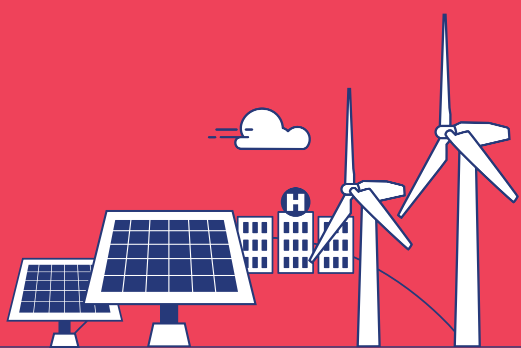
A ROADMAP TO 'NET ZERO'



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

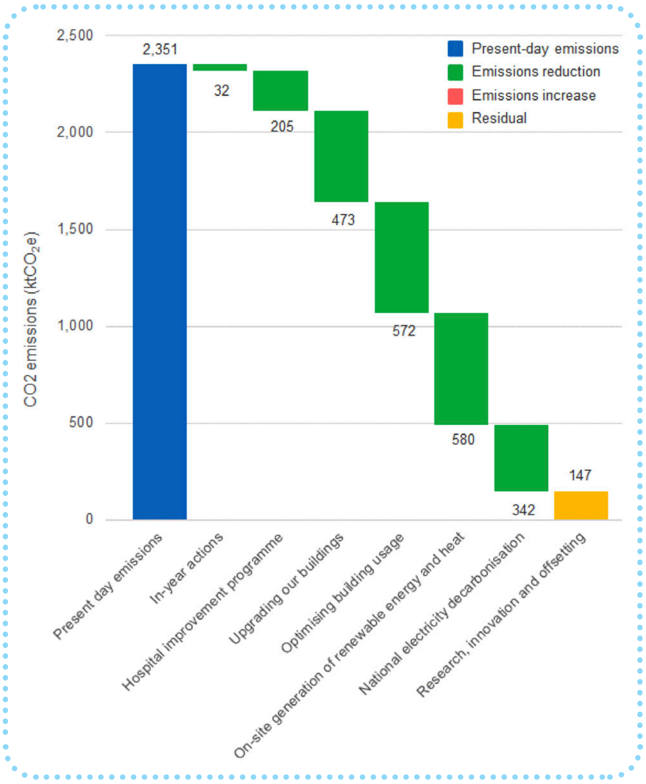
Electricity, gas and oil consumption are usually by far the largest influencers to a healthcare facility's carbon footprint, although there are still other important contributors from waste and transport and clinical activities such as dialysis for kidney patients and anaesthetic gas use in operating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

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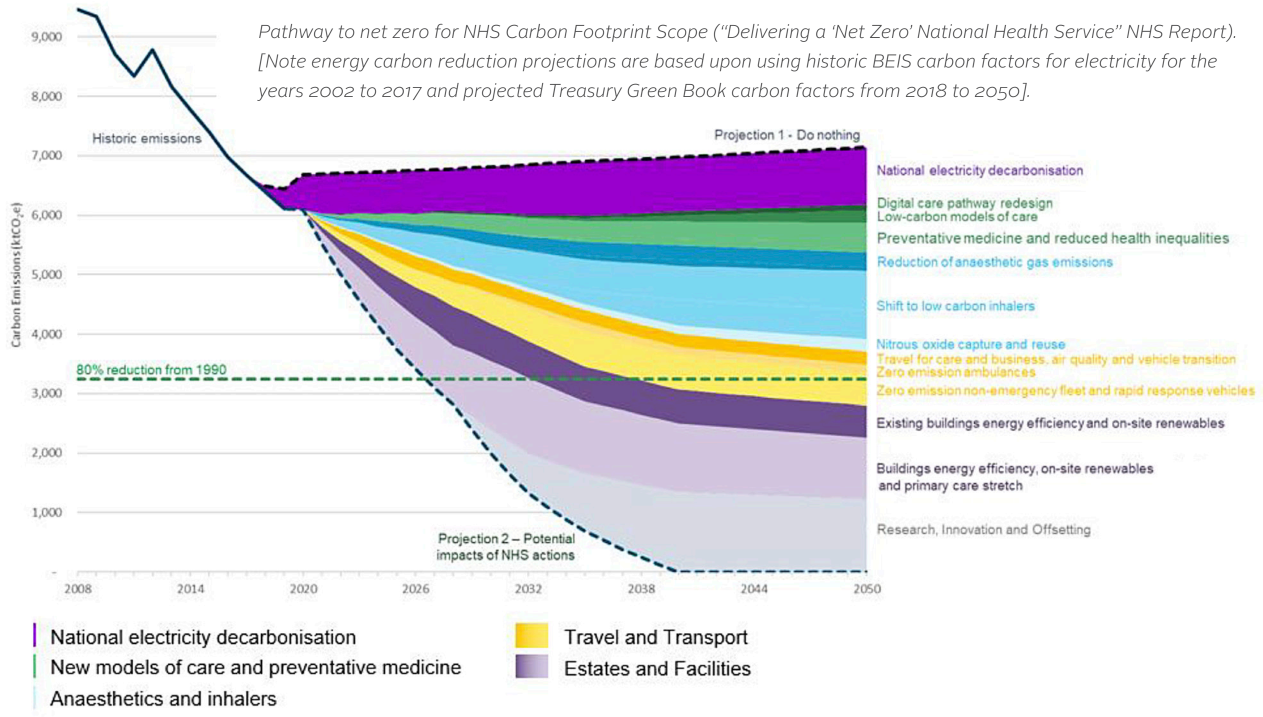

Pathway to net zero for NHS Carbon Footprint Scope ("Delivering a 'Net Zero' National Health Service" NHS Report). [Note energy carbon reduction projections are based upon using historic BEIS carbon factors for electricity for the years 2002 to 2017 and projected Treasury Green Book carbon factors from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

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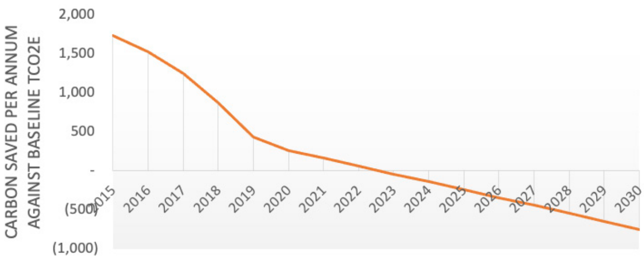

A typical existing unoptimized (electricity led) gas CHP potential carbon saving performance in the future - based upon assumed continuing decarbonisation of UK National Electricity Grid

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.

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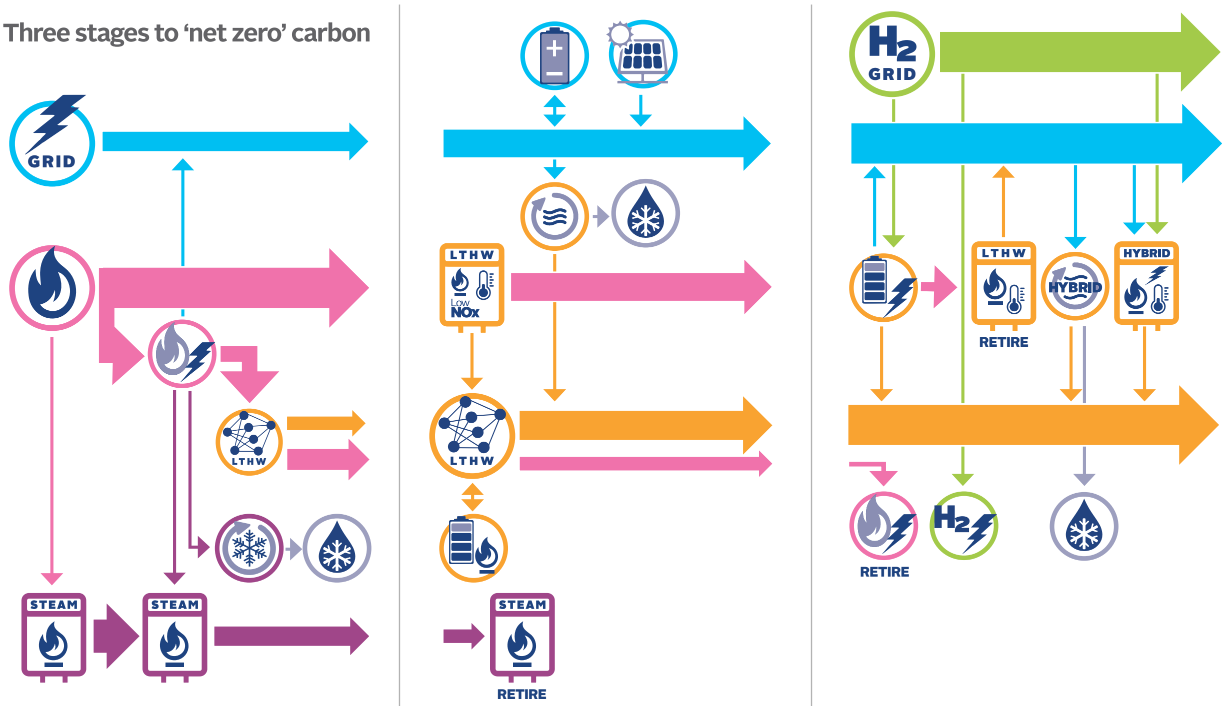
Three stages to 'net zero' carbon



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

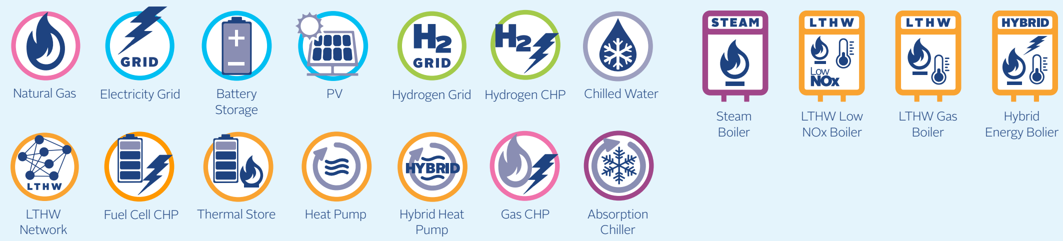
STAGE 3

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.

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.

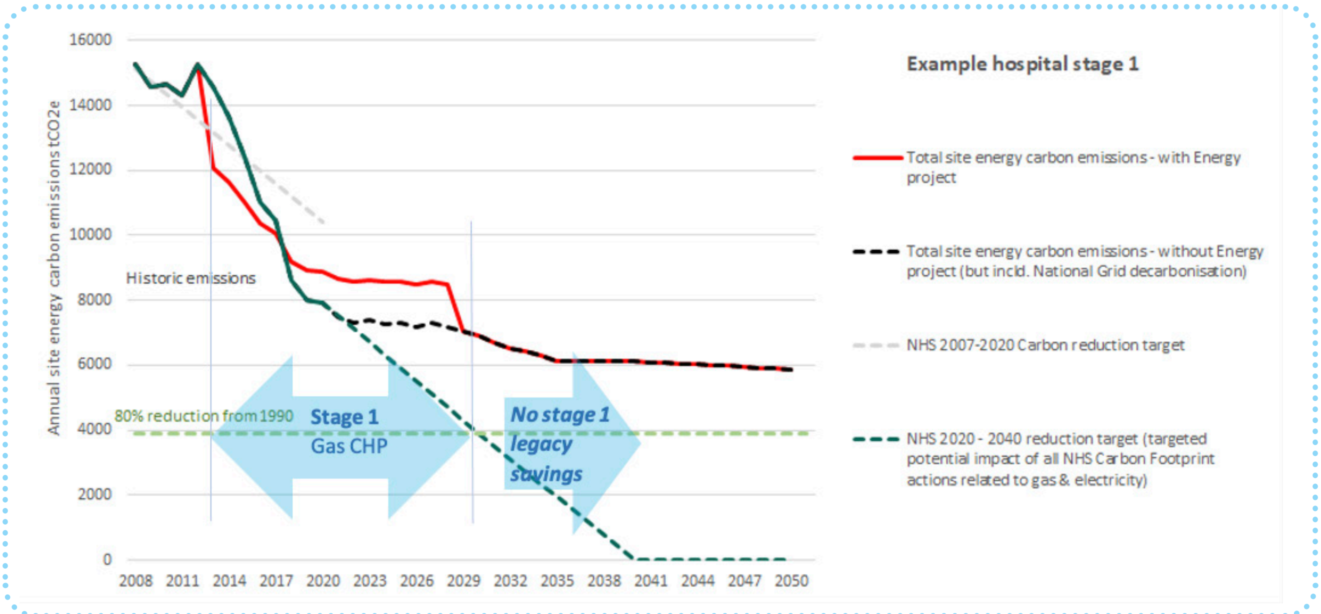


Figure: Stage 1 CHP carbon savings compared to "Do Nothing" (Using same basis of forward projecting carbon emission factors as NHS "Delivering a 'Net Zero' National Health Service" report)

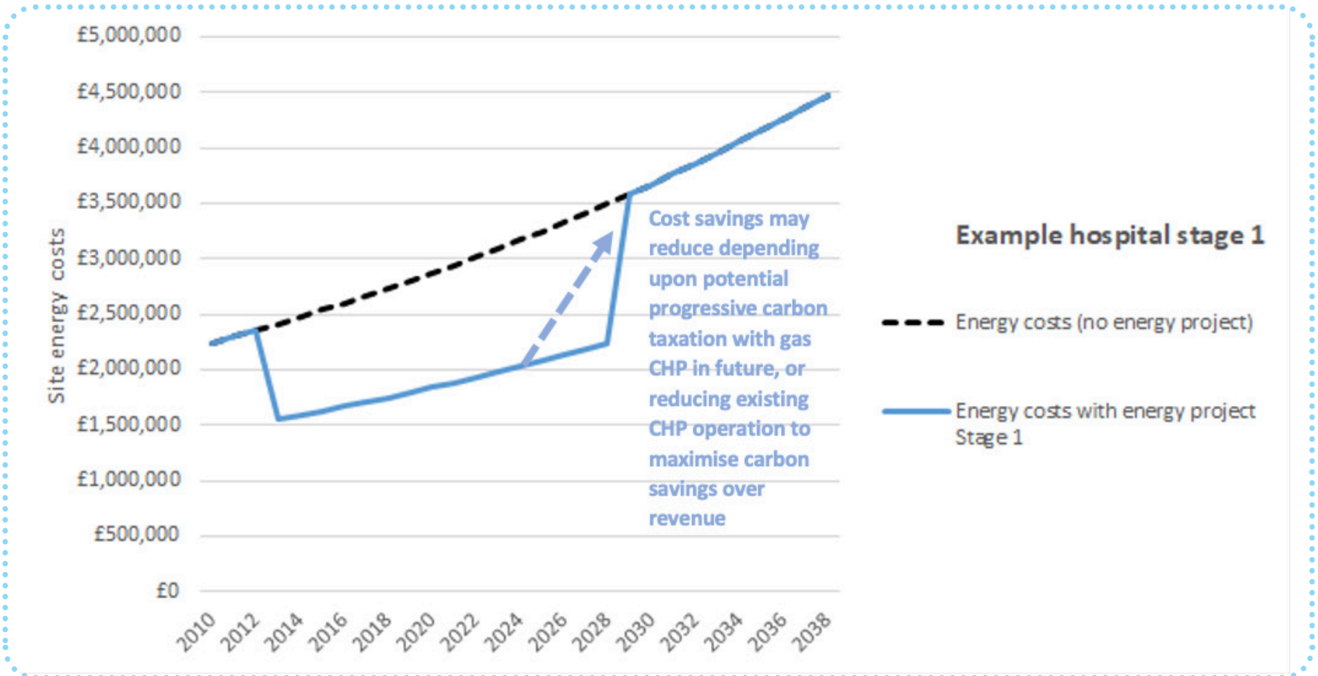


Figure: Stage 1 Existing CHP energy savings likely to remain attractive subject to extent of future carbon taxation impact or change in the way plant is operated to prioritise carbon savings over revenue.

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 CO2e) 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

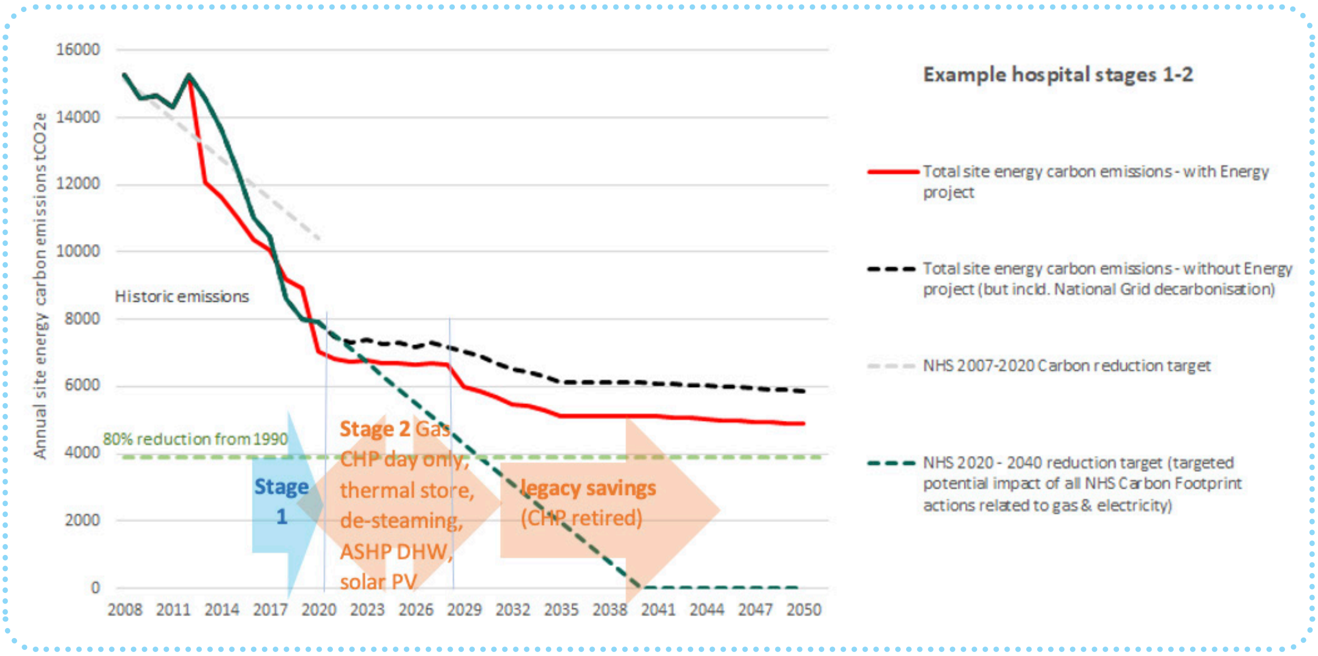


Figure: Stage 2 CHP daytime operation only, thermal store, small DHW ASHP and other demand side carbon savings compared to "Do Nothing"

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)