steam from CHP exhaust gas. • Works using the same principles as a conventional steam boiler but uses CHP exhaust gases in place of a conventional fuel burner. • Can be supplied as a combination boiler that is also fitted with a conventional burner.
Absorption chiller (optional)	• Allows waste heat to be converted into chilled water. • Lower seasonal efficiency (COP = 0.6 to 0.8) compared to electric chillers (COP = ~3 to 4.5). • Economics for tri-generation (heat, power, cool) are site specific and will not be applicable to all sites.
Gas booster (optional)	• Required for sites where mains gas pressure needs to be increased to meet CHP requirements. • Approval from gas shipper is required
Step-up transformer	• Enables low voltage CHP engines to convert output to high voltage to supply hospital HV ring main (usually the preferred method). • High efficiency models should be specified to maximise return on investment <<need to insert a guide of value difference of low and high eff transformers and savings over life>>.
Ring main unit	• Required to enable the CHP to connect to the site HV network. • Might not be required if the CHP is able to connect to spare switch on an existing substation.

Item	Description
Mains protection (G59) relay	• Monitors stability and quality of incoming site electricity supply and disconnects the generator if the network exceeds parameters set by the local Distribution Network Operator (DNO).
Lubrication oil tanks	• Supplied as clean and dirty tanks, usually located outside of the CHP enclosure for convenience of servicing. • CHP control systems monitor oil quality and automatically replace oil using these tanks.
Control system and metering (including for parasitic losses)	• Monitors and controls all CHP functions. • Provides telemetry of alarms and performance data to enable remote – Data frequency monitoring and management. • Can be proprietary and might need to be changed in the event of change of maintainer. • Should collect energy data (heat utilised, power produced, parasitic power consumed, gas consumed) at half-hour frequency to enable accurate appraisal of ongoing economics.
Plate heat exchangers	• Enables low grade heat from the engine cooling circuit to be connected to (for Low Grade Heat) hospital heating circuits. • Hydraulic isolation between CHP cooling circuits and hospital heat distribution prevents accidental contamination of either system and seen as best practice.
Acoustic enclosure	• CHPs should be supplied with outdoor or indoor acoustic enclosures. • Typical specifications for hospitals range from 65-75dBa at 1 metre.
Flues	• A CHP will require an exhaust flue if one is not already available. Flues can be mounted within an existing chimney structure or on a separate chimney. • Gas turbines are sensitive to back pressure and to freewheeling (being spun by an updraft when they should be stationary)
Thermal buffer vessels	• For some site energy demand profiles, it may be advantageous to incorporate a thermal store. A thermal store is essentially a large hot water tank. The CHP can continue to run at higher outputs, where electricity demand is higher than the required heat, but store the heat to enable it to be used at a later period. Likewise an ice-store or cold water store may supplement absorption chilling.

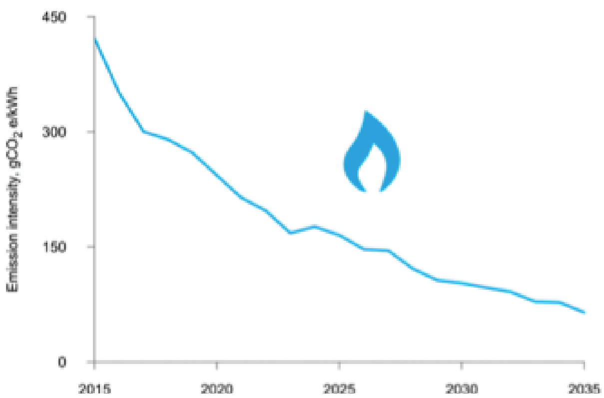
9. Carbon savings

In the past a CHP project would have made a significant contribution to NHS targets on carbon reduction. However, with the progress made in grid electricity carbon reduction in recent year,s this has eroded. The same sample calculation (below) in the original version of this guide showed an 18% reduction in carbon compared to a 5% reduction using the current carbon factors. However, if using biogas as the fuel source the carbon savings remain excellent and a CHP project can be used to generate revenue savings that be invested to prepare the estate for future low carbon technologies. The table below shows carbon savings based on the same example as shown in section 7 and using 2020 carbon factors;

	Without CHP (Business as Usual)	**With CHP** (Reduced Cost Senario)
Electricity from grid	2,532 tonnes	536 tonnes
Gas from Grid	3,677 tonnes	5,362 tonnes
Total Carbon Emissions	**6,209 tonnes**	**5,898 tonnes**
Annual Carbon Saving (Year 1)		**311 tonnes**
		5%

The UK Government has been reducing the carbon intensity of the national grid and it is noted that the table above shows a significant reduction in carbon savings compared to the original version of this guide where the electricity carbon factor was much higher.

The chart below from the Governments Energy and Emissions projections (2015) shows the target reduction. As the grid emissions reduce the carbon benefit will decrease, however the cost of implementing grid carbon reduction is likely to increase electricity costs and therefore increase the spark gap.



Source: Updated energy and emissions projections 2015, Department of Energy and Climate Change

10. Governing legislation and compliance

There are a range of legislation that CHP projects need to comply with depending on size and location.

CHP Quality Assurance (CHPQA)

The CHPQA programme encourages CHP owners to operate their CHP to a "Good Quality CHP" standard. This is measured using a QI (Quality Index) measurement, which is derived from the power efficiency and heat efficiency of the unit. Units that achieve a CHPQI above 105 (for new units) are not required to pay CCL on the gas consumed by the engine and receive an exemption from HMRC (renewed each year provided performance continues to exceed requirements).

Medium Combustion Plant Directive (MCPD)

CHPs can be designed to operate at different NOx levels, and with clean air rules constantly tightening, the choice of engine and its efficiency is coming under pressure from environmental requirements. The MCPD is a European Directive that requires operators of combustion plant with an input of 1MWth to 50MWth to regulate pollutant (SO2, NOx and dust) within specific parameters. For new CHP plant this sets a NOx limit from 2018 of 250mg/ Nm^3 at 5% excess oxygen.

G59 and G83

G59 is an Engineering Recommendations document produced by the Electricity Networks Association (ENA). All embedded generation above 50kW that will be synchronised with and run in parallel to the utility network must follow the requirements of these recommendations. Review and approval of a G59 application is undertaken by the Distribution Network Operator (DNO). For generators below 50kW, G83 applies. This is an essential requirement for connection and Trusts should try and establish if there are any network constraints that would otherwise prevent approval of a new embedded generator at their site or if any additional grid reinforcement costs will be levied by the DNO.

Planning

CHP installations often require planning consent unless they can be sited within an existing building, and even in that situation ancillaries such as the heat rejection radiators, oil tanks, and flues need to be located externally. Planners, particularly in areas with an Air Quality Management Plan (AQMP), will request a flue dispersion study to ensure the proposed project does not impact air quality. Noise emissions are also of interest to planners. Typical specification for reciprocating CHP engines is 65-75dBa @ 1metre. Planning requirements can require no increase in the noise levels at site boundary, in which case the position of the energy centre and its construction can become determining factors and require extra sound attenuation.

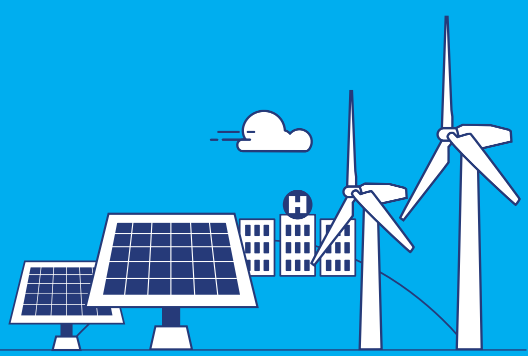
References

- ***BEIS, Combined Heat and Power Quality Assurance Programme*** - *https://www.gov.uk*
- ***CIBSE, AM12 Combined Heat and Power forBuildings -*** *http://www.cibse.org*
- ***CIBSE, CHP NOx Datasheet*** - *http://www.cibse.org*
- ***CIBSE, Datasheet 03, Gas Turbine CHP*** - *http://www.cibse.org*
- ***Energy Networks Association*** - *http://www.energynetworks.org*
- ***Estates Return Information Collection*** - *http://hefs.hscic.gov.uk*
- ***European Commission, Medium Combustion Plant Directive*** - *http://ec.europa.eu*
- ***NHS Sustainable Development Unit – Saving Carbon Improving Health***
- ***Ofgem - Targeted charging review: decision and impact assessment*** - *https://www.ofgem.gov.uk*

ENERGY GENERATION

STAGE 2

- District Heating
- Electricity Storage
- Energy from Waste
- Heat Pumps
- Solar Photovoltaic



ENERGY GENERATION - STAGE 2

District Heating

KEY FEATURES

- Utilises waste heat to provide local heating requirements
- Combined with CHP, can represent a step change in fuel conversion efficiency
- Hospitals in a scheme can be heat providers, consumers or both
- Can offer opportunities for funding de-steaming
- Resilience and compatibility need careful consideration.

1. Introduction

District heating (DH) is the connection of two or more buildings to one or more shared heat sources.
As shown in the diagram below, around 50% of the energy contained in the raw fuel that goes into the UK's centrally generated electricity network is lost as heat, since there are no convenient local consumers for the heat.

DH networks are local, so they can utilise the waste heat. They can be entirely contained within a site of single ownership, or be part of a network that distributes heat to consumers in a town or city. Many acute hospital sites already have some form of their own district heating network, where a central energy centre supplies steam or hot water to various buildings on the site.

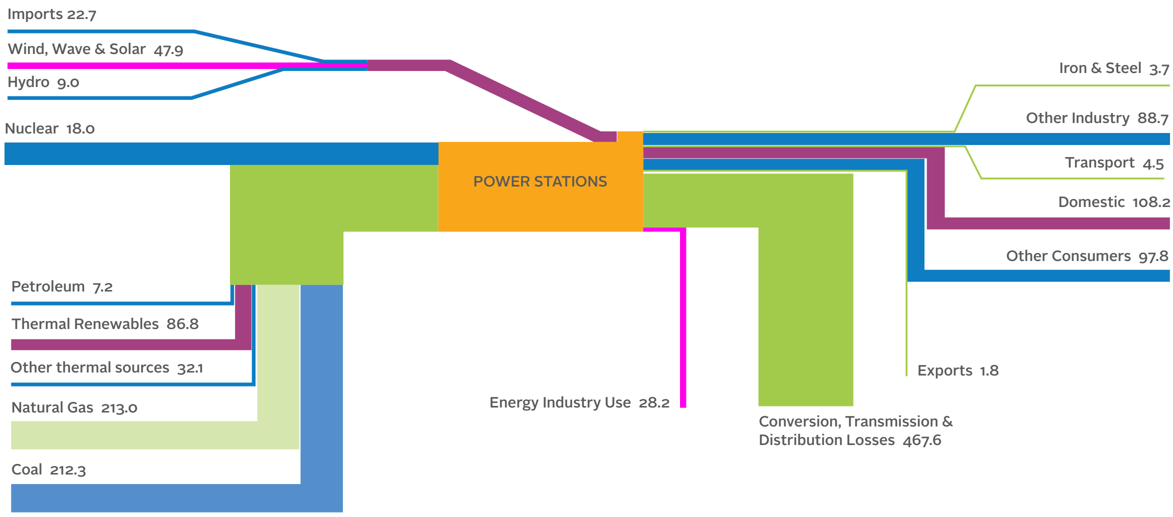
DH networks can have one or more heat source, and several source types are suitable. The most common choices are combined heat and power (CHP) with top-up gas boilers, or utilising heat from landfill gas plant or geothermal plant. CHP-generated DH enables the waste heat from power generation to be captured and used locally, thus increasing the overall system efficiency. For more detail, see the CHP section of this guide. There are also emerging systems that use a type of district heat loop that transfers very low temperature heat between bi-mode heat pumps that can delivery heat to some consumers and chilled water to other; however the right balance of loads is necessary for such a system to operate successfully.

When coupled with heat from CHP, DH provides a step change in fuel conversion efficiency, compared to traditional methods. The key is to utilise some form of waste heat, rather than simply replace decentralised boiler plant with a centralised boiler plant.

2. Assessment of feasibility

A strong case can be made for investment in DH by bringing several smaller consumers together to create sufficient volume and diversity of load.

Electricity Flow Chart



Source: Digest of United Kingdom Energy Statistics 2016, Department for Business, Energy & Industrial Strategy

The UK Government, through the Department of Business Innovation and Skills and led through local authorities, has a programme for undertaking feasibility studies and funding public DH networks. Through this initiative, several hospitals have been approached to become consumers of heat from a network and, in some cases, providers of heat to the network.

This section outlines some of the issues that should be considered by Trusts considering joining a public district heat network. The market is continually evolving, so it is worth keeping an open mind when being approached by DH operators.

For those interested in finding out more, the Chartered Institute of Building Service Engineers (CIBSE) has produced a Code of Practice (CP1) that sets out guidance on how to approach DH schemes. It is recommended that Trusts considering DH schemes consult this publication or one of CIBSEs accredited DH consultants.

Heat delivery. District heating networks can utilise any heat medium, but most are based on Low Temperature Hot Water (LTHW) with a typical operating temperature differential of 30 degrees, to achieve maximum system efficiency. Heat is circulated to consumers via a heat interface unit (HIU), which contains a plate heat exchanger and metering system for billing. The plate heat exchanger(s) maintain hydraulic separation between the network and the consumer, to prevent any cross contamination.

System compatibility. Hospitals considering participating in a DH scheme need to establish if their site's existing heating infrastructure will be compatible with that of the DH or, if not, whether it can be easily upgraded. For example, a hospital with its own LTHW DH network should be able to connect reasonably easily to a DH scheme; whereas a steam-based hospital would need to look at partial or full site de-steaming. If the steam assets are at end-of-life, this could be a good opportunity to work with the DH scheme to co-fund a de-steam project, reducing backlog and improving resilience.

Resilience. Resilience is key to hospital heat and power systems. Boiler plant usually have dual fuel boilers (typically gas and oil) and are designed for N+1 resilience (i.e. sufficient plant to cover the peak demand plus one spare). In joining a DH scheme, Trusts need to consider how resilience will be maintained, either through the DH provider or continuing in part or whole with their own plant. Where a Trust is a heat provider, rather than a consumer, this risk is mitigated, and the Trust is paid a fee for the energy supplied to the network. This can be attractive, particularly on sites where the electricity load is high in comparison to the heat load and where connection to a DH network would enable larger CHP plant to be installed, generating increased savings. However, Trusts also need to be mindful of the long-term availability of the load and ensure that, in the event of the DH load reducing over time, that it has the necessary contractual protection.

Financial. The cost of heat from DH networks is usually higher than the cost of gas since the network operator needs to cover the cost of installing and operating the infrastructure. It is generally considered that consumers can afford to pay more than the raw price of gas, since they do not pay for boiler servicing, repairs and replacement, or standing and unit charges for fuel supply. Trusts entering DH arrangements should seek professional advice on contracts and also ensure that the costs and risks are appropriately apportioned.

For example, if the hospital needs to retain existing infrastructure to maintain resilience, it would be expected that the heat supply charge would be lower.

Existing NHS experience. The greatest opportunity seen in the UK for heat networks has been where the hospital is adjacent to one or more major energy consumers. In these cases, a common energy centre serving the needs of those consumers can be constructed, maintained and operated through a multi-party agreement. In this situation, the parties collectively retain control of the operation and issues of resilience can be addressed. An excellent example of this is the Leeds teaching hospital and Leeds University joint energy centre. The two organisations are partners in the Generating Station Centre (GSC), which supplies heat and power to both campuses.

References

- ***CIBSE, District Heating CP1*** - *http://www.cibse.org*
- ***UK Government, Digest of UK Energy Statistics (DUKES)*** *https://www.gov.uk*

Electricity Storage

KEY FEATURES

- Enables the Trust to reduce energy costs and increase resilience
- Cuts electricity costs by reducing exposure to peak power prices and grid fees
- Makes best use of on-site generation
- Excess storage capacity can be offered on the energy market to generate additional income
- Capital costs have reduced in recent years with development and mass manufacture of battery cells for the automotive industry
- Can enable sites unsuited to CHP to participate in the Capacity Market and Triad Avoidance.

1. What is electrical storage?

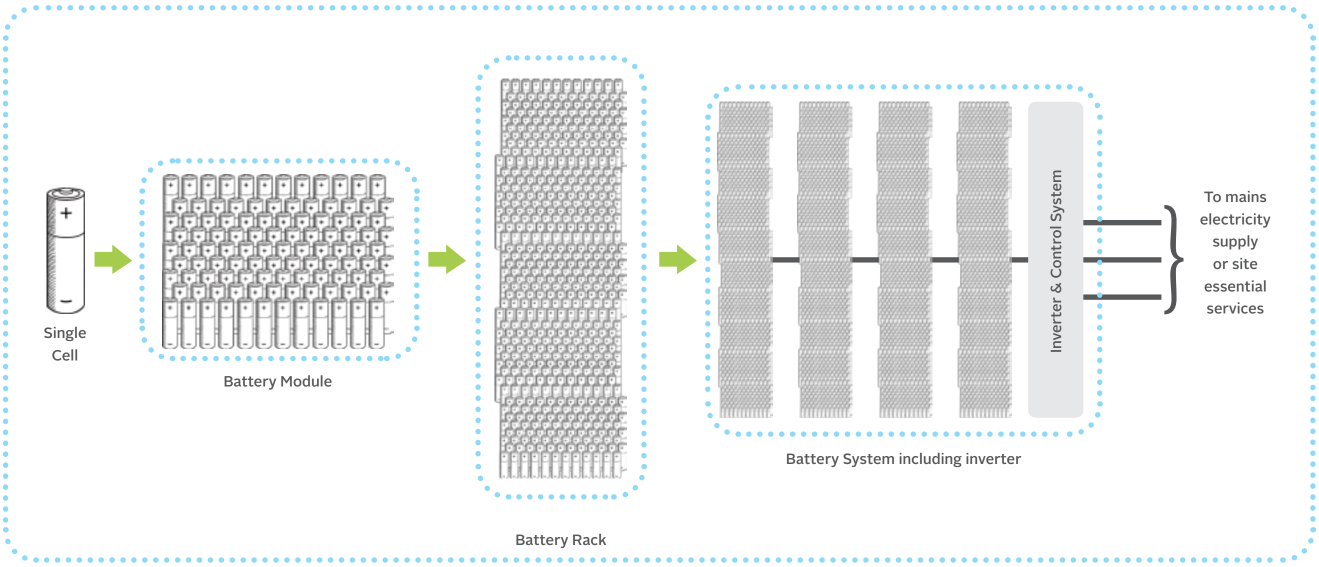
Electricity storage is most likely to be provided by batteries in a hospital environment. In batteries, electrical energy is converted into chemical potential energy for storage and the process is reversed when the electrical energy is required. An inverter is required to convert the site AC power to the DC power in the batteries.

Battery storage systems have historically been used in hospitals as UPS (Uninterruptable Power Supply) systems for loads that require maximum resilience, such as operating theatres and data centres. However, with the increase in charges for using electricity at peak times (Triad/TNUoS, DUoS etc.) plus the potential to earn income from helping the grid at times of both high and low load (capacity market, demand response etc.) there is the opportunity to benefit financially from a battery storage system. For example, a battery storage system could allow a hospital to store excess on site generation (from renewables or spare CHP capacity) or obtain electricity at a cheaper rate (from purchasing off-peak grid electricity) and store it to use at a time when electricity is more expensive, or unavailable.

Large-scale battery storage systems historically used flow cell technology, but with the development of the electric vehicle industry, lithium cells are becoming the technology of choice for stationary applications such as in a hospital, as they are often lower cost and require smaller plant footprint.

2. How battery storage works

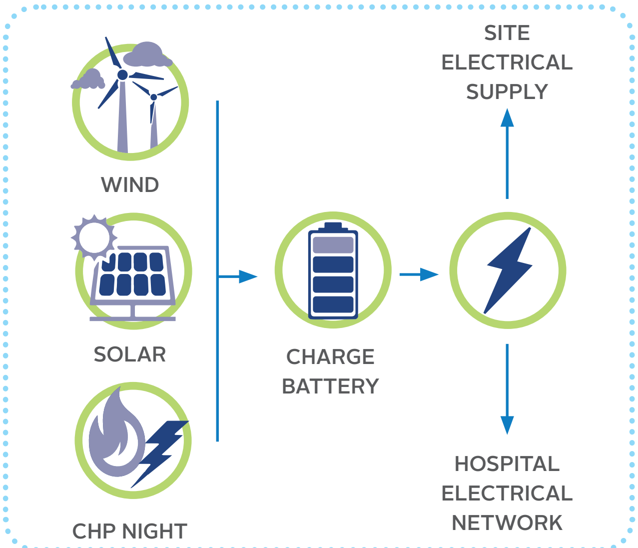
Battery systems at a basic level are very simple and usually built up from hundreds or thousands of small cells, as shown in the diagram below. Technology is evolving rapidly and there are different cell chemistries and structures depending on the type and requirement of the application. For example, prismatic cells are designed for very high discharge rates for applications such as the Formula E racing series. However, these cells are more volatile and have shorter lives. The 18650 cells as shown in the diagram below (so named because of their 18mm diameter and



65mm length), are more commonly found in applications requiring more gradual discharge and longer life.

Battery systems comprise a series of racks that are connected to an inverter and a battery management system. Each rack contains a series of modules and each module contains several cells. The configuration of racks and modules is based on the required operating voltage, battery capacity and anticipated charge and discharge cycles. A critical factor in battery management systems is the detection of cells that are failing and those that are starting to overheat. The battery management system continuously monitors cell temperatures and where it identifies a problem will shut down the module or rack until the problem is resolved. Some systems may have supplementary cooling but heat loss should ideally be minimal, as any heat generated is wasted energy. The inverter converts incoming AC to DC and back to AC as required. The battery management system also monitors the state of charge and ensures that the system cannot be overcharged or charged too quickly.

The electricity storage system is connected to the site's electrical network and delivers power to the site and the local grid system as required.



3. Initial assessment

When considering battery storage technologies for a hospital estate the following questions should be considered during initial assessment:

- How big is the site power load?
- What is the Peak/Off-peak demand?
- Is there existing renewable generation or an opportunity for it?
- Are there generation units with under-utilised periods or periods of surplus generation?
- Is there sufficient connection capacity in the network?
- What site locations could be suitable for a battery?
- Are there any power quality issues?

4. Implementation

Battery systems are extremely modular and scalable and can be installed both indoors and outdoors, typically using modified shipping containers. Battery systems have no moving parts and therefore have extremely low noise levels and require limited maintenance. In addition, they do not generate emissions during operations.

Costs are developing with the technology, and range to £3 to £4K for a system suitable for a house or similarly sized facility, to c. £1,000/kWh for a larger unit. There is a nascent industry that uses recycle electric vehicle batteries which reduces costs further to c. £500/kWh. The development of the Tesla and Panasonic Gigafactories should also help drive down costs.

Small household/ ambulance station sized devices will require connection to a dedicated MCB on the main incomer board. Larger installations require careful integration into hospital power systems, due to the nature of the fault currents and fault modes that can occur should a unit's control system fail. For most instances, the control system will disconnect the batteries in a controlled manner in the event of a fault outside or inside the battery installation.

One of the biggest safety issues with batteries is that they remain live, even when the mains is removed. Most systems use high voltages and maintenance requires very specialised safety measures, often involving special non-magnetic tools and protective clothing. It should also not be forgotten that Lithium batteries can burn fiercely, releasing toxic fumes, and that such fires do not respond well to most fire extinguishing systems, since a lithium battery fire is self-sustaining. However, this should not be a significant risk for systems that have been designed to best practice guidance.

Most battery systems will need a grid connection agreement to be connected to the network.

5. Calculating savings

Battery technology can deliver revenue and cost savings through several different channels. These can be divided into two categories, reduction in existing energy bill costs and revenue through participation in energy markets, such as Fast Frequency Response.

Energy bill cost reduction. The main energy bill cost reductions that can be achieved through installation of a battery system are: DUoS and day/night rates, where the battery can charge during Green band Night rates and discharge during Red/Amber band Day rates; and TNUoS, where the battery is charged outside of Triad periods and discharged during Triad periods.

It should be noted that DUoS and TNUoS charges are changing in April 2022 which is likely to see a reduction in savings from these two elements.

Participation in energy markets. The primary revenue generator for battery systems come from balancing services such as Frequency/Demand response, FFR, EFFR and other forms used to assist the national network when it is under pressure. These services require very short-term usage that may require several iterations over a period of unstable system frequency. Batteries are ideally suited to such applications since, unlike diesel generators, they can have almost instantaneous response.

Reserve services such as the Capacity Market, STOR and similar look to bolster the electrical network for a few hours at a time when the network is under heavy usage. An example is set out in the table below:

Energy bill savings	
Triad	£14,700
DUOS	£4,000
Energy market revenue	
Capacity market	£4,800
Fast frequency response	£36,000
Energy cost of operation	
Battery efficiency loss	-£2,700
Other O&M costs	-£1,500
Total annual benefit	**£55,300**

The above savings are based on a 300kW battery using recycle electric vehicle batteries that would cost around £168,000, installed. Whilst this offers an attractive payback, consideration should be given to the nature of the Capacity Market (see section on CM) and Fast Frequency Response as there currently is no certainty over long-term revenue rates. As more providers join the market it is likely the price will reduce. However, it is not known how long this will take. Triad savings are also due to be completely eliminated by April 2022 along with a likely reduction in DUOS savings.

Batteries can also provide other benefits to Trusts as follows:

Negating connection costs. Some Trusts are constrained by the site power supply or, in some cases, within certain substations onsite. A battery can enable the peaks and troughs to be smoothed out, drawing additional power during periods of low demand and topping up in periods of high demand. Based on some DNO reinforcement costs for additional supply capacity, this can enhance the case for a battery, particularly if it is supporting a business case for expansion of clinical services elsewhere onsite.

Optimising renewable generation. Many Trusts have invested in solar photovoltaics. Combining a battery with a solar power system enables a Trust to store surplus solar-generated electricity during times of low electricity rates and then use it to offset import of electricity from the network during periods of high unit rate.

6. Other considerations

Battery life. Battery life depends on the application and on the warranties negotiated with suppliers. 12+ years is typical, so the business case above is therefore built over this time. Factors to consider include the deterioration of the batteries over time, redundancy of circuits, the risks of overheating, and that it is generally not sensible to charge batteries to 100% or discharge them to 0%, so the best installations operate between 20% and 80% of the nameplate capacity of the cells.

Resilience. Batteries can be used to support Trusts suffering from power quality issues. Some hospital units have highly sensitive power requirements, where small voltage dips can be crucial. The grid operator is not forced to act if the drops are within the statutory allowed range. After an investigation into the duration and frequency of drops, a battery may be the right solution, though modern electronic hospital equipment is generally hardened against mains voltage and frequency variations, as are sensitive MRI and linear accelerator technology.

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ENERGY GENERATION - STAGE 2

Energy from Waste

KEY FEATURES

- Existing incineration plant likely to be old/ at end of life
- New replacement incineration facilities on sites which do not already have existing waste treatment plant are unlikely to secure permissions/licences very easily
- New technologies offer more efficient and acceptable alternatives to conventional incineration
- Significant savings to be made on third-party offsite disposal
- Business case can be complex but compelling for some hospitals.

1. Introduction

Energy from waste covers a broad range of technologies. For the NHS, the most common technology used is incineration. However, incineration poses its own issues and opportunities and there are also emerging technologies that have the potential to offer innovative new solutions.

2. Incineration

Healthcare clinical waste is usually sent off site for incineration by third-party waste management contractors.

Some large acute hospitals have their own on-site waste incinerator facilities, which may also take waste from other sites and third parties. Existing on-site incineration plants within hospital estates might be considered as a valuable asset to the hospital, or a liability, depending on whether their continued operation remains viable.

Where incineration is possible, heat can be harvested indirectly from the incineration process to supplement or partially supplant gas boiler use for space heating and DHW, or to provide heat for absorption cooling. The amount of energy recovered will depend on the make-up of waste feedstock (calorific value), the amount of supplementary firing required from gas, and the efficiency of the heat recovery boiler deployed.

However, many onsite incinerators are old and may have reached end of life, or require significant reinvestment to retain their Local Authority or Environment Agency incineration licences. Hospitals that do not already have on-site incineration are very likely to have difficulty in obtaining planning and environmental permissions and licences for installing any significant new conventional incineration plant. Depending on proposed scale and hospital location, the Trust may never be able to meet these requirements or satisfy local objections.

There are, however, new types of thermal waste treatment that are more likely to meet with approval, including pyrolysis and biogas, and for some Trusts there will be a compelling case to develop them. These technologies are relatively new to the NHS, so projects should be contracted with great care to ensure that the Trust receives the benefits originally envisaged in the business case and that the risks are appropriately apportioned between the Trust and the contractor.

The fundamental problems relate to how a technology is classified under the Environmental permitting guidance: *The directive on the incineration of waste.*

3. Pyrolysis

Pyrolysis is combustion in the absence of oxygen. The process is initially heated from an external source to drive off the volatile organic compounds (VOCs) from the waste. These VOCs are then, in turn, fired to drive the first stage of the process. This happens at a sufficient level of heat (circa 1,200degC) to ensure that all pathogens are destroyed.

An advantage of these systems is that the waste heat can be out-put as LTHW, MTHW, HTHW or steam.

At a large scale (c.600kWth), obtaining permissions might be less arduous than traditional incineration, because pyrolysis is classed as advanced thermal treatment, although flue gas treatment is required to meet the criteria in operating permits. These systems can be implemented within a standard container-sized external plant room.

This type of plant benefits from continuous operation to optimise efficiency, so batching of waste is important. It also requires a team of trained operators and the Trust will need a method to divert waste to an alternative disposal source during servicing or unscheduled downtime. The latter could be provided by a third-party operator.

Typical installed costs are in the region of £1.47 million and operating and maintenance cost, including staffing, will be around £160,000/pa, before allowing for the offset cost of alternative clinical waste disposal and heat. As with other waste treatment technologies, the business case is largely dependent on the existing waste volume, segregation and costs per waste stream. Where effective source segregation has been implemented and third-party disposal costs are low, achieving a viable business case can be challenging. The NHS is yet to undertake a large-scale pyrolysis project.

At a smaller scale, pyrolysis technology is available as a small packaged solution that can be used in remote settings where it may not be cost-effective to provide a clinical waste collection service. Clinical staff can easily be trained to use the unit and it simply requires connections to water, gas, flue and sewerage.

4. Biogas (anaerobic digestion)

Biogas refers to the production of methane and carbon dioxide from the decomposition of once living matter. Biogas can be produced from:

- sewage sludge.
- landfill (i.e. Landfill Gas).
- municipal waste / food waste.
- energy crops.

Gases from landfill are not an attractive proposition for Trusts since very few hospitals are located near landfill sites. It would therefore be better to convert the gas to heat and power and ship it to the hospital via a heat and power network, thus avoiding contamination issues. Digestion of sewage sludge to biogas is popular in the UK, but the gas tends to be converted to power onsite to provide energy for pumps and other process equipment.

Municipal waste, where the biodegradable fraction has been source-separated, can be used in an anaerobic digester. The digester uses bacteria that break down the feedstock into biogas and a compost-like output (CLO). There are two types of digester bacteria, mesophilic and thermophilic, the most common in the UK being mesophilic. This operates at a lower temperature (around 36degC) and takes around 30 days to digest a batch of feedstock. It is also more reliable than the thermophilic digester. There is a wide range of digester technologies, depending on the nature of the feedstock. It is outside the scope of this document to discuss this in depth, but interested readers are recommended to visit the website of the Welsh Centre of Excellence for Anaerobic Digestion. This has a wealth of information on the technology, its features and benefits.

Once produced, biogas can be fed into a specially converted CHP engine, which produces heat and power. A key advantage of biogas CHP is that it attracts the Renewable Heat Incentive and unlike natural gas fired CHP, delivers excellent cost and carbon savings.

In practice, it is unlikely a hospital would generate sufficient suitable biological degradable waste for an anaerobic plant to be viable and, even then, it is likely that there would be concerns raised relating to potential air-borne pathogens. However, that does not mean hospitals cannot consider anaerobic digestion projects. Several local authorities and private providers are implementing anaerobic digestion plants and, where hospitals are within a reasonable range of the plant, gas can be piped directly to the hospital and converted to heat and power in a biogas CHP. Alternatively, heat and power can be converted at the anaerobic digestion plant and shipped to site via a heat network and private wire.

5. Calculating savings

Over and above the potential savings from harvesting heat, the main business case for investment in energy from waste technology is the saving to be made on gate fees for third party disposal services.

Prices for off-site clinical waste disposal typically range from £200/tonne for soft clinical waste to £600+/tonne for cytotoxic or cytostatic hazardous classification, although this will depend to a certain extent on UK region. Typical costs are shown below:

	Hazardous	Non-hazardous	Pharma	Controlled drugs (cytotoxic or cytostatic)
Average cost per tonne	**£475**	**£325**	**£500**	**£600**

Hospital waste volumes relate to size and extent of clinical activity. On-site hospital incineration facilities may be geared up for focused, segregated clinical waste incineration or limited segregation, and possibly combined with other waste streams. A typical large acute hospital may have a clinical waste volume of 1,000 tonnes a year, but with proper point-of-use segregation, half this volume might be non-hazardous class, leaving around 500 tonnes that would need incineration destruction, either on or off-site. The combination of hazardous and non-hazardous clinical waste may typically account for much less than half of the total site waste that needs to be processed. The ability to incinerate this in an onsite facility will depend on the licence and what is practical to manage.

Based on the table above and on a hospital site disposing of 500 tonnes of hazardous clinical waste and 500 tonnes of non-hazardous waste a year, both of which could be incinerated on site, the onsite incinerated waste treatment could potentially avoid average off-site costs of:

500 tonnes hazardous waste x £475/tonne = £237,500
500 tonnes non-hazardous waste x £325/tonne = £162,500
Total cost saving = £400,000

The energy recovered from a conventional onsite rotary kiln or multi-hearth stepped incinerator, processing 1,000 tonne/ annum, would be typically around 2,200,000 kWh. Given a typical site boiler seasonal efficiency of 75% to 80%, this would be worth around 2,900,000 kWh of gas. At a tariff of 2.3p/kWh, the energy saving on avoided boiler gas would be £67,000.

From this we can see that the energy savings from conventional on-site incineration are small compared to the value of costs avoided from waste processing off site. From this saving, parasitic energy losses on the system need to be deducted, such as pumps etc., but these will be relatively small.

The overall business case however, is more complicated than this, and the solution would need to consider some or all of the following aspects.

Potential cost influence on replacement incinerator scheme	Typical influences
Third party waste contract income	Usually significant if existing incinerator plants capable of taking hazardous waste have something in place to increase revenues and ensure maximum plant and staff utilisation.
Avoided operation and maintenance capex of existing onsite incinerator from replacement with new plant.	Depends if new incinerator is a replacement plant. For existing old plant, this could be significant.
Avoided off-site waste costs for existing planned onsite incinerator shut-downs.	The incinerator may be off-line for periods in the year and alternative waste disposal off-site needs to be arranged.
Avoided domestic waste costs.	Some plant may combust non-clinical waste.
Staff costs.	Is reduced staff resource to be deployed elsewhere?

A generic example of the viability of a large hospital replacement on-site incineration scheme is shown below. However, each site and project will have different influences, baselines and drivers, and will apply different technology, so the outcomes will be very different from site to site. One of the biggest drivers to improve the business case is likely to be how much additional revenue is possible from incinerating third party waste.

Net energy savings improvement from recovered incinerator heat (compared to existing recovery)	£21,000
Net improvement on existing Trust third party waste contract income	£210,000
Avoided existing incinerator	£841,000
New incinerator O & M costs	-£788,000
Avoided existing planned onsite incinerator shut-downs off-site waste costs	£47,000
Avoided domestic waste costs	£63,000
Total savings for replacement incinerator	£394,000
Total cap-ex of new replacement incinerator	£6,304,000
Simple pay-back (years)	**16 years**

References

- ***Welsh Centre of Excellence for Anaerobic Digestion*** *http://www.walesadcentre.org.uk*
- ***Pyropure*** *- http://www.pyropure.co.uk*
- ***Ofgem, Renewable Heat Incentive*** *- https://www.ofgem.gov.uk*
- ***Ofgem, Feed-in-Tariff*** *-https://www.ofgem.gov.uk*
- ***DPS Environmental*** *- http://www.dps-ps.com*

Heat Pumps

KEY FEATURES

- Well established technology deployed in HVAC systems
- Can provide heat from ground or air to buildings from electricity
- Most efficient when supplying heat to low temperature systems such as underfloor heating
- Good incentives available through the Renewable Heat Incentive.
- Ground source systems need careful design of the ground collector.

1. Introduction

Heat pumps are a well-established technology that use the same principle as a refrigerator to generate heat efficiently from electricity. In the same way that a fridge becomes colder on the inside and warmer on the outside (though the condenser on the back) a heat pump makes the outside colder and the inside warmer.

Although heat pumps consume electricity, they can, in the right situations, provide up to five times the input electricity in heat out. This ratio is known as the Coefficient of Performance (CoP). A heat pump with a CoP of 4 will produce 4kWh of heat output for 1kWh of electricity input. With the UK Government working to decarbonise the electricity grid, heat pump technology is actively encouraged as part of delivering low carbon heating solutions, supported through the Renewable Heat Incentive.

2. Types of heat pump

There are three main types of heat pumps.

Ground Source (Closed Loop). A closed loop ground source heat pump (GSHP) uses the temperature of the earth's surface as a source of heat. The temperature of the ground remains reasonably constant beyond a metre below the surface year-round, which can make it suitable for providing efficient heat during the coldest weather. Ground-source energy collectors can be deep bore-holes as much as 200 metres or more in depth, or horizontally buried coils only a meter or so deep, sometimes referred to as slinkys.

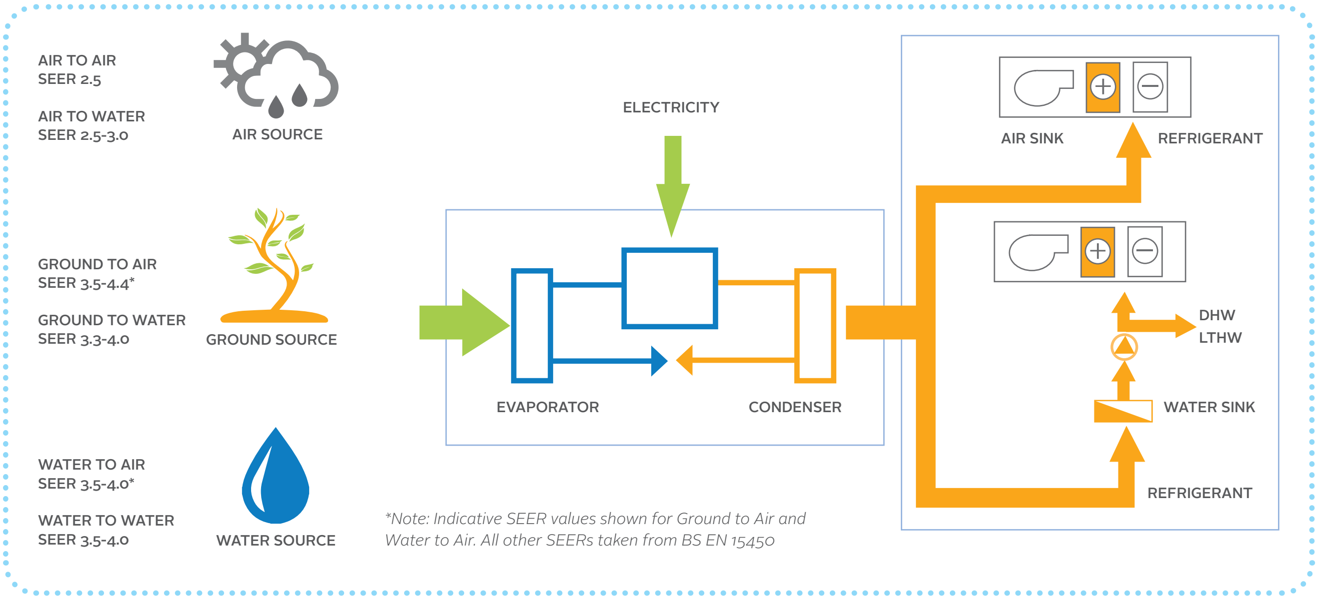
Most commercial scale ground source heat pumps will utilise bore holes as the space needed for horizontal coils becomes quickly unfeasible on most urban sites. It may be possible to locate horizontal coils under external car parks, but the rule of thumb space needed for a modest (by hospital standards) 100 kW heat output will still be around 4,000 m^2 (approximately one acre).

Vertical bore holes can be closed loop (most common) or open wells. Closed loop piles utilise a circulating fluid, usually brine or glycol in a pipe within the bore, that conveys heat transfer from the ground up to the heat pump via a brine/glycol- to-refrigerant heat exchanger near the well head.

Water Source (also known as Open Loop GSHP). Open loop boreholes extract ground aquifer water which can be used for heating or cooling via the heat pump. The ability to do this will depend upon site locality (geological conditions and water table), other users of the aquifer, and its capacity and anticipated life. It is also usually a requirement to obtain an abstraction licence from the Environment Agency. This is a specialist area and would need a suitably experienced consultant to look at in any detail. A similar approach using a specialist would be needed when reviewing the potential to utilise local rivers and lakes as an energy source.

It is important to note that Ground Source Heat is not geothermal heat. Geothermal refers to heat from springs or aquifers that pass through hot rocks. This occurs in only a few locations in the UK and produces hot water (for example Bath's natural geothermal spring produces water at 46degC and the Southampton geothermal reserve produces water at 76degC).

Air Source Heat Pumps (ASHP). Air Source Heat Pumps (ASHP) – ASHP have been utilised as part of mainstream HVAC solutions for many years. Typically, they are found at small scale within unitary packaged systems, added to provide year-round heating and cooling in areas of hospital estates where access to gas fired boilers is not viable, such as in temporary buildings or other buildings divorced from the main hospital service zones. ASHP systems are usually air-to-air; that is, they generate usable heat from ambient air which they transfer to the space via refrigerant condensing in a room-located fan-coil unit.



Heat pump efficiencies. The diagram below shows the various types of heat pumps and the net overall seasonal energy efficiency ratios shown are generally taken from BS EN 15450:2007 "Heating systems in buildings — Design of heat pump heating systems". In practice these values will vary depending on the local conditions of the energy source, manufacturers' engineered solutions and the type of building heat distribution system.

3. Implementation

To date, widespread retrofitting and integration of heat pumps at large scale within existing hospitals has been limited because the grade of heat delivered by the heat pump has been difficult to utilise effectively within existing hospital site solutions that operate on steam and MTHW.

Heat pumps typically deliver heat between 50 and 60degC. Higher temperature solutions claiming delivery of 75degC or more are now available from some manufacturers. However fundamentally, heat-pump efficiency is best when the temperature difference between source and sink is lowest. For air-source heat pumps, this means their CoP tails off the lower the outside temperature becomes, which is very inconvenient, as low external temperatures happen just when you need the most heat out of the heat pump.

A GSHP system that delivers hot water at 45degC to an underfloor heating system is likely to have a coefficient of performance of around 4.

4. Calculating savings

The economics of commercial scale heat pumps will be governed by the type of energy source chosen. Air source solutions are generally compatible with air-conditioning costs, whereas ground and water source schemes will be very bespoke.

Capital cost. Capital costs will need to reflect the civil engineering and building work required, as well as the mechanical and electrical costs. Large heat pumps may need new electricity power feeds. Savings in capital cost may be possible if bivalent solutions are provided, which enable heating and cooling from the same heat pump unit(s) and avoid separate conventional boiler and chiller procurement.

The running costs will be governed by the spark gap (difference between cost of electricity and alternative of operating a gas boiler) and efficiency improvement. It is very likely that future increases in climate change levy and potential further taxation applied on fossil fuels could make heat pump running costs more favourable. It is certainly possible to optimise heat pump operational regimes, so that they do not operate during more expensive electricity tariff periods (i.e. avoiding DUOS Red tariff periods) and that they might also operate to avoid increasing a sites maximum demand period (difference of SEER between the heat pump and gas boiler that it is replacing).

ENERGY GENERATION - STAGE 2

At the time of publication of this guide, the Renewable Heat Incentive (RHI) is available for all the primary energy source technologies identified above. Ground and water source heat pumps attract a higher tariff than air source heat pumps, reflecting the higher installation costs. These subsidies should be considered when assessing economic viability. The UK government has previously confirmed the continuation of the non-domestic RHI until 31 March 2021. The 2020 March UK Government Budget identified an allocation of 'flexible' tariff guarantees where applicants who apply for non-domestic RHI on a flexible tariff guarantee basis after July 2020 will then have until 31 March 2022 to commission a scheme and have it accredited. A tariff guarantee allows applicants to the Non-Domestic RHI to secure a tariff rate before their installation is commissioned and fully accredited on the RHI.

These projects will then be eligible to receive payments from the submission of a properly made stage 3 application (date of accreditation) for up to 20 years. It is currently understood that tariff guarantees will allow the RHI for large installations commissioned after 31 March 2021, but before 31 March 2022. This applies to water source and ground source heat pumps only. The future of RHI support on non-domestic heat pumps post 31st March 2022 currently remains unclear and so schemes in early planning stages now, may need to look hard on how the viability stacks up without RHI. A summary table of the tariffs at the time of publication is shown in the table below, based on tariffs applicable from 1st April 2020. Tariffs change regularly so readers are recommended to check the latest tariffs and forecasts on the OFGEM website.

Ground source heat pumps (100 kWth and above) - Tier 1	6.98 p/kWh
Ground source heat pumps (100 kWth and above) - Tier 2	2.08 p/kWh
Air Source Heat Pumps	2.79p/kWh

Tier 1 refers to the first 1,314 hours of operation in the year and Tier 2 all other heat generated.

The following example shows an example calculation for a 400kWth ground source heat pump that is providing a baseload of heat throughout the year as a replacement for a 400kWth gas boiler.

Before Heat Pump

GAS IN → GAS BOILER ~ 80% EFF → HEAT OUT

Afer Heat Pump

ELECTRICITY IN → HEAT PUMP CoP ~ 4 → HEAT OUT

Before heat pump	
Gas consumption (kWh)	4,380,000
Boiler efficiency	80%
Heat demand (kWh)	3,504,000
Unit cost of gas (p/kWh)	2.3 (incl. CCL)
Total cost of gas	£100,740
After heat pump	
Heat demand (kWh)	3,504,000
Coefficient of Performance	4
Electricity demand (kWh)	876,000
Unit cost of electricity in the day (p/kWh)	11.8 (incl. CCL)
Unit cost of electricity at night (p/kWh)	10.1 (incl. CCL)
Total cost of electricity	£99,024
Annual energy cost saving	£1,716
Amount of heat produced at Tier 1 (kWh)	525,600
Amount of heat produced at Tier 2 (kWh)	2,978,400
RHI Tier 1 rate (p/kWh)	6.98
RHI Tier 2 rate (p/kWh)	2.08
RHI Revenue	£98,638
Total benefit	**£100,353 with RHI** **£1,716 without RHI**

In the above example, the stand alone heat pump installation financial viability is highly reliant on RHI subsidy and its ability to achieve the COP of 3.5. A small reduction in the COP or increase in electricity price compared to gas wipes out the financial saving without the RHI buffer. That said, the case for heat pumps outside of RHI support should be significantly improved if they can be harnessed with waste heat to improve their COP, or benefit from cheap electricity from on-site solar PV. Furthermore, the UK government has already identified that the climate change levy (CCL) applied to natural gas is scheduled to rise at a faster rate in the next five years compared to the levy applied to electricity. This should improve the financial case of operating electric heat pumps, demonstrating more robust financial viabilities for schemes operating without the benefits of historic RHI subsidies.

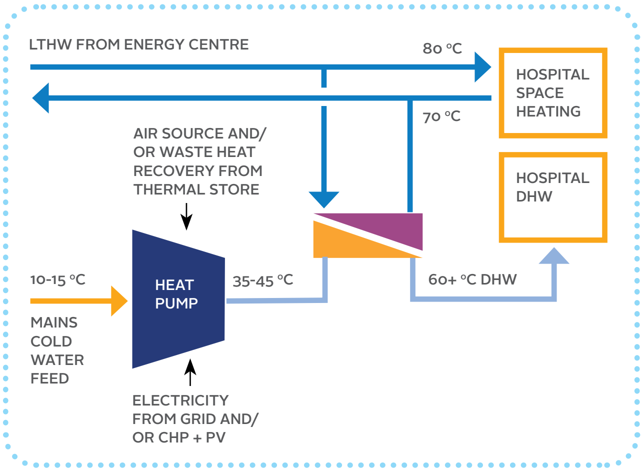
The carbon saving potential for the example heat pump operation quoted above would be circa 30% less carbon emissions compared to running a gas boiler based on current National Grid carbon intensity. This is anticipated to increase as the electricity grid decarbonises further in the next few years. It is for this reason – the heat pump's ability to decarbonise heat, that the technology is likely to increase in utilisation, despite the current limitations on energy financial savings outside of RHI support.

It is also worth noting that a heat pump drawing electricity from the utility grid will incur DUoS charges that have not been shown in the above calculation, which will reduce savings accordingly, although this can be minimised by controlling the heat pump operation so that it is not operational during the Red DUOS period.

5. Other considerations

Heat pumps for preheating. As heat pumps function better at low temperatures, it can sometimes be possible to configure heat pumps as a pre-heating system working in conjunction with other heat generators, such as gas fired boilers. However, careful design is required to ensure a meaningful heat uplift can be achieved and that the heat pump will work at an acceptable efficiency.

Although currently commercially available heat pump technology may not be able to supply temperatures that are as high as those needed in typical acute hospital distribution systems, it is possible for them to act in combination with conventional heat raising technology such as gas boilers. For example air or ground source heat pumps might act as



Potential electric heat pump at standard heat pump operating temperatures for hospital DHW baseline heat supply

the primary heat generator for domestic hot water services, heating cold water mains (at circa 10-15 deg C) up to 35 to 45 deg C, with top up heat from gas boilers or CHP waste heat ensuring normal storage and distribution DHW temperatures (at circa 60 deg C) are achieved.

Sizing ground collectors. BS EN 15450:2007 gives an indication of the range of space needed for both horizontal and vertical ground collectors, and a very approximate rule of thumb area required per kW of heat provided can be derived as shown in the table below. A geological survey should be undertaken prior to proceeding with a GSHP project along with support from a suitably qualified specialist.

Ground collector solution	Typical energy delivered (2,400 hrs/year heat operation)	Approx. horizontal coil ground area or depth of bore hole per kW of heat output
Horizontal coil	25 W/m² (moist ground)	40 m² / kW
Vertical close loop pile	60 W/m (normal conditions)	17 m depth / kW

References

- ***BS EN 15450:2007 - Heating systems in buildings. Design of heat pump heating systems***
- ***Renewable Energy : Power for a Sustainable Future, Godfrey Boyle, 2004***
- ***Ofgem – Non-Domestic RHI*** - *https://www.ofgem.gov.uk*

Solar Photovoltaic

KEY FEATURES

- One of the simplest electricity generation projects to implement
- Popular and widely used across the NHS for some years
- No moving parts, so very low maintenance requirements and good life expectancy
- Most panels expected to be producing at least 80% of the original output at 25 years from installation
- Silent in operation and provides a zero-carbon source of electricity.

1. Introduction

The term Solar Photovoltaics (PV) covers technologies that convert sunlight into electricity. PV panels comprise an assembly of solar cells, connected in one or more parallel series (known as strings) and mounted on a frame. There are three main types of solar PV panels. Silicon is the technology used for utility power generation; multi-junction and gallium arsenide are used in high performance applications, such as satellites.

Panel efficiencies for silicon cells (i.e. the portion of energy that can be converted into electricity) vary between manufacturers and models, typically ranging between 18% and 22%, with the best available achieving performance in the region of 24%.

A solar PV electricity generating system comprises several panels and one or more inverters. Systems are described in terms of kilowatt peak (kWp), meaning the theoretical peak kilowatt output. As a very rough guide, 1kWp of solar panels takes an area of approximately 7m^2.

The cost of purchasing a solar PV system has reduced significantly over the last 10 years, from around £6,000/kWp to around £1,300/kWp today, although large multi-megawatt installations can be closer to £1,000/ kWp. The cost varies with installation complexity. Car park canopies are typically the most expensive option, although they are coming down in cost and provide utility value to users in terms of weather protection.

2. How solar PV works

Solar PV panels will produce electricity from both direct and diffuse (indirect) sunlight, although the output on overcast days will be reduced. Output is also seasonal, with less output in the winter months and peak output in summer. The maximum yield is achieved when the panel is facing due south, at the optimum inclination, which in the UK averages approximately 36 degrees. Other orientations give a reduced output, although good financial cases are still achievable.

Solar PV cells and panels produce DC electricity. This is converted to mains electricity with a solar PV inverter. PV inverters usually also monitor the PV panels and synchronise and regulate their electricity output to the distribution network. Inverters also switch off the output if a fault is detected on the incoming mains electricity supply. PV systems require metering to measure the amount of electricity produced, which can be used to reclaim government incentives. Solar PV panel manufacturers usually state that their products will produce around 80% of the original output at 25 years. Inverters have a shorter life, typically around 8-10 years.

Solar PV output depends on system size, efficiency, orientation and location. Selecting a slightly higher-cost, higher-efficiency panel could result in greater financial benefit over the life of the equipment, so it is important to take this into consideration when reviewing offers from prospective suppliers. In the south of England, typical system output can be as high as 950kWh/kWp. In the north of England, this reduces to around 650kWh/kWp.

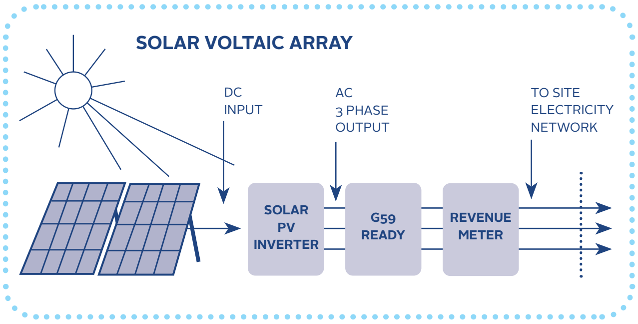
3. Implementation

Panels are normally mounted on pitched roofs in line with the pitch, on frames on flat roofs, on the ground, or above car park spaces. The solar PV market is well established and there is a wide range of suppliers providing mounting systems. When selecting mounting locations, consideration needs to be given to where the PV system will connect to the electricity grid. This is not usually an issue in healthcare facilities, particularly acute sites, as there is extensive site-wide electricity distribution and a choice of distribution boards or sub-stations where the system can be connected.

There are a number of dedicated system design tools for PV systems. The free online tool PVGIS can give a reasonably accurate guide based on system size, efficiency, inclination and geographical location. http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#

As with any estate capital project, there are considerations and risks that need to be identified and managed. The size of the project determines the significance of the different risks. Key considerations include:

- Location of electricity connection point in relation to the installation.
- Permission to connect to the electricity network (G59 approval).
- Availability and accessibility of installation locations.
- Planning permission.
- Load bearing capacity of chosen location (in some roof structures).
- Existing location features (skylights, roof vents, etc).
- Wind considerations, particularly on high buildings.
- Over-shading from trees or other buildings.
- Potential for theft or vandalism and mitigation measures.



It is worth noting that it is likely that many NHS estates would only be able to offset part of a site's electricity demand and associated carbon emissions with solar PV, even when considering integrating it with electricity storage technologies. By way of an example an acute Trust in the south of England with an electricity demand of 16,000,000kWh/annum would require a solar PV system in the order of 16.8MWe. If ground mounted that would require around 11.7 hectares of available land.

4. Calculating Savings

Savings can be achieved from two sources: the Smart Export Guarantee (SEG), where the Government ensures a minimum price for generated electricity; and offsetting electricity that would otherwise need to be purchased.

The Smart Export Guarantee (SEG) ensures that small-scale low-carbon generators are offered a tariff and payment from licensed suppliers. It applies to installation capacities of up to 5MW for Solar PV, Wind, Hydro Power and Anaerobic Digestions plants and up to 50kW for micro

Description	Total installed capacity (kW)	Total installed capacity (kW)
Standard solar photovoltaic receiving the higher rate	0-10 10-50 50-250	4.07 4.29 1.94
Standard solar photovoltaic receiving the middle rate	0-10 10-50 50-250	3.66 3.86 1.75
Standard solar photovoltaic receiving the lower rate	0-10 10-50 50-250	0.43 0.43 0.43
Standard large solar photovoltaic	250-1000 1000 - 5000	1.59 0.43
Stand alone solar photovoltaic	0-5000	0.29

It is expected that rates will continue to fall as further systems are installed.

CHP. The licensed supplier determines the tariff, payment terms, agreement length and other contractual conditions. The SEG ensure that whilst at certain times the wholesale price of electricity can fall below zero, the small-scale low-carbon generator will always receive a payment above zero.

Offsetting electricity. The electricity produced by the solar PV system reduces the amount of electricity purchased from the utility network. Current grid electricity costs vary between sites but typically, including charges, range between 10p/kWh and 15p/kWh. This represents a direct operational saving.

Exporting electricity. Most healthcare providers are large consumers of electricity and would be able to use all the electricity produced from a solar PV array. If surplus electricity is produced, the Trust can receive a payment under the FIT Export Tariff. However, this is a comparatively low sum, currently set at 5.03p/kWh and index-linked.

It is noted that the previous version of this guide featured the Feed-in-Tariff as a support mechanism for Solar PV installations. However, this scheme has since been closed to new entrants. However, the cost of solar PV installations has reduced overtime meaning that even without the Feed-in-Tariff, Solar PV projects can generate good revenue and carbon savings.

ENERGY GENERATION - STAGE 2

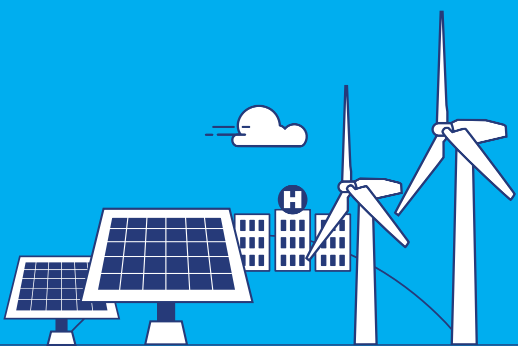
References

- ***Renewable Energy: Power for a Sustainable Future, Godfrey Boyle, Ofgem, Feed-in-Tariff*** - *https://www.ofgem.gov.uk*
- ***British Photovolatic Association*** - *http://www.bpva.org.uk*
- ***European Commission, PVGIS*** - *http://re.jrc.ec.europa.eu*

ENERGY GENERATION

STAGE 3

- Fuel Cells
- Wind Power
- Hydrogen Energy Systems



Fuel Cells

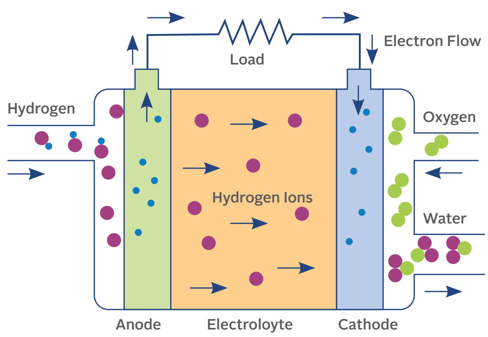
KEY FEATURES

- An alternative combined heat and power technology
- Technology is now becoming commercially viable and proven in a range of applications
- Capital and operating cost continue to reduce
- Fuel stack has a shorter life span than a gas engine
- Can provide a modular and flexible solution for varying heat and power demands
- Almost silent with minimal NOx emissions.

1. Introduction

The fuel cell is a solid-state device that uses a chemical reaction to convert hydrogen and oxygen to heat, power and water. Fuel cells are a combined heat and power (CHP) technology, meaning they produce both heat and electricity.

PHOSPHORIC ACIDAND PEM FUEL CELLS



2. How fuel cells work

In commercial applications, hydrogen is produced for the fuel cell by including a steam methane reforming stage, prior to the fuel cell, that converts natural gas to hydrogen with carbon dioxide as a by-product.

Fuel cells have four major advantages in hospital CHP applications:

- they can run continuously at part load for extended periods with only minor deviation in efficiency
- they can produce all their heat as LTHW or MTHW
- they have very low NOx output;
- they are very low vibration compared to the main alternative, reciprocating engines.

There has not been a fuel cell CHP installed in the NHS at the time of writing. However, there are several fuel cell installations in the UK and in some hospitals in America.

Most notable UK projects include the fuel cell installed by Woking Council in a leisure centre in 2003, and the Transport for London fuel cell installed in the Palestra Building in Southwark. In America, the Saint Francis hospital in Connecticut has a fuel cell CHP. Links to these projects are listed in the reference section below.

For hospitals with uncertainty over future loads, they represent a modular and flexible solution that can adapt to varying heat and power demands. They also have higher electrical efficiencies than reciprocating engines.

3. Assessing fuel cell CHP

There are several different fuel cell technologies, all with different operational characteristics:

- PEMFC: Proton Exchange Membrane Fuel Cell
- DMFC: Direct Methanol Fuel Cell
- PAFC: Phosphoric Acid Fuel Cell
- AFC: Alkaline Fuel Cell
- MCFC: Molten Carbonate Fuel Cell
- SOFC: Solid Oxide Fuel Cell

For hospital applications, the most important factors are electrical efficiency, thermal efficiency, maintenance cost, reliability and capital cost. Those factors should be compared against other CHP technologies and equivalent solutions to determine the most appropriate option to progress.

4. Implementation

Fuel Cells are assessed and integrated using the same principles as other CHP so, for further detail, please refer to the section on Combined Heat and Power.

References

- ***UK Hydrogen and Fuel Cell Association*** *http://www.ukhfca.co.uk*
- **Woking Borough Council, Woking Park Fuel Cell CHP** *https://www.woking.gov.uk*
- ***Transport for London, UK's biggest hydrogen fuel cell to generate greener energy for TfL and LDA*** - *https://tfl.gov.uk*
- ***Fuel Cell Today, Saint Francis Care Expands its Use of UTC Power Fuel Cells*** - *http://www.fuelcelltoday.com*

Wind Power

KEY FEATURES

- Larger turbines (c. 100kW) may be viable for some hospitals
- Good levels of strong wind exposure will be essential
- Site will require sufficient space for a large installation
- Planning constraints will need to be considered
- Small scale/micro turbines are unlikely to be viable.

1. Introduction

Wind turbines are an increasingly common sight in the UK landscape, mainly in open hilly areas and coastal regions. Utility-scale turbines have an individual turbine generator capacity usually greater than 1MW, and are installed in 'wind farms' where many turbines on one site are rated in tens of megawatts. They are so prominent because their large generating capacity requires turbine blades of significant size and mounting heights.

Small-scale and micro wind turbines. Generally, small scale / micro wind turbines will be capable of being either building-mounted or free-standing up to a few metres above the height of the nearest building. Typical small-scale turbines can range in generating capacity from 150W up to 15 - 20kW. Even generators of modest capacity can be quite large; the typical dimensions of a 1kW free-standing turbine may require an 8m hub height and 3.2m blade rotation diameter. It is possible to utilise vertical-axis rotating blades, which may take up comparatively less space for the equivalent capacity, but they are generally less aerodynamically efficient.

Maintenance of small scale turbines is typically in the range of 1.5% to 2% of the original investment per annum. Those looking to mount wind turbines on buildings need to give thought to the additional wind pressure that the building will be subjected to.

2. How wind generation works

Outputs from wind turbines depend on prevailing wind speed. The power of the wind is related to the cube of its speed, so at low wind speeds, power is almost zero, but when the wind is strong there will be significant increases in power. Higher wind speeds will prevail at higher turbine mounting heights.

Most sites have a low background wind speed most of the time, so high-level estimates of generation yields should be based on average speeds prevailing for the longest periods. Estimates should consider a realistic turbine mounting height as well as the impact from the proportion of the year when the wind is below turbine start up speed.

Older wind turbines generated AC and were restricted as to the range of wind that netted generation. Modern wind turbines use inverters and have a wider operational range. Despite this wind turbines, as a rule of thumb, require average wind speeds in excess of 6m/s.

Large wind turbines are controversial, largely based on the perceived noise (which is much less with modern wind turbines that have no gearboxes) and also because many people don't like the look of wind turbines. Wind turbines also have a reputation for killing birds and bats, though the extent to which this occurs is disputed.

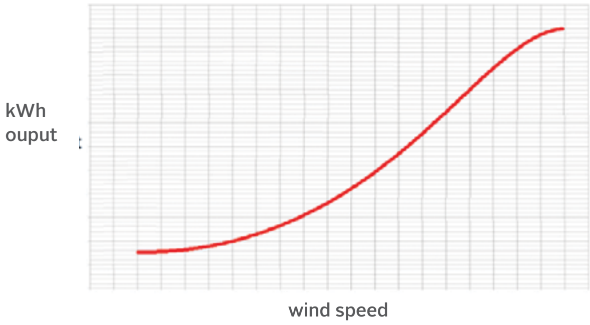
3. Implementation

Many hospital locations are situated in high population density locations, which tend to have more onerous local planning restrictions. It is possible to install a micro-wind turbine as a permitted development in certain domestic dwelling situations. However, hospital sites considering small-scale wind turbines will probably fall under the requirement for compulsory pre-application engagement, which is applicable where more than two turbines or any turbine exceeding 15 metres height is proposed.

One of the few examples of significant turbine installations on a hospital site is the Queen Elizabeth Hospital, Kings Lynn. The hospital has a single utility-scale 0.8MW wind turbine on site with a 75-metre high hub and 48 metre diameter rotor. It is unlikely that a turbine of this scale could be accommodated on most urban hospital sites. Even if there were space for a 1MW+ sized unit, there would be significant licensing and approvals processes to be overcome.

The low energy exemplar hospital at Wansbeck has had a 110kW turbine sited with wind speeds between 3.5 and 14m/s. and generating 4% of the site electrical power. The wind turbine had a payback period of just under 20 years, but this was when lower energy prices were lower and prior to the Feed in Tariff.

4. Output



Electricity generation viability depends on the local topography of the site and local wind exposure. A wind study should be undertaken as part of establishing technical viability. The savings estimated below have been based upon generic allowances only:

- an average wind speed over the year of 4 m/s for a hospital site (Beaufort scale = 2, which is equivalent to a light breeze: "wind felt on exposed skin, leaves rustle, wind vanes begin to move").
- 20% of the year in calm (i.e. wind speed no more than 0 - 2 m/s).

On this basis, the calculated average annual output from a single 10 kW turbine (mounting height 12m and rotor blade diameter of 8m) would be 1.3 kW, providing annual electricity generation of c.9,000 kWh / year. This is less than a 0.1% saving on a typical hospital electricity demand and around 5 Tonnes of CO_2 savings.

A turbine ten times the capacity at 100kW rating (still considered small scale), a mounting height of 30m and rotor blade diameter of 21.5m, should be exposed to slightly higher average wind speeds and provide annual electricity generation of circa 130,000 kWh / year. This would give c.1% saving in a typical hospital electricity demand and c. 33 Tonnes of CO_2 savings.

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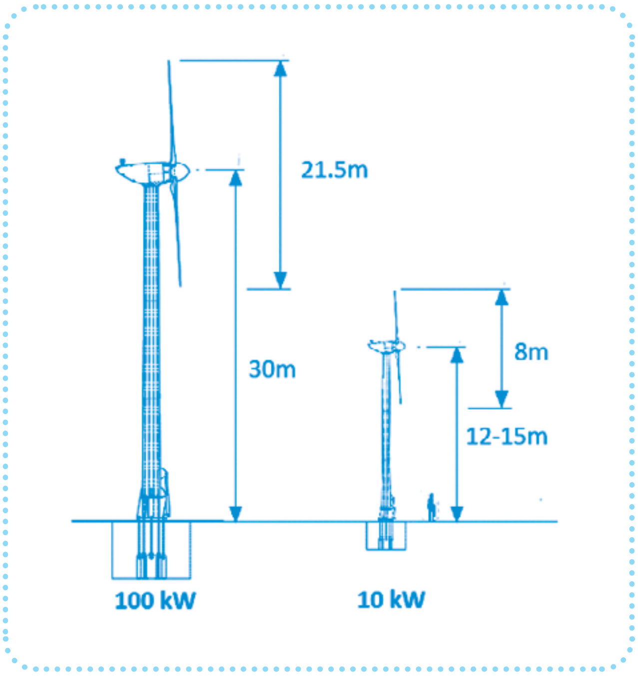


5. Calculating savings

Qualifying on-site, small-scale wind turbine installations should receive subsidies through the FiT scheme. At the time of publication, the FiT rate for wind turbines < 50 kW was 8.33p/kWh and 4.92p/kWh for wind turbines < 100kW, subject to terms and qualifying conditions. Based on the estimated annual generation output for a 10 kW turbine, the total annual savings from avoided electricity import + FiT revenue would be circa £1,600. This assumes all electricity generated is used by the hospital and that there is no export to grid.

Installation costs for a 10kW free standing turbine would be c.£50,000 -£60,000. This means it is unlikely that it will pay back within an anticipated 15-20 year life.

The actual savings achieved may vary, depending on actual wind availability. While the above estimate is conservative and there is potential for greater volumes of generation, it is important to avoid over- estimates where limited wind data and detailed generation modelling is yet to be carried out.

Larger turbines may be possible, subject to local planning restrictions and space on site.

A 100kW turbine would be nearly twice the physical size of the 10kW unit and, based on the estimated annual generation output identified above, the savings from avoided electricity import plus FiT revenue would be c.£17,000. Installation costs for the larger 100kW turbine would be c.£250,000 and it is likely the unit would pay back within 10 to 15 years.

In conclusion, small scale wind turbines are unlikely to be viable. However, if the hospital site has access to good levels of strong wind exposure, sufficient space and limited planning constraints, then larger turbine solutions have the potential to show reasonable levels of viability. Given these circumstances, widespread adoption of wind turbine installations across the NHS hospital estate is likely to be limited.

References

- ***Wind Measurement International, Operational and Maintenance Costs for Wind Turbines*** *http://www.windmeasurementinternational.com*
- ***Queen Elizabeth Hospital Kings Lynn, News*** *http://www.qehkl.nhs.uk*
- ***Renewable Energy: Power for a Sustainable Future, Godfrey Boyle Ofgem, Feed-in-Tariff*** - *https://www.ofgem.gov.uk*
- ***Renewable UK*** - *http://www.renewableuk.com/*

Hydrogen Energy Systems

KEY FEATURES

- Has the potential to realise significant heating decarbonisation for some consumers
- Likely to be focused on decarbonisation of the existing natural gas grid
- Still sometime away with some areas able to take early advantage
- Consideration should be given for 'Hydrogen Ready' in new plant procurement

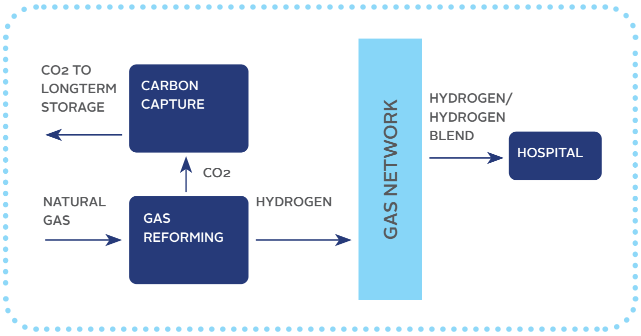
1. Introduction

There are many tangible steps an NHS Trust can take right now to begin the decarbonisation process and start the work towards meeting the NHS 'Net Zero' target by 2040. However, in defining a successful strategy it is important to also understand what opportunities may become realities within the life of the plan, such that the Trust can keep abreast of developments and adapt as those opportunities reach maturity. Hydrogen is one opportunity that some Trusts may wish to include in their longer-term strategies and for a small number of very fortunate Trusts, located within reach of pilot programmes, maybe even include in a near or medium term strategy.

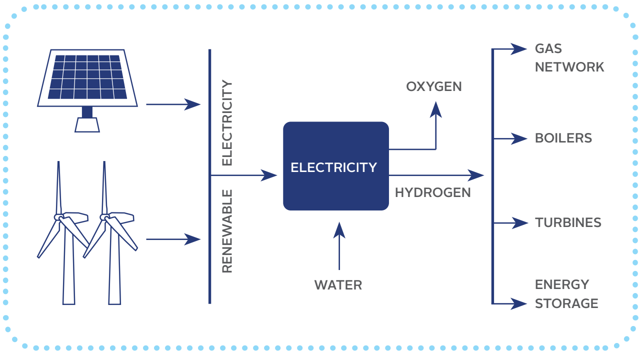
2. Production

Hydrogen is not an energy source but is an energy vector, just like electricity. Hydrogen is primarily produced using one of two methods:

Blue Hydrogen: Blue hydrogen is made from the steam reforming (SMR) of natural gas. Steam reforming is a well-established chemical process where natural gas (methane) is converted to hydrogen and carbon dioxide. In traditional blue hydrogen systems SMR rejects the carbon dioxide produced to the atmosphere. However, it is anticipated that in the future, carbon capture and storage technology will be integrated with blue hydrogen production to enable blue hydrogen to be produced with little or no carbon emissions. Provided the national gas network can support high proportions of hydrogen transmission, this could deliver significant decarbonisation of heat in the UK.



Green Hydrogen: Green hydrogen is made from water by electrolysis renewable electricity. Electrolysis is also a well-established process, where electricity is used to split water into its constituent elements, oxygen and hydrogen.



Both blue and green hydrogen have the same chemical composition and the name simply refers to how it was produced.

It is worth noting that Hydrogen can also be produced in other ways, such as a biproduct from chemical manufacture, however, these are not covered in this guide.

3. Transmission

As a gas hydrogen can be transported in much the same way as natural gas and used in combustion appliances in a similar way to natural gas. The existing natural gas network is around fifty years old. To support the journey to net-zero the network has to evolve to enable support for low carbon gases such as hydrogen and biomethane. It is estimated by National Grid that there will need to be around a 75% conversion to hydrogen from natural gas to support the UK meeting it's net-zero 2050 target.

Hydrogen is the smallest molecule and therefore can escape where natural gas (methane) molecules cannot. Hydrogen also has lower calorific value than natural gas meaning greater volumes and throughputs are required to transfer the same amount of energy. These are just two of the many complexities in adapting the gas network to enable hydrogen transportation There is a national road-map called "Gas Goes Green", which is a pathway initiative between the Energy Networks Association and National Grid to transform the network to deliver net zero.

The National Grid has a programme projects underway called HyNTS that seeks to identify the opportunities and address the challenges of transporting hydrogen within the national transmission system (NTS). There are a number of projects within HyNTS and an example of one of these projects is the Cavendish Project that seeks to create viable hydrogen production in London and the South East from the Isle of Grain.

4. End Use

Hydrogen has several potential end-uses, some, which maybe more relevant to some NHS Trusts than others. The main ones are as follows:

1. Combustion appliances such as boilers where it is 10burnt in a similar way to natural gas
2. Non-Combustion appliances where it is used in chemical reactions, principally fuel cells
3. Vehicles, where it can be used with either combustion (engines) or non-combustion appliances (fuel cell/electric) to generate motive power
4. Energy storage, where electricity is converted to hydrogen using electrolysis and stored for use in the future.

5. Combustion

From an end-user's perspective, hydrogen can be used in much the same way as natural gas. Combustion appliances need to be 'hydrogen ready' as the calorific value and some other characteristics are different from natural gas. However, manufacturers are already producing boilers that are 'hydrogen ready' and these should be considered as part of any installation or replacement programme. This is because, despite recommended lifecycles, boilers in NHS organisation can still be seen operating over 40 years after their original date of installation.

For gas fired combined heat and power, hydrogen or high proportion hydrogen blends will be a game changer. Natural gas fired CHP engines are becoming net emitters of carbon as the carbon intensity of the electricity grid reduces ahead of the gas network. If a CHP has access to a source of hydrogen, then this will enable the CHP to return to a carbon saving technology. It is worth noting that there would need to be approximately 90% zero carbon hydrogen mixed with 10% natural gas to enable a carbon positive CHP system, based on the predicted carbon emission of the electricity network in 2050. However, it maybe that some area see a wholesale conversion from natural gas to hydrogen, in which case, CHP will once again become an important technology for Trust's to consider, particularly if the spark-gap remains attractive.

5. Non-Combustion

Where 100% hydrogen supply is available, this can be used directly with fuel cells. From an NHS perspective, fuel cells are essentially a combined heat and power appliance since it produces both electricity and heat. There are also some innovations that may also enable fuel cell systems to provide oxygen to medical gas systems. For more information on fuel cell-based CHP systems, see the earlier section on Combined Heat and Power.

6. Transport

In the same way as with combustion and non-combustion appliances for stationary buildings, hydrogen can be used for transportation. It can either be used in traditional reciprocating spark ignition engines or fuel cell electric powered vehicles. Whilst this is an unlikely near-term option for NHS Trusts, it is possible that in the medium and long-term, that Trusts who have access to hydrogen distribution systems may also choose to look for hydrogen powered vehicles that may provide further economic benefit. It is worth noting at the time of writing there are a limited number of hydrogen powered vehicle, however, this may change over time.

7. Energy Storage

Hydrogen can also be used as a method of storing electricity. Energy in electricity can be converted to hydrogen through electrolysis. It is then cleaned, compressed and then stored either cryogenically (in liquid form) or as a gas. It can then be converted back into either heat or heat and power using boilers, reciprocating engine CHP or fuel cell CHP. At the current time, the round-trip efficiency of this technology is comparatively low when compared to electricity storage with batteries.

8. What does it mean for the NHS?

Hydrogen could be a game-changer for some NHS Trusts. For Trusts with older building stock that will face challenges in adapting to low temperature heat generation, such as heat pumps, hydrogen would enable an alternative path to achieve decarbonisation targets.

In the short-term, at the minimum, Trusts undertaking upgrade programmes should be seeking to ensure that all new combustion plant is able to accept hydrogen or at the very least has an option for conversion during the life of the product.

Hydrogen has the potential to make a significant difference in decarbonisation of some NHS heating system in the longer-term, however, for NHS sites located near early stage pilot projects, those opportunities could be realised much sooner and Trusts should keep abreast of developments in their areas. For example, Trusts in London and the South East that could take advantage of the National Grid Cavendish project, would be advised to explore the opportunities to become early adopters.

Finally, for Trust's considering the efficacy of combined heat and power in their future strategies, especially those with existing plant, it will be worth establishing what hydrogen opportunities exist or are planned for in their locality as that should be taken into account as part of an effective holistic energy strategy.

Finally, it is worth noting that it likely, in the future, hydrogen will also be used for commercial and private transport. These are not discussed in this edition of the guide but maybe something that Trusts may wish to explore.

References

- ***Committee on Climate Change – Hydrogen in a low carbon economy*** - *https://www.theccc.org.uk*
- ***Energy Networks Association – Gas Goes Green*** *https://www.energynetworks.org*
- ***National Grid – Hydrogen National Transmission System (HyNTS)*** - *https://www.nationalgrid.com*

ENERGY MARKETS

- Capacity Market
- Power Purchase Agreements

Capacity Market

KEY FEATURES

- An income stream in return for delivering capacity in times of network stress
- Eligible assets include CHP generation, energy storage and demand side response
- Capacity market agreements range from 1 year to 15 years
- Capacity auctions for 1 year ahead and 4 years ahead markets
- Penalties for non-delivery but these can be mitigated through secondary trading

1. What Is the Capacity Market?

The Capacity Market is a potential additional income steam for hospital sites that are already running controllable generation equipment such as CHPs or are planning to do so. While there could be other potential ways in which Trusts could participate in the Capacity Market, such as through use of backup generators, UPS system or demand-side response, these would potential reduce site resilience.

The Capacity Market was introduced as part of the UK Government's Electricity Market Reform (EMR) package, with the aims of securing the future supply of electricity in the UK.

It is a technology-neutral scheme designed to secure a predetermined amount of capacity each year, at the best possible cost for the end customer.

A capacity provider will receive a predictable income stream in return for National Grid being able to call on it to deliver capacity in times of stress on the network. As such the Capacity must be controllable, as it needs to be generating a specified amount when called upon, and not receiving low carbon support, which rules out most renewable generation.

The Capacity Market requires specialist knowledge of the rules and regulations, which is unlikely to be readily found with in most Trusts. It is therefore likely that a third party will be required for Trust to participate in the scheme.

2. Eligibility to participate

The Capacity Market is open to existing and new capacity providers, including Trusts with existing and new:

- Combined Heat and Power (CHP) systems.
- Energy storage systems.
- Demand-Side Response (DSR) providers (organisations that can reduce their demand when requested).

Although the Capacity Market is technology-agnostic, there are some key criteria for being eligible to participate which Trusts need to consider:

- Minimum size 2MW (aggregation with other units at other sites is possible).
- Should not be receiving other low carbon supports (such as FIT, CFD, ROCs etc.).
- Not receiving long term STOR contracts.

Embedded generation (i.e. connected to the distribution network) can enter either as DSR or existing generation. Although the minimum size to enter is 2MW, it is possible to aggregate several smaller assets into a single Capacity Market Unit (CMU) to reach this threshold. This can be achieved across the whole Trust portfolio or aggregators can be used to join up with other small generators looking to enter the capacity market.

3. Participation

Organisations that enter the Capacity Market, whether generation or DSR, are known as Capacity Market Units (CMUs). All CMUs go through a prequalification and auction process.

4. Prequalification

All prospective Trust CMUs that wish to enter the auction and obtain a CMA will first need to prequalify the asset, to allow the EMR Delivery Body to undertake certain checks to ensure the CMU will be able to meet its obligation and is eligible to participate. Prequalification can only take place during a predefined window each year, which is open for 10 weeks over the summer months. Each CMU needs to apply separately, and an application is required for each auction the CMU intends to enter. The prequalification process requires each prospective CMU to provide information to verify that the CMU is eligible to participate.

Key information required includes:

- Copies of Connection Agreements.
- Single line diagrams of CMUs.
- Review of metering.
- Calculation of capacity figure and evidence of recent highest outputs.

In most cases for existing hospital generation new metering will need to be installed. However, this does not need to occur until after successful bidding and therefore does not pose an upfront cost risk. The metering accuracy required for the Capacity Market is greater than normal utility meter accuracy. It requires the meter accuracy to be better than 1.5%, compared to a typical utility meter accuracy of around 2%.

After the prequalification window closes, the EMR Delivery Body will check all the information provided and several weeks later will either confirm successful prequalification and entry into the auction, or reject the CMU. If a CMU is rejected it will have the option to go through an appeal process to rectify the reasons for the rejection.

5. Auction

The Capacity Market auction is a competitive process designed to award the required capacity for each delivery year at the lowest cost to the end consumer. The main risk is on the amount actual secured for the capacity.

There are two auctions each year, one for a four-year-ahead auction (T-4) and one for the year-ahead auction (T-1). For example, in 2017 the two auctions taking place will be for capacity delivery year October 2021 to September2022 (T-4) and for delivery year October 2018 to September 2019 (T-1).

The EMR Delivery Body will aim to secure the majority of the capacity in the T-4 auction, to ensure security of supply, with a much reduced amount of capacity being left to the T-1 auction.

If a CMU has already received an agreement for a delivery year in the T-4 auction, it cannot subsequently enter the T-1 auction for the same delivery year. However, T-4 auctions generally deliver a higher price as the capacity is being guaranteed further in advance.

Results. National Grid will notify all bidders whether they have been successful or not within 24 hours of the auction closing, and at the same time will notify the Government. The final results will be made public within eight working days of the auction closing.

Past auction results. The Capacity Market has seen several auctions already, with varying clearing prices, as shown in the table below.

Capacity Market auction prices

Delivery year	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
T- 4 £/kW - Cleared price		£19.40	£18.00	£22.50	£8.50	n/a	£15.97
T- 1 £/kW - Cleared price	£6.95	£6.00	£0.77	£1.00			

● Auctions in which customers could participate

■ Auction has already taken place. Now closed

Due to a ruling by the General Court of the Court of Justice of the European Union the Capacity Market was suspended at the end of 2018. The Court did not find the design of the GB Capacity Market to be incompatible with State aid guidelines. This causes a pause in all payments and auctions while the UK government worked closely with the European Commission to resolve the issue. This cause the lower clearance prices and a missed T-4 auction for 2022/23. The missed T-4 auction was replaced by a T-3 auction which cleared £6.44.

Example of Capacity Market Income:
*A 2MW CHP that had participated in the T-4 auction for 2020/2021 delivery year would have received: £22.50/kW * 2,000*
= ***£45,000***

The Capacity Market payments are issued monthly from the start of the delivery year, to a set schedule, so are a predictable source of revenue for participants.

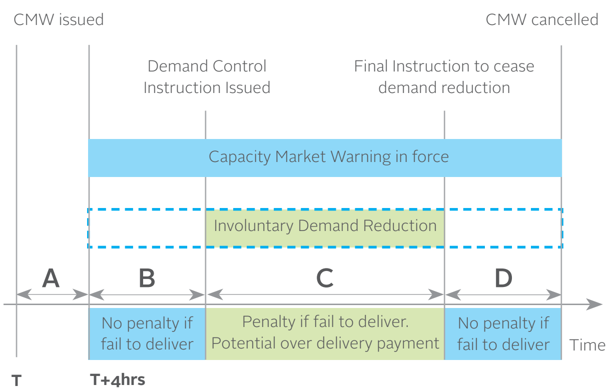
6. Delivery

Capacity market delivery year. All CMUs which are successful in a Capacity Market auction will receive the CMA which details their obligation to deliver a certain amount of capacity in the case of a 'system stress event' for the relevant delivery year. All CMUs will need to be available at all times (24 hours, 365 days a year) in case the System Operator (National Grid) issues a Capacity Market Warning (CMW). This is a signal to all participants that a system stress event is expected and it will be issued four hours in advance. Currently, there is no limit on how long a CMW can be issued for, as the rules do not determine a maximum length.

Capacity market penalties for non delivery. If any CMW periods become a system stress event through further notification, any CMU not delivering their obligation will be subject to penalties. It is important to note that not every CMW will become a system stress event and CMUs are not penalised on whether they react to these warnings.

The penalties only apply if a CMW has been issued and subsequently a system stress event occurs. To ensure CMUs meet their Capacity Market obligation, it is advisable to ensure they can react to all CMWs.

All penalties are linked to a CMU's Capacity Market payment, the Penalty Rate for a missed stress event is 1/24 of the of this. In any one month, a CMU can be penalised a maximum of 200% of a potential monthly payment. However, over the Delivery Year the sum of all monthly penalties cannot be greater than the sum of all the CMU's Capacity Payments (i.e. capped at 100%).



Source: National Grid, https://www.emrdeliverybody.com/CM/Delivery.aspx

7. Potential impact on MCPD

Participation in the Capacity Market can bring forward the compliance date for the Medium Combustion Plant Directive (MCPD) requirements as well as any associated costs (EA applications fees etc.). New CHPs will already need these in place and therefore there would be no change.

There is also the possibility that additional work would need to be carried out in order to obtain the relevant EA permit such as flue dispersion modelling. Other potential impacts of the MCPD on older high NOx CHPs is that they may need to be detuned in order to achieve the required NOx levels. This would slightly reduce the efficiency and output of the unit.

8. Secondary trading

There are potentially two other options available to Trust that are in line to receive penalties or are no longer able to meet their obligation - volume reallocation, and physical trading.

Volume reallocation. Once a stress event has occurred, CMUs that have over-delivered on their obligation can transfer this capacity to another CMU that has under-delivered. The CMU which has under-delivered will not receive any penalties, as it will have met its obligation through a combination of its own capacity output and that of the nominations from other CMUs. This process is managed by the Capacity Market Settlement Body.

Physical trading. Physical trading allows any CMU with an obligation to sell the obligation in its entirety to another CMU and completely remove its participation in the Capacity Market. The original holder of the CMA would no longer receive any payment and completely eliminates any exposure to penalties. Any potential CMU wishing to purchase a CMA will have needed to prequalify and cannot have already received an obligation for the capacity. The trading of CMAs can take place once the T-1 auction for the delivery year is complete, up to the end of the delivery year.

References

- ***Ofgem, Capacity Market Rules*** *- https://www.ofgem.gov.uk*

Power Purchase Agreement

KEY FEATURES

- A stable revenue stream from surplus electricity generation
- Suitable for any form of exporting asset
- Agreement options to meets individual financial and risk requirements
- Additional embedded benefits

1. Introduction

A Power Purchase Agreement (PPA) is a contract between two parties: the seller, who generates electricity, and the buyer, who is looking to purchase electricity. If an NHS Trust is in a position to export power from an onsite generation scheme, it will require a PPA with an off-taker. The PPA will define all the commercial terms for the sale of electricity between the two parties, from how much power will be delivered to the payment terms. It can be for periods as short as three months or the lifetime of an asset - typically 15-20 years.

2. Types of PPA

The PPA market is very competitive, with varied options available directly from suppliers or through aggregators. The choice of option will depend on:

- type of generation asset
- how often it exports
- predictability of the output
- how much involvement the asset owner wants in maximising revenue
- risk appetite – how much budget certainty is required from export volumes

Cashout/Spill PPA. A cash-out or spill contract will generally be the best option for an asset (for example, back-up generation) that will only export for a small amount of time over the course of a year, with no predictability. There is complete flexibility as to when and how much power is exported, and there is no need to provide an export forecast to the off-taker. This type of PPA will pay the exporter the national System Marginal Price (SSP) that is determined by Elexon, whose role it is to operate the wholesale electricity market.

The cash-out prices are determined for each half-hour trading period and are based on the whole system balance. They are not fixed or forecastable, so there is no certainty over what price will be achieved. Prices can be volatile or even negative, in cases where there is significant over-supply or lack of demand.

Indexed PPA. A PPA linked to a wholesale energy market index such as N2EX or LEBA will give more confidence on price, while still allowing flexibility on how much is exported.

It will generally allow a seller to forecast its expected export for the day ahead market (usually at 8am on the working day before delivery). This secures the forecast against the more stable day ahead price published by the index, and is not subject to the volatility associated with cash-out contracts.

Fixed PPA. This form of PPA is suited to assets that have very predictable export volumes, such as a base-loading CHP. The seller will agree its export profile in advance and receive a fixed p/kWh price from the off-taker. This gives a scheme a certain income stream and reduces volatility and risk. The income from exporting the power can be fixed for a period, from 3 months to 15 years, giving certainty to a scheme. A fixed PPA will generally come with forecasting accuracy clauses and it is important for the seller to understand the full implications of over- or under-delivery.

Flexible PPA. A flexible PPA is suited to more experienced generators, used to interacting in the energy markets. It gives the seller more scope to try to maximise the value received from its export generation, by selling export volumes in smaller tranches to take the opportunity of wholesale power market movements. The export volume can then be traded on the forward energy market (generally up to 3 – 5 years out), all the way down to a day ahead stage.

Sellers wanting to enter into this type of agreement must have a comprehensive risk and hedging strategy to ensure that the volatility in prices are managed.

3. Additional embedded benefits

An exporter can receive financial benefits in addition to the price it receives for its export. Assets that are connected to the local, low-voltage distribution network can receive embedded benefits, and these payments will also be included in the PPA contract. The PPA will generally stipulate a percentage of the embedded benefit that will be shared between the buyer and seller.

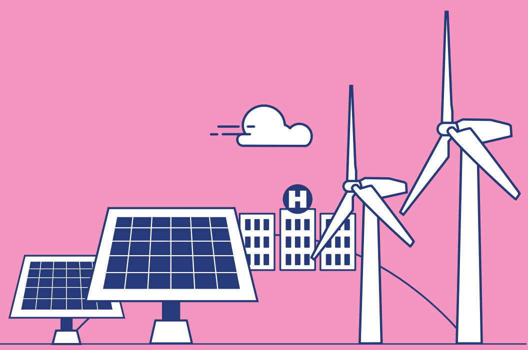
There are numerous embedded benefits available, some more widely known than others, including:

- Transmission Network Use of System Charges (Triads)
- Generation Distribution Use of System (GDUoS)
- Balancing Services Use of System (BSUoS)
- Hydro Benefit (AAHEDC)

The embedded benefits can change over time and is important that the PPA reflects the impacts of existing benefits being removed, or new ones being introduced.

COMMERCIAL APPROACHES

- Finance and Balance Sheet Treatment
- Procurement and Contracts



Finance and Balance Sheet Treatment

KEY FEATURES

- Funding options are available for most energy projects
- Funding can be on- or off-balance sheet
- Capital charges and depreciation need to be taken into account
- NHS capital is cost-free but still incurs capital charges and depreciation
- Private sector capital options are varied and risk-based

1. Project funding

Project funding can be a complex area and many aspects might not be obvious at the outset. Access to funders and funding can depend on the scale of the project, how it is being procured and contracted, whether or not it will be on the Trust's balance sheet, the financial stability of the Trust itself and (in the case of Salix funding) the level of carbon savings generated.

The good news for NHS Trusts wishing to proceed with an energy project is that there is almost always a cost-effective route available, even if the Trust has entered special measures.

It is important to ensure that all financial factors in the business case are considered, to ensure an apples-for-apples comparison between the options. The table below shows a summary of the main sources of finance and the key differentiators.

Funding option	Comment	Balance sheet treatment	Cost
Trust own capital funding	Very limited availability, usually deployed for clinical services or critical estates backlog	On balance sheet	No cost of finance but Trust pays 3.5% capital charge and depreciation
Department of Health Grants	None currently available for energy projects, however some grants available where Trusts are merging or have specific estates issues	On balance sheet	No cost of finance but Trust pays 3.5% capital charge and depreciation
Independent Trust Financing Facility (ITFF)	Currently our understanding is the ITFF do not have any funds available for Trusts pursuing energy projects	On balance sheet	No cost of finance but Trust pays 3.5% capital charge and depreciation.
Salix finance	Interest free government loans for energy projects. Projects must meet specific criteria and loan paid back in 4 years. For large projects this can cost the Trust more in the first 4 years	Off balance sheet	No cost of finance but Trust pays 3.5% capital charge and depreciation. CEF analysis shows this is broadly comparable to 3rd party off-balance sheet funding except it impacts prudential borrowing limits
Contractor funding	Provided by contractor, where they have in-house financing arrangements	On or off balance sheet	Typically 7%-15% depending on contractor. No capital charges if off balance sheet
CEF third party funder	Market tested for value for money for each project. Best rate with CEF 'Bankable' contract and deal-flow	Off balance sheet	Typically 4%-6% depending on funder. No capital charges if off balance sheet
Hybrid of two or more of the above	The CEF will work with any finance source or a combination of sources as best suits the Trust's requirements	On or off depending on configuration	Depends on hybrid combination

2. Key considerations

Important factors that need to be considered when completing the Value for Money exercise and reviewing options for funding are described below.

Capital Department Expenditure Limit (CDEL). CDEL is the amount of capital spend a Trust can make, including expenditure incurred in relation to finance leases and is reported to the Department of Health annually. The limit and management varies between type of NHS body - NHS Trusts and Foundation Trusts in financial distress have to work to delegated limits for capital investments. If a Trust or Foundation Trust is in a strong financial position, additional on-balance sheet debt may not be an issue. However, if the provider is already at its CDEL limit, it will not be able to take on any further on-balance sheet funding.This will automatically disqualify finance options, which by their nature must be held on the Trust's balance sheet.

Public Dividend Capital or Capital Charges. Where a project is on-balance sheet, the project must also allow for the cost of capital charges, calculated at 3.5% per annum on the providers average net relevant asset balance which includes annual depreciation adjustment. These charges should be included in the cost of a project. It should be noted that this accounting methodology is specific to the NHS as a means of managing cash within the national health economy and not seen in other parts of the public sector.

Control Total. The annual Trust financial target (control total) is set in advance of a financial year and must be achieved to unlock access to national funding and other financial benefits applicable to all NHS providers (trusts and foundation trusts). Access to national sustainability and transformation funding is conditional on providers agreeing and delivering their control total; which includes the annual repayment of PDC.

Interest rate. The lower the interest rate, the lower the cost of the project over time and the better the net savings. However, the best interest rates can come with conditions, such as needing a bankable contract or being on-balance sheet, which then attracts capital charges.

Bankability of contract. There is a wide variety of contracts available for energy projects in the NHS, presenting a wide range of risk for potential lenders. Bankability refers to the lender's confidence to fund a contract. Where a contract is well developed and has a good track record in the market, funding rates will be low, since the investment carries a very low risk, and the funder will have certain controls enabling it to manage any issues that could change the risk profile.

3. Funding through NHS capital

The Trust will have several options available to fund its energy projects. It can use NHS money such as its own cash, grants, or borrowing from the Independent Trust Financing Facility (ITFF).

Trust's own cash. The Trust may have cash in the bank that it has generated from its operating activities, or it has a capital budget. This money is not free, as it will attract capital charges at c.3.5% and the capital amount will need to be depreciated. It will impact on the balance sheet, and therefore the Trust's ability to borrow capital for other activities.

Independent Trust Financing Facility (ITFF). A Trust can make an application for capital from the ITFF. This capital attracts an interest payment and the capital is repaid like a traditional loan. It is on-balance sheet and will therefore impact the Trust's borrowing limits and is also be subject to capital charges.

Public Dividend Capital. The government may issue new public dividend capital as a way of giving finance to NHS trusts which is not treated as debt in the same way a loan is. A provider may apply through the ITFF or NHSEI. There is no repayment on the capital received however, the transaction is on balance sheet as a relevant asset and therefore attracts annual capital charge, currently at 3.5%, on the Trust's average net relevant asset balance.

Grants. Occasionally the NHS will create a pool of capital that is to be used for energy reduction projects in response to the national obligation to reduce carbon emissions and so it is worth investigating this possibility. Depending on how the grant is set up, it may attract capital charges too, through its Department for Business, Energy & Industrial Strategy.

4. Funding through private sector capital

In addition to NHS capital, a Trust has other methods for funding its energy project in the form of private sector capital.

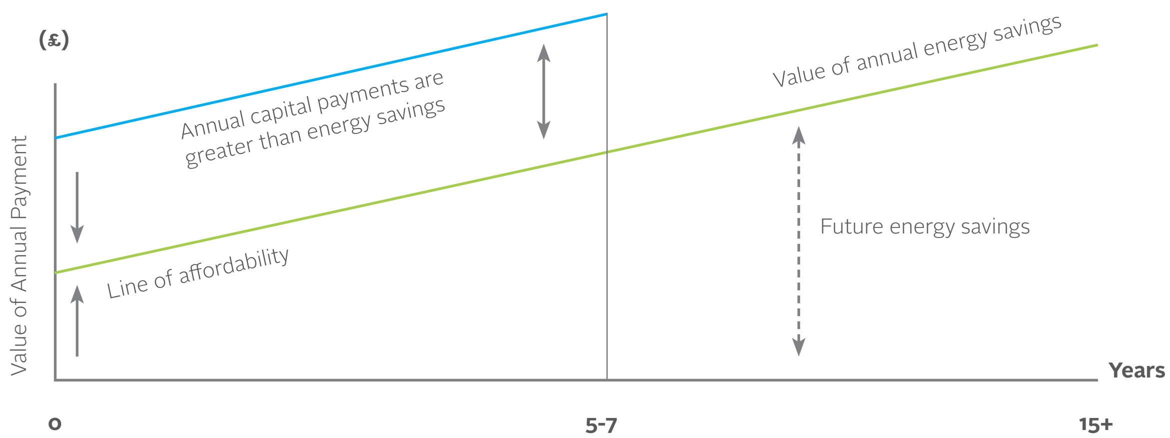
Finance Costs	Construction	Equity	Due Dilligence	Legal Fees	Post PC Debt	Term	Suitable for Small Projects
Project Finance	6%-8%	10% to 12% IRR	£150,000 plus	£30 to £100,000	6% to 8%	10 to 30 years	No
CEF Finance	2.5% to 4.0%	Not required	Nil	£30 to £40,000	4% to 6.0%	7 to 30 years	Yes
High Street Lenders	No	Not required	Risk averse/NA	£30 to £40,000	8% to 10%	5 to 7 years	Yes
Equity	10% to 12% IRR	Not required	£150,000 plus	£30 to £40,000	10% to 20% IRR	5 to 7 years	Yes but needs high yield

As a demonstrable Value for Money proposition, the NHS has been funding projects in this way for many years and it is accepted by NHSI and others as a way of making energy projects happen. When considering private sector capital, the structure of the deal and the source of finance will significantly impact on the price of finance and therefore on project viability. Professional advice should be sought and the Trust should seek prior approval from NHSE/I DHSC but the previous table provides an indicative example.

As can be seen, not all finance is the same. Lenders will assess the project risk and allocate a cost of finance and the level of due diligence required to mitigate that risk. The contract that is used, the way the payments are allocated, and whether the project is on- or off-balance sheet for the Trust will impact on that perception of risk. A contract needs to be bankable, i.e. can be approved by a lender's credit committee. A Trust can obtain private sector capital by going directly to a lender, via a framework or, if it is able, via an energy company.

5. Interest free loans

In October 2020 the Government, through its Department for Business, Energy & Industrial Strategy, released the Public Sector Decarbonisation Scheme (PSDS) to be managed by state owned Salix Finance Ltd. This scheme is open to the full public sector and made £1bn of grants available under very specific conditions relating to carbon reduction and infrastructure investment. It also set strict application and programme delivery timelines. A material benefit to qualifying NHS providers is that capital investment is not a relevant asset under PDC rules and therefore introduces cash into the system at no cost.
In addition to the PSDS Salix Finance Ltd provides interest-free Government funding to the public sector to improve their energy efficiency, reduce carbon emissions and lower energy bills. Salix is funded by the Department for Business, Energy and Industrial Strategy, the Department for Education, the Welsh Government and the Scottish Government. It was established in 2004 as an independent, publicly funded company, dedicated to providing the public sector with loans for energy efficiency projects.



Salix loans are interest-free but on-balance sheet, impacts on borrowing and attracts capital charges that need to be considered. Salix has only had limited use in the NHS, as it requires fast payback periods on the limited specific technology it can support. The capital itself typically needs to be repaid in 4 to 5 years, which makes it difficult to achieve savings in year one.

6. Finance terms and payment profiles

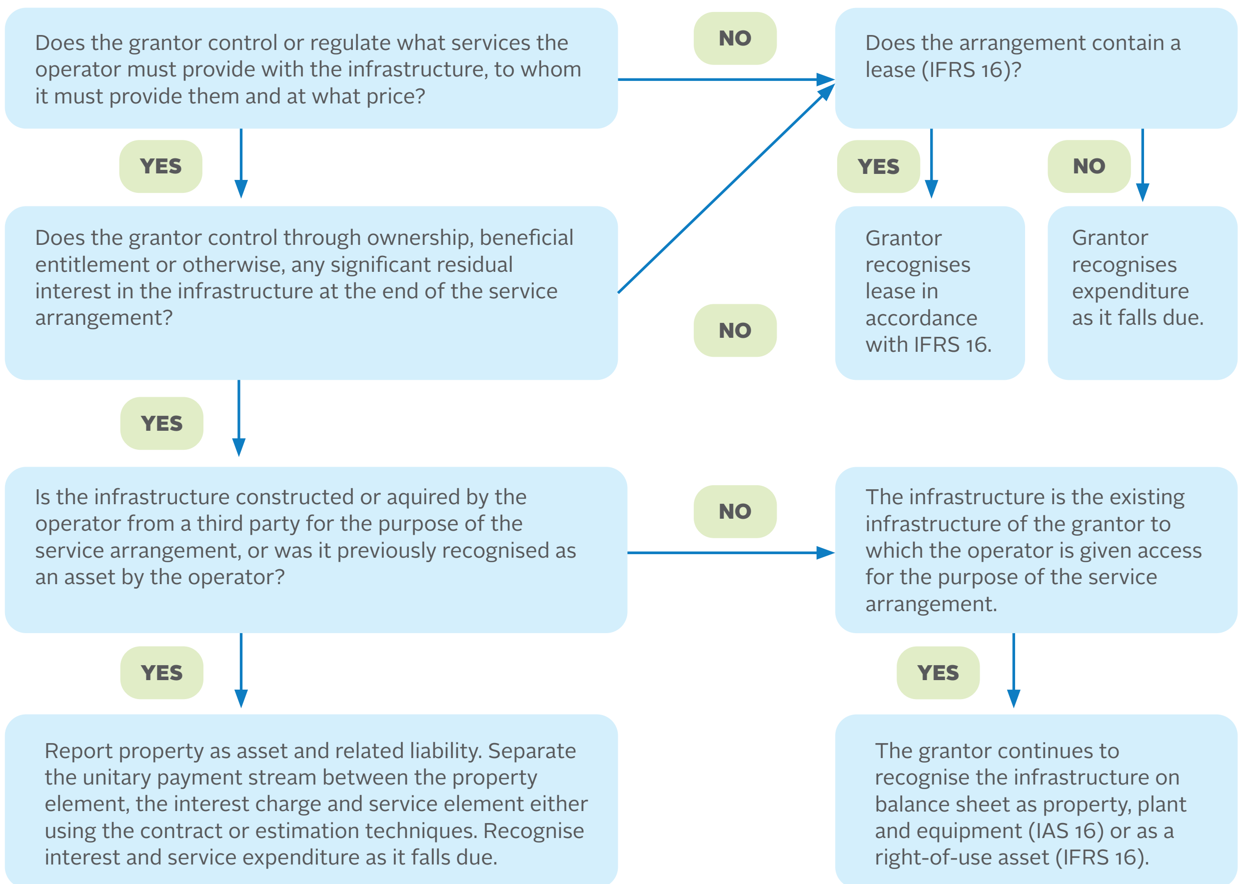
Whatever the length of an agreement, the amount of savings that can be achieved per annum will stay the same, but the amount of interest and capital to be paid back each year will change depending on the financial term.

As a simple example, if the capital required is £100 and the energy savings are £20 p.a., then there is a simple payback of 5 years. If the loan must be repaid in 4 years, then £100/4 = £25, which is greater than the savings p.a., so the project is not viable. If the £100 required is borrowed over 15 years, the annual payments would be £15 p.a., so with an energy saving of £20 p.a. the Trust would achieve a saving of £5 pa. This is further complicated, of course, when interest is added.

7. Balance sheet treatment of infrastructural assets or their usage

It is important that estates directors and engineers leading energy projects are familiar with and understand balance sheet issues, since Energy and infrastructure projects that make big inroads to backlog maintenance and generate large volumes of savings normally deploy the appropriate amount of capital, and this can have a significant effect on the balance sheet of some or all of the parties involved including (for health) the DHSC, NHS, the Trust, Integrated Care System (ICS , contractor, funder and even the nation.

Flow chart of accounting for PPP arrangements



A typical simple energy project might involve £5m of capital for a basic Energy Performance Contract rising to £10m or £15m if the project is designed to have a material effect on the Trust's journey to net Zero carbon. It is a fact of accounting that even when the capital deployed is procured by a contractor at their own risk, that accountants see this as a lease and thus creating an asset for the Trust. Trust capital expenditure is counted towards its, or the ICS delegated capital limits (Cdel), and because Cdel is limited, ultimately by Treasury, it means that any expenditure on energy schemes that creates an asset reduces the remaining available Cdel for clinical and other uses. So a Trust investing £5m into its infrastructure will use up some or all of its Cdel limit, potentially restricting other investments, for example, a clinical upgrade.

Additionally a NHS Trust using Cdel will be subject, at the very least, to capital charges at 3.5% of the amount of Cdel deployed. Even though Trusts typically spend all their Cdel, some prefer not to spend Capital Charges "revenue" on energy projects if it can be avoided.

Public bodies in Wales, Scotland, Ireland and Northern Ireland also all have additional and differing reasons as to why they wish to restrict the value of assets on departmental, and thus the national balance sheet. Since the collapse of Carillion suddenly placed a large set of assets on the DHSC balance sheet, the issue has received a lot of attention from DH SC in England too. Estates departments have historically found it much easier to get infrastructural projects approved by their Trust Boards if they could show that not only are they self funding through savings, but that they also have no impact on Cdel through being off balance sheet.

Prior to the introduction of IFRS 16 most EPCs were viewed as operating leases and many were classified as off balance sheet. From the 1st April 2022, it is proposed that all leases above a certain value or with more than a year to run will be on-balance sheet under International Financial Reporting Standard 16 (IFRS 16), so Trusts wishing to have their projects off-balance sheet will need to use a contract that has been very carefully constructed to be off-balance sheet and this is possible under the current Consolidated Budget Guidance (CBG). At this time the approach is not acceptable to DHSC under the guidance issued at the same time as the current CBG by Treasury and which does allow this approach.

IFRS16 does allow an alternative approach to traditional lease accounting, whereby the Trust places the lease as an asset on its balance sheet, but offsets it with the liability associated with the EPC. This might not reduce the Cdel impact but will Impact on the capital charges due. The Financial reporting Manual contains the diagram on the previous page by way of explanation.

Contracts that are Service Contracts do not affect balance sheet, but may well attract significant accounting scrutiny. Traditionally a catering contract could include a refurbishment of a Trust Restaurant or food trolleys and often these were not seen as on balance sheet, Laundry and maintenance contracts traditionally enjoy the same freedoms.

References

- *https://www.gov.uk*
- *http://www.ifrs.org*
- *https://ec.europa.eu*
- *https://www.england.nhs.uk*

Procurement and Contracts

KEY FEATURES

- Compliance required under procurement regulations
- Advertising in 'Find a tender' has pros and cons
- Wide range of framework options available, including all-in-one
- 'Devil is in the detail' with contract terms

1. UK public procurement policy

Public sector procurement is subject to a legal framework which encourages free and open competition and value for money, in line with internationally and nationally agreed obligations and regulations. As part of its strategy, the government aligns procurement policies with this legal framework, as well as with its wider policy objectives

Above set financial thresholds, if you are buying supplies, services or works for central government, a non-ministerial department, executive agency, or non-departmental public body, you must follow the procedures laid down in the Public Contracts Regulations before awarding a contract to suppliers.

"The over-riding procurement policy requirement is that all public procurement must be based on value for money, defined as "the best mix of quality and effectiveness for the least outlay over the period of use of the goods or services bought". This should be achieved through competition, unless there are compelling reasons to the contrary."

In order to encourage competition and value for money, UK public procurement policy requires any project carried out at public sector expense to be procured through a mechanism that enables different suppliers' offerings to be compared, and the best value for money to be assessed.

These procurement mechanisms vary slightly, depending upon the project, sector and location, but each mechanism typically requests the submission of offers, or bids, by a supplier, followed by the structured assessment of those bids in a way that enables direct comparisons of value for money.

2. UK procurement regulations

Following the expiry of the Brexit transition period (which ended at 23:00 on 31 December 2020) UK contract notices and other notices such as prior information notices, contract award notices, contract modification notices as well as voluntary ex-ante transparency (VEAT) notices will no longer be dispatched to and published in the Official Journal of the European Union (OJEU). Instead, whenever you would have published a notice in the OJEU, you will now need to publish a very similarly worded notice using the UK's new e-notification service "Find a Tender". The same financial thresholds and timescales apply to publication of notices as before as all of the pre-Brexit Procurement Regulations continue to apply, albeit without reference to OJEU and some of the European dispute resolution mechanisms.

Existing requirements to publish on Contracts Finder, Sell2Wales or e-TendersNI continue to apply.

On 23 November 2020 the Cabinet Office published PPN 08/20 'Introduction of Find a Tender' which includes FAQs and a flowchart illustrating where to publish procurement notices after the end of the Transition Period.

Contract Types

Construction Contract	Energy Performance Contract (EPC)	Dynamic Purchasing System	Service Contract
Traditional and very familiar adversarial, QS certification, etc	Output based, payment on performance, partnership based	Simple procurement against a set of requirements	Totally service based
Risks with client	Guaranteed performance	Simpler contract structure such as PPA	Service guaranteed and valued
Retention and standard warranties	Risks with contractor	Easy to add and update contractors	Risks with contractor
P22, NEC or JCT	High visibility on the solution Can be operating lease	No room for negotiation	May avoid VAT

On 15 December 2020 the Cabinet Office published its green paper consultation 'Transforming public procurement' setting out a number of proposals with regards to UK procurement (although importantly, not the procurement of UK healthcare services, which are covered in a separate white paper published by the DH on 11 February 2021) in order to seek feedback on the same. The content of the consultation is not covered here, but suggests a forthcoming simplification of UK procurement law, with responses due from interested parties by 10 March 2021.

3. Advertising a project

There are several main ways to advertise a project: if below the procurement thresholds set out in law, they may be tendered as per a contracting authority's standing financial instructions, but if above those thresholds, they must be procured in accordance with the regulations, usually through a bespoke procurement advertised on Find a Tender, through a previously procured framework, or through a dynamic purchasing system (DPS). A framework or DPS may already exist, or a contracting authority may set up its own.

A bespoke procurement, properly advertised does allow a Contracting Authority to procure exactly what it wants, but that benefit is offset by increased complexity and timescales, greater chance of competitive challenge, and possible lack of interest if contractors feel that the risks and rewards of a single procurement are too high.

The other main problem with any bespoke procurement (including many pre-existing frameworks and DPSs) is that they only address the project itself, leaving the Authority to carry out separate procurements for advisers. Many organisations are quite happy with this restriction, but it is important to note that maximum contract value for the provision of services to a central government body, before publication in and procurement through Find a Tender becomes mandatory, is only £122,976. This means that it will be very difficult to secure a partner who will assist through procurement, installation or the operational phase of a project, without going through the mandatory procurement process.

Dynamic purchasing systems. Dynamic purchasing systems are useful for certain procurements because they have inherent flexibility in terms of the qualifying contractors seeking to supply goods and services. If they do not already have a list of suitable suppliers to procure from, then the list can easily be supplemented with new suppliers at any time. However, this does not work well for complex procurements, so whilst a procurement for LED lights may be done through a suitable DPS, it would be very difficult to include replacing the site transformers, or adding a CHP plant, at the same time. Therefore, the best use of a DPS is usually to bring a single special technology or goods to a wider project or framework.

Frameworks and business case. NHS England and others have at various times recommended that NHS bodies use frameworks for procurements to ensure standards, reduce challenges and costs, and benefit from best practice.

Frameworks normally have a maximum lifespan of up to four years, and that is important because the framework defines what is possible to procure under the framework; also a long framework may restrict access of new companies to the market place.

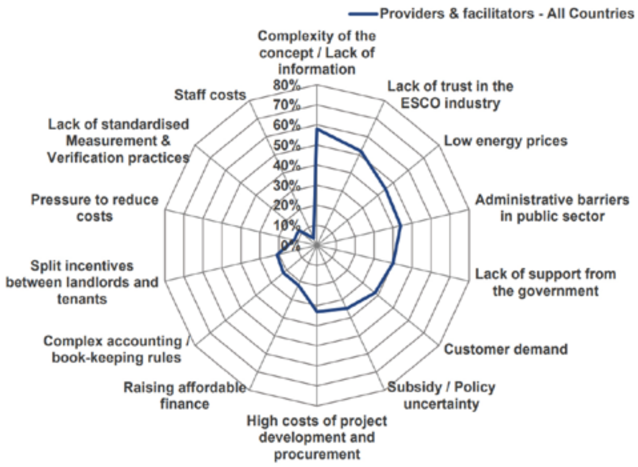
It is worth considering how the use of a framework impacts upon the business case process. The Treasury guide to developing the project business case assumes that a project starts with a Strategic Outline Case, develops and explores a long list of options, which is narrowed down by the use of assessment criteria, to a shortlist, which is explained carefully in the Outline Business Case, which targets the most likely solution, which is then fully detailed for the final business case.

This means that the project should start by establishing its strategic project deliverables before it seeks to choose a procurement strategy.

Key to the process is the determination of the desired outcomes and what is considered acceptable risk. This can be illustrated by looking at the NHS record on the effectiveness of its fleet of Combined Heat and Power plants, where there is a strong correlation between the installations that show high availability and efficiency, and how they were procured.

For installations where the Authority drafted the specification and then bought to that specification the availability of CHP plant is typically below 62%, and where the Authority placed the design, operation and lifecycling with a suitable contractor, the availability exceeds 87%.

Barriers to EPC business. Research under the EU Horizon 2020 project which found the following barriers to implementation of an EPC:



Two initiatives have looked to shape and improve the performance of energy projects away from the dismal performances achieved when public bodies carry out complex energy projects using the traditional adviser, specification and tender route. These are the Investor Confidence Project and the work done by the European Investment Bank (EIB) in collaboration with Eurostat (the statistical authority for the EU). The former addressed the financial risks of such projects and the EIB addressed the level of risk transfer that the EIB felt necessary to allow the project not to record on national balance sheets and in effect be relied upon to deliver the required outputs to the Public Sector.

The EIB guidance looks at the performance of contracts under a series of themes, and then grades deviations from the desired position, which would move a project to a risk level where it needs to be recorded on the Authority's accounts.

The key themes are: legal ownership, who specifies the installation, who maintains and operates it, how robust are the guaranteed savings, how comprehensive the payment mechanism, the treatment of changes in law, who insures the plant, warranties and indemnities, early termination and resultant compensation between the parties, expiry of the project, financing arrangements, governmental involvement and a few smaller provisions.

The guidance has had a marked effect on EPCs across the EU and the UK. Initially the sector was brought to a near standstill as old arrangements whereby Contracting Authorities took on-board large risks became apparent.

Since then Eurostat guidance-compliant contracts have emerged, with the required risk transfer and independent review, which has developed from Measurement and Verification into fully-fledged Contract and Performance Assurance.

4. Contracts for energy projects

Traditionally, energy projects in the Public Sector have been delivered by construction contracts, supported by service contracts. For a while Discounted Energy Purchase Agreements were used for the purchase of discounted energy (usually in the form of heat and electricity from CHP plant). More recently there has been the development of performance contracts sometimes referred to EPC or ESCO agreements.

Contract element Legal elements	What it includes
Project agreement	Indemnities, liability, liaison, land interests, consents, access, ground conditions, asbestos, Tupe, changes in law, delay, relief events, force majeure, default, expiry, IP, FOI, Taxation.
Definitions	
Completion documents	Especially important for external funding - board minutes, SFIs, drawings, programme
Collateral warranties	Direct recourse to main suppliers if required
Design review procedure	Projects are designed by the contractor to deliver the contracted outputs, but the design is subject to client review
Variation procedure	This often contains a supplemental agreement provision
Transition procedure	Ensures handover in condition B upon termination of expiry of the contract
Record provisions	Sets out the records the parties must keep

Dispute resolution	
Refinancing requirements	NHS requirement
Commercially sensitive information	To protect both parties' commercial confidentiality
Insurance requirements	Construction and operational insurances, third party insurance, vehicles, employers and PII
Funder centric	
Funders direct agreement	Required for external funding and covers partial termination and replacement of the contractor if required
Termination schedule	Deals with payments to be made between the parties upon early termination of the contract, usually triggered by default of the parties, force majeure events or corrupt gifts
Technical schedules	
Client requirements	This is normally an output specification for risk transfer
Contractors proposals	Depending on the form of the agreement (see balance sheet section) this is a detailed description of the works
Service requirements	Service requirements using the NHS standard service specifications and including KPI's
Interim services	Depending on the form of the agreement (see balance sheet section) this is a detailed description of services to be carried out during the works phase of the contract
Measurement and verification	How all services will be metered and performance will be proven
Payment mechanism	Payments Guaranteed savings and how each is calculated and proven Availability and performance deductions (KPIs)
Termination and delivery points	Defines the boundaries of all services inputs and outputs
Plans	All drawings and plans

There are many elements to consider when sharing risks and this section seeks to summarise some of the key aspects identified in the EIB/Eurostat guidance. The summary extracts elements that are high risk and very high risk (in each case of failing to deliver the required outputs). Many EPC forms exist but the common aspects and risks are:

5. Ownership

Typically, legal ownership of the site (i.e. the land and/or facilities in/for which the energy efficiency measures will be implemented) remains with the Authority for the duration of the EPC (and after its expiry) and the Authority grants access rights over the site to the Contractor.

Traditionally under operating lease contract structures, plant and equipment utilised to provide the project would belong to the Contractor for the duration of the project term. Depending upon accounting opinion and desired balance sheet treatment, assets would be specified to either transfer automatically to the Authority or be removed by the Contractor at the end of the project term. Under EIB/Eurostat guidance, ownership of the EPC assets does not have as big an effect on balance sheet treatment as with an operating lease, allowing treatment of title to assets to better reflect the commercial requirements of the parties.

6. Specification

The extent to which the energy efficiency measures and EPC assets are specified and designed before the EPC is signed, and who is responsible for that, varies widely in practice. In some cases the task of specification and design is led by the Contractor (e.g. during a procurement process or during an initial phase under a framework arrangement). In other cases the Authority itself specifies the energy efficiency measures and the EPC assets (and may carry out some or all design work) before initiating a procurement process.

Any risk(s) that the Authority takes under the EPC for:
- construction and/or installation delays or deficiencies;
- increased construction, installation or maintenance/ operating costs; and/or
- performance failures;

that may arise as a consequence of developing, reviewing and/or approving the specification and/or design is/are of high importance to the performance of the contract, and consequently are often risks that public sector Contracting Authorities are unwilling or unable to take.

7. Maintenance and operation

Market practice varies widely when it comes to defining the scope of the Contractor's maintenance and/or operational responsibilities under the EPC. The scope of the Contractor's obligations is typically influenced by factors including the scale and nature of the EPC assets themselves and the facilities management arrangements that the Authority has in place at the site. For example:

- a specialist stand-alone item such as a CHP boiler will typically be maintained by the Contractor;
- an LED lighting system might be maintained by the Authority itself or by its facilities management provider for the site.

Under EIB/Eurostat guidance, the standards to which the Contractor is required to maintain the EPC assets must, as a minimum, establish conditions in which the EPC assets are genuinely capable of delivering the energy consumption and/or cost savings required under the EPC; and the regime for monitoring and reporting on the Contractor's performance against those standards must allow the Authority to sanction the Contractor for non-performance . An EPC that does not meet these two conditions is seen as a very high risk.

8. Guaranteed savings

Eurostat's view is that the EPC must guarantee an amount of savings which, at financial close, are calculated so as to satisfy the following conditions:

- on a net present value basis, the level of savings guaranteed over the duration of the EPC is equal to or greater than the sum of (a) the Operational Payments forecast to be made over the duration of the EPC and (b) any amount of government financing that is not repayable by the Contractor (e.g. capital grant); and
- the level of savings guaranteed for each period over which performance against the guarantee is tested is equal to or greater than the Operational Payments that the Authority is forecast to make to the Contractor in that period.

Guaranteed savings that are expressed in units of energy (e.g. kWh) in the EPC must be demonstrated to satisfy these conditions by applying a reasonably assumed baseline energy price. An EPC that does not meet either of these Guaranteed Savings requirements Is seen as very hight risk (of not delivering).

9. Monitoring and measuring performance

Ongoing monitoring and measurement of the EPC assets' performance in delivering energy consumption and/or cost savings is a core element of any EPC. It is typically defined as a service to be provided by the Contractor but in some cases the EPC might provide for it to be undertaken by an independent third party.

The EPC defines the scope, frequency and standards of monitoring and measurement activities. These can be highly technical and can vary significantly from EPC to EPC. Reference is often made to independent industry-standard protocols such as the International Performance Measurement and Verification Protocol as well as to applicable laws, manufacturers' specifications and guarantees and the Authority's access restrictions.

Eurostat's view is that the EPC must contain a regime that allows for objective and robust measurement of the EPC assets' performance in delivering the guaranteed savings. An EPC that does not contain such a regime is seen as being very high risk.

Eurostat's view is that the EPC must provide for routine testing of performance against the guarantee at least annually (with consequences of performance being dealt with through the payment mechanism). An EPC with no mechanism for routine testing of performance against the guarantee, or that provides for testing less frequently is seen as being very high risk.

10. Payment mechanism

The operational payments are defined in the EPC as an amount (typically expressed annually) which then adjusted for:

- indexation (as the contracts tend to be quite long);
- pass-through costs (to the Authority); and
- deductions for failures in service delivery (Availability deductions and performance/KPI deductions).

In EPCs, the Contractor's right to start receiving the operational payments is triggered on or after the date that the construction and/or installation of the EPC assets is complete.

The guarantee of energy consumption and/or cost savings is at the core of the EPC. In broad terms, the baseline operational payments represent the "steady state" situation where actual savings are equal to the guaranteed savings. In this situation, the operational payments are due by the Authority to the Contractor (adjusted for indexation, energy-supply costs and service failure deductions) and no further amount is due by one party to the other.

The payment mechanism also contains provisions that foresee under-performance against the guarantee (i.e. where actual savings are less than guaranteed savings, including where no savings are achieved and energy consumption and/or costs increase) and over performance against the guarantee. Failure to include these provisions in an EPC is considered by Eurostat to be very high risk for the Contracting Authority.

11. Changes in law

Almost all EPCs contain specific provisions through which the Authority takes the risk of changes in law that affect the EPC, meaning that the Authority is required to compensate the Contractor for costs incurred or revenues lost as a result of changes in law. In many EPCs, the Contractor's right to claim compensation is limited to changes in law that were unforeseeable at the time the contract is entered into. The definition of unforeseeable" varies from contract to contract, but usually encompasses changes in law that the Contractor could not have been expected to reflect in its bid for the EPC.

12. Insurance

The EPC typically specifies particular insurances that the Contractor is (as a minimum) required to have in place during the contract. The required insurances typically include:

- professional indemnity insurance (covering the Contractor's design liabilities);
- construction/property damage insurance (covering damage to the construction works/EPC assets);
- public liability insurance (covering product liability and liabilities to third parties); and
- insurances required by law (for example employer's liability insurance, or motor vehicle insurance).

13. Early termination

Early termination of EPCs can typically be triggered by the following events:

- default by the Contractor;
- default by the Authority;
- unilateral (or voluntary) decision by the Authority;
- extended and continuing force majeure event; or
- uninsurability or the occurrence of an uninsurable risk.

The greatest risks to the Authority lie around the calculation of compensation in the event of Contractor default. The acceptable approach entitles the Contractor to compensation based on the market value of the EPC, determined either:

- by the market itself through a process of re-tendering the EPC; or
- by estimating how the market would value the EPC.

The methodology for estimating the market value of the contract (where the re-tendering process is not followed) is designed to reflect the approach that the market would take in valuing the EPC and not to ensure the recovery of the Contractor's incurred costs or outstanding debt. The methodology needs to take into account any remediation costs resulting from the Contractor's underperformance (i.e. the forecast cash-flows should take into account costs to complete/rectify the EPC assets as well as additional operation, maintenance and financing costs).

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Summary Conclusions

Since the first edition this Guide, much has changed in terms of the emphasis on priorities which dictate the immediate and future landscape of estates management and energy projects in particular. The most obvious being the impact of COVID and how this has placed an unprecedented demand on NHS front line and support services in an effort to respond and cope with the impacts of a global pandemic. Understandably, focus has moved to resolving immediate issues and delivering accelerated measures; to ensure NHS estates and facilities provide the services needed to support the clinical efforts to combat the virus and the challenges in so doing have been truly immense.

Notwithstanding the extraordinary responses demanded of the NHS in the last year in response to COVID, there has remained the underlying global threat of Climate Change and its existential threat to our world and our future; and the increasing pressure being placed on governments worldwide to accelerate a response. In part, the need for response is now perceived to be even greater because of the pandemic and therefore the need to refocus efforts has become more urgent.

Delivering 'Net Zero'

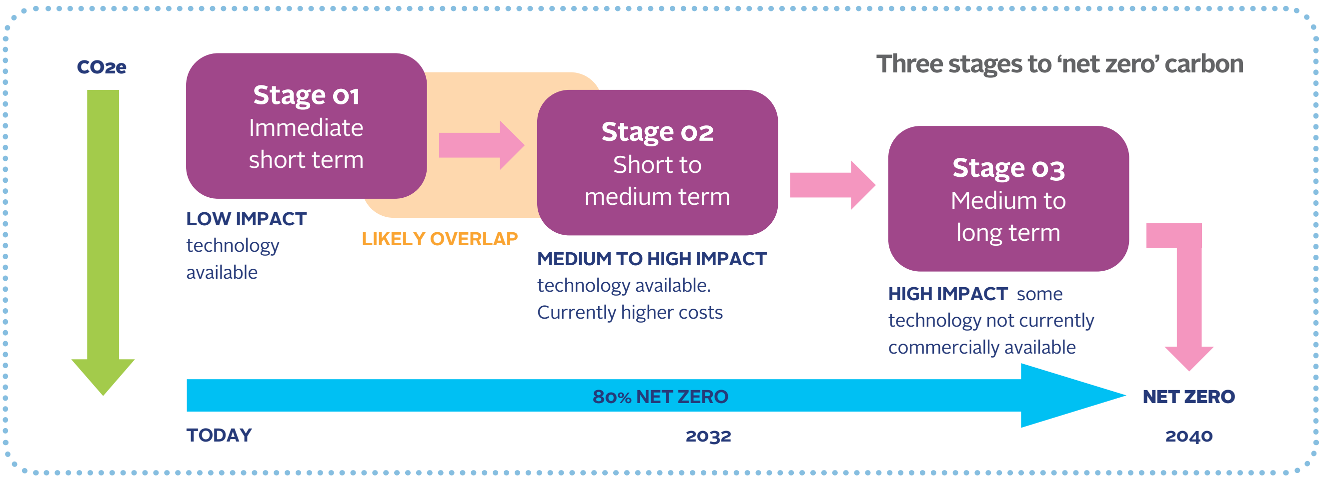
Subsequent UK government targets have started to become clearer for the public sector and the response needed from the NHS in order to reduce UK carbon to net zero by 2050. In fact, it was the publication of the NHS strategy "Delivering a 'Net Zero' National Health Service" in October 2020 that heralded the NHS aim to be the first national health service in the world to deliver net zero by 2040. This is ten years before UK government national targets and now really sets the agenda for the immediate, not just the longer term.

Therefore, this has now become the primary focus of this publication; how do we get from where we are now, in terms of the carbon emissions generated by our NHS estate, to a viable net zero position by 2040. Indeed, how do we achieve 80% of that objective by 2032 at the latest, which is an inherent part of the trajectory defined in the "Delivering a 'Net Zero' National Health Service" report.

The NHS report makes it clear that most of the carbon reductions required from the estate are anticipated to come from a demonstrable reduction in demand from hospital site activity, buildings consumption or from self-generation, to maximise 'Additionality'.

Real change – a three stage attack

In order to deliver 'Additionality'; that is a real change from the business as usual position, this guide has set out a three stage approach towards net zero. This approach attempts to recognise and prioritise areas of investment that can be accomplished now and that can then also act as an enabler for further improvements to follow on. Stage 1 and 2 initial investments can be added to in a progressive and strategic manner and built upon towards a third stage as and when more funding becomes available or is affordable, to take advantage of more advanced technology as it comes on stream. This guide has identified how a 3-stage approach can also be mapped out to demonstrate to stakeholders and the general public, a Trust's pathway towards net zero. This inspires confidence in a workable and realistic way forward and enables progress and future changes to be monitored and accounted for as they arise.



Decarbonising heat – the biggest challenge

Decarbonising heat is probably one of the biggest challenges we face. The UK Government's recognition and commitment to decarbonising heat is clearly visible through financial support such as the recent Public Sector Decarbonisation Scheme (PSDS) that has invested a £1 billion in lowering the public sector carbon footprint; and specifically, it places heat decarbonisation at the heart of its application.

This guide has attempted to identify a workable pathway through heat decarbonisation. It has provided examples of practical strategies and currently available and usable technologies. However, it is important to reflect that large scale heat decarbonisation cannot suddenly happen by switching large site heat demands over to run on green electricity, without major impacts to local and regional grid infrastructure. Hydrogen as a 'drop-in' replacement fuel for natural gas is also not yet inevitable for all parts of the UK in the short to medium term. It is very likely that a compromise between reducing heat demand (through improving building fabric, improving heat delivery efficiency from reduced losses and lower temperatures) and developing energy storage solutions (that store heat and electrical energy for use during peak demand periods) will be crucial. This guide has shown that it is very necessary to take solutions forward in a staged and managed way, so that they do not create unintended future infrastructure problems.

The road ahead

It may be that further PSDS money may become available and it is certainly likely that fossil fuels such as natural gas will become more aggressively taxed either directly or indirectly, to encourage the move towards lower carbon energy infrastructure. The ability to accelerate future carbon tax drivers will be a balance between the need to deliver change at pace, versus not stifling economic recovery from the impacts of COVID and BREXIT in the short term. In the medium to long term, it is clear that more radical steps will be needed at scale to enable the change from fossil fuel to take place.

This guide has shown some of the ways in which energy projects can be procured and funded and the importance of ensuring that the value they deliver is monitored through measurement and verification of savings and performance. The goal should always be to ensure that their impact is not left to degenerate and that subsequent changes to the estate that would otherwise dilute the continuation of the original value can be understood. Therefore it is essential that schemes are varied and evolved to maintain relevance and ensure carbon savings prevail.

Given the NHS 80% carbon reduction target set against 1990 baselines needs to materialise by 2032 at the very latest, it is clear the response has to start now if the progressive reduction pathway is to take effect in a manageable way. It is of vital importance that action is taken now, since if we wait for potential future technologies that may or may not materialise, the greater the pressure will be brought to bear, reflecting on the increasing challenge – both in terms of ability to implement in shorter timescales and the cost required to do it.

Glossary

AHU	Air Handling Unit
ASHP	Air Source Heat Pump
Barg	Short for Bar gauge. A measure of pressure as shown on a gauge accounting for atmospheric pressure at 1 bar.
BEIS	Department for Business, Energy and Industrial Strategy
BMS	Building Management System
CCL	Climate Change Levy - UK Government tax on non-domestic energy users
CEF	The Carbon and Energy Fund
CHP	Combined Heat and Power
CHPQA	Combined Heat and Power Quality Assurance Programme: a voluntary government initiative for assessing CHP schemes
CHW	Chilled water
CISBE	Chartered Institute of Building Service Engineers
CM	Capacity Market. Part of the government's Electricity Market Reform (EMR) package (see below)
Control system	Computer-based system controlling plant operations by constant performance measurement and feedback
COP	Coefficient of Performance, in relation to a heat pump (also CP, CoP)
CRC-EES	Carbon Reduction Commitment – Energy Efficiency Scheme. A UK government scheme now being replaced with higher Climate Change Levy (CCL) charges (see above)
DAC	Dry air cooler: heat rejection radiator used to reject the engine jacket cooling heat from a CHP engine.
dBa	Decibel, measure of environmental noise
Delta T	Flow and return temperature differential in a hot water system
DH	Department of Health
DH network	District Heating network
DHW	Domestic hot water
DNO	Distribution Network Operator, a company that owns the electricity distribution assets (towers and cables) for a specific UK region
DUoS	Distribution Use of System charges, levied by the UK's regional Distribution Network Operators, which go towards the operation, maintenance and development of the UK's electricity distribution networks.
ELV	Emission limit values, in reference to nitrogen oxide or other greenhouse gases
EMR	Electricity Market Reform: a UK government policy to incentivise investment in secure, low-carbon electricity, improve the security of Great Britain's electricity supply, and improve affordability for consumers
EN/ES EN	European Standards: EN documents are ratified by one of the three European Standardization Organisations (ESOs)
ENA	Energy Networks Association
ERIC	Estates Return Information Collection, the main central data collection for estates and facilities services from the NHS in England
EPC	Energy Performance Contract
FBC	Full Business Case
F-Gas Regulations	EU regulations on the use of fluorinated greenhouse gases, including hydrofluorocarbons (HFCs)
FIT	Feed-in Tariff: payments for generating electricity from renewable/low-carbon generation and exporting it into the national grid
FR	Frequency Response: a National Grid balancing service. National Grid has a licence obligation to control frequency within ±1% of nominal system frequency (50.00Hz) save in abnormal or exceptional circumstances. Firm Frequency Response (FFR) and Enhanced Frequency Response (EFR) are service options
G30, G50, G100	A size classification for wood chip particles based on a recognised Austrian norm (ÖNORM M7133). G30 and G50 are fine-grade for used in smaller furnaces; G100 is a large-scale chip for power plants.
G59, G83	Engineering Recommendations produced by the Electricity Networks Association (ENA). G59 establishes connection requirements for embedded generators above 50kW. G83 establishes connection requirements for generators below 50kW.
GT1 test	Gas Transporter 1 test: carried out by a gas network owner to establish the capacity and pressure of gas at the mains emergency control valve (ECV)
GSHP	Ground Source Heat Pump
GWh	Gigawatt-hours
HEFMA	Health Estates and Facilities Management Association
HH	Half-Hourly, in reference to the frequency of collection of energy data in automated systems

High grade heat	Heat (e.g. from exhaust gases of a CHP plant) which can be converted to low, medium or high temperature water, or steam
HTHW	High temperature hot water
HTM	Health Technical Memoranda, issued by the Department of Health, which give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare
HV	High voltage
HVAC	Heating, ventilation and air conditioning
IHEEM	Institution of Healthcare Engineering & Estate Management
IPMVP	International Performance Management and Verification Protocol
kV	Kilovolt
kW	Kilowatt
kWe	Kilowatt electrical, a kilowatt of electrical power produced, consumed or transmitted
kWh	Kilowatt hour: a unit of energy (equal to 3.6 megajoules) representing the power in kilowatts multiplied by the time in hours. A commonly used billing unit
kWp	Kilowatt peak, the theoretical peak kilowatt output of a solar PV assembly.
kWth	Kilowatt thermal, a unit of heat supply capacity used to measure the (instantaneous, not hourly) potential output from a heating plant.
Low grade heat	Refers to water at c. 70 – 90 degC, e.g. cooling water from a CHP.
LTHW	Low temperature hot water
MACC	Marginal abatement cost curve – measures the cost of reducing each unit of pollution
MCPD	Medium Combustion Plant Directive, a European Directive that places limits on the concentration levels of sulphur dioxide, nitrogen and particulates from plant exhaust gases.
MWh	Mega Watt hours
MTHW	Medium temperature hot water
M&V	Monitoring and Verification
MW	Megawatt, equivalent to one million watts of power
N+1 redundancy	A form of resilience that ensures system availability in the event of component failure. Each component (N) has at least one independent backup component (+1)
NHSi	NHS Improvement
NOx	Nitrogen Oxide
NPV	Net present value, the difference between present value of cash inflows and outflows, used in capital budgeting to analyse projected profitability
OBC	Outline Business Case
OJEU	Official Journal of the European Union
Parasitic electricity	The power consumed by plant (e.g. CHP) in production of energy
PID	Proportional, Integral and Differential control, a control algorithm used to regulate processes (such as temperature, pressure, and flow)
PIR	Passive infra-red sensor, used as an occupancy detector
PPM	Planned preventive maintenance
PV	Photovoltaic (solar power generation system)
RH	Relative humidity
RHI	Renewable heat incentive, a government environmental programme that provides financial incentives to increase the uptake of renewable heat.
RMU	Ring main unit, normally associated with high voltage electricity systems
Salix	Salix Finance Ltd, which provides interest-free Government funding to the public sector on energy projects.
SEER	Seasonal energy efficiency ratio, in relation to chiller efficiency
SO2	Sulphur dioxide
SOC	Strategic Outline Case
Spark Gap	The difference between the electricity price displaced by combined heat and power onsite generation, and the cost of gas required to fuel the CHP
STOR	Short term operating reserve: a National Grid service for the provision of additional active power from generation and/or demand reduction
T value	The diameter of a fluorescent tube as a proportion of an eighth of an inch
Tesla	Tesla Inc, US manufacturer of electric cars and lithium-ion battery energy storage
TNUoS	Transmission Network Use of System charges, levied by National Grid to recover the cost of installing and maintaining the transmission system in England, Wales, Scotland and offshore.
Tonne	A metric ton, equal to 1000 kilograms. The standard measure for carbon output/savings.
Triad charges	Part of TNUoS charges (see above), based on usage during the highest three half-hour periods of demand on the transmission network.
VSD	Variable speed drive: equipment used to regulate the speed and rotational speed of an electric motor
VO	Voltage optimisation

Credits

Principal Authors
Steven Heape, *Carbon and Energy Fund (CEF),* Stephen Lowndes, *CEF*

Steering Group
Clive Nattrass, *CEF,* David Mackey, *CEF,* Pete Sellars, *Institute of Healthcare Engineering and Estate Management (IHEEM),* Steven Heape, *CEF,* Stephen Lowndes, *CEF*

Contributors
Christine Rishton, *CEF,* Clive Nattrass, *CEF,* David Mackey, *CEF,* Paul Stott, *CEF,* Pete Sellars, *Institute of Healthcare Engineering and Estate Management (IHEEM),* Steven Heape, *CEF,* Stephen Lowndes, *CEF*

Reviewers
Professor Alan Short, Andy Waverhill, *IFHE Worldwide,* Daniela Pedrini, *IFHE Worldwide,* David Whiteley, *IFHE-EU Europe,* Grant Mills, *Bartlett School of Construction and Project Management, University College London,* Gunnar Baekken, *IFHE Worldwide,* Ian Hinitt, *The Rotherham NHS Foundation Trust,* Jacques Roos, *IFHE-EU Europe,* Jonathan Stewart, *Health Estates and Facilities Management Association (HEFMA),* Paul Brooks, *University Hospitals of Derby & Burton NHS Foundation Trust,* Paul Fenton, *East Suffolk and North Essex NHS Foundation Trust,* Pete Sellars, *Institute of Healthcare Engineering and Estate Management (IHEEM),* Simon Adamson, *Bradford District Care NHS Foundation Trust,* Wayne Carr, *City Hospitals Independent Commercial Enterprises (CHoICE)*

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Nick and Cherry Stewart - www.stewart2.com

For enquires, comments and suggestions, please contact **guidance@cef.net** or to obtain copies of this document, please visit **www.carbonandenergyfund.net/net-zero-carbon-guide**.