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COMMERCIAL HEATING SPECIAL

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Striking the right balance

We are in a period of profound change – the Department for Business, Energy and Industrial Strategy is currently consulting on the options for how we heat our buildings in the future and how they may work in different building types.

The rapid decarbonisation of the electricity grid is only part of the answer. Another challenge is decarbonising gas, which offers flexibility to meet extreme demand. Currently, battery storage and smart systems are able to balance supply and demand for a few hours, but that is not enough. Offering a mix of incentives and regulation could be the best solution to create the right market conditions.

Despite the furore in Northern Ireland, where the Renewable Heat Incentive (RHI) contributed to the collapse of the power-sharing government in Belfast, the scheme is here to stay. On page 12, we examine the changes to the revamped scheme, which will offer guaranteed returns for investors, with half of the budget allocated to 'guaranteed tariffs'.

On page 16, Martin Crane explains that correctly sized combined heat and power with thermal storage still offers an economic, low carbon energy option, despite falling electricity supply emission factors. He says its profitability can help fund the development of heat networks, which would allow renewable heat sources to be used in the future.

Vital Energi designs, builds and operates heat networks and is set to deliver more than 200MW of district heating across eight major projects. Schemes range from 12MW to 60MW and some will feature water source heat pumps and energy from waste. On page 22, the firm shares the factors that lead to best practice.

David Palmer focuses on overcoming conventional boilerhouse defects on page 30, while Ideal Commercial's Chris Caton details key issues to consider when integrating new boilers in existing buildings. He says a life-cycle costing approach ensures benefits can be realised over the boilers' life.

■ **LIZA YOUNG, DEPUTY EDITOR lyoung@cibsejournal.com**

Small step for big changes

As energy security rises up the political agenda amid Brexit discussions, geopolitical tensions and reports of gas shortages, the focus on improving UK energy efficiency has intensified.

The greatest challenge for this industry lies in the UK's inefficient existing buildings – and, in particular, their heating systems. Typically the largest user of energy in a building, heating offers huge potential for big efficiency gains.

Which brings us to the role of condensing boilers in improving energy efficiency. A high proportion of non-domestic buildings use commercial boiler plant for their heating. The problem is that far too many still rely on old, inefficient, gas-guzzling boilers that create needlessly high bills and pollution levels.

Replacing them with commercial condensing boilers, which achieve near maximum efficiencies and ultra-low Class 6 NO_x emissions, is a rapid, cost-effective solution to high-performance heating and cleaner air.

Added to which, condensing boilers use gas effectively, making efficient use of national resources, as Ferndown First School in Dorset has shown. Since replacing its old boilers to Remeha Gas 220 Ace condensing boilers with upgrading controls, the school has reduced its gas consumption by an outstanding 48%.

Small steps can lead to big changes. Relatively simple boiler replacements bring clear economic and environmental benefits – delivering lower operational costs and greater comfort levels, while reducing greenhouse gas emissions and supporting improved energy security. In today's uncertain times, greater emphasis on boiler replacements might be the small step needed to put ticks in all the energy boxes.

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Government publishes papers on heat decarbonisation

Research includes focus on low carbon gas, hybrid heat pumps and biomass

The Department for Business, Energy and Industrial Strategy (BEIS) has published four research papers on the decarbonisation of heat.

International comparisons of heating, cooling and heat decarbonisation policies, by Vivid Economics and Imperial College, examined how other countries have driven heat decarbonisation. It found that all face challenges moving away from heating powered by a gas network, but measures in new-build homes and the off-gas-grid sector have resulted in successful transitions in several countries.

Frontier Economics' *Market and regulatory frameworks for a low carbon gas system* examined three low carbon gas system scenarios for 2050: high hydrogen – conversion of the gas supply to hydrogen, including to meet transport demand; methane peaking – low carbon methane used only in industry and for meeting peak demand via hybrid heat pumps (HHPs); and regional gas grids – splitting the network into multiple grids, 70% using hydrogen and the rest using low carbon methane.

Element Energy's *Hybrid heat pumps* looked at the advantages of HHPs over stand-alone gas boilers or heat pumps in terms of carbon emissions intensity, cost-effectiveness, and impact on the wider energy network. It found that HHPs are more cost-effective and achieve better carbon savings in medium- and low-efficiency homes, but are less effective in high-efficiency homes, such as new builds.

Ecofys' *Innovation needs assessment for biomass heat* identified actions to drive biomass technology and feedstock options where innovation could make the biggest difference to their potential to decarbonise heat by 2050.

To read the reports, search for the titles at **www.gov.uk**

Tube produces 500GWh of waste heat

Transport for London (TfL) has called on the industry to help reuse the waste heat generated by the city's tube network. Every year, 500GWh of heat is produced by the London Underground, according to Sharon Duffy, head of transport infrastructure at TfL Engineering.

Speaking at last month's CIBSE Technical Symposium, Duffy said there was an opportunity for industry and academia to work with the authority to develop new technology and identify opportunities to reuse waste heat.

According to Duffy, 79% of the heat generated by trains is transferred into the tunnel walls, with only 11% escaping to the surface through what she described as the piston effect. She added that 50% of the heat energy was produced by trains braking, while other energy sources include: aerodynamic drag and other frictional losses (21%); motors/drives (15%); and electrical systems (6%). People produce only 2% of the heat.

TfL is looking at recycling waste heat at various locations, including Bunhill Energy Centre in Islington. Here, a fan, powered by a combined heat and power (CHP) system, will extract heat from the underground and use it to produce hot water for residents via an existing heat network.

LSBU introduces BEN to CIBSE Technical Symposium

The latest findings from a prototype heat network at London South Bank University (LSBU) were presented at the 2018 CIBSE Technical Symposium last month. The balanced energy network (BEN) combines low carbon heating, cooling and electricity with a demand-side response management system and distributed thermal storage.

Presentations looked at the feasibility of integrating heat pumps into the boiler-fed heating circuits of two 10,000m^2 office buildings and explored the long-term planning for heat networks, as well as the addition of waste heat into a network.

CIBSE Journal will look at BEN in detail in a future issue.

Rinnai on the road

A Rinnai hot-water heater system is one of the features serving up high-end, mobile accommodation on the Bedroam bus – a luxury tour-bus-meets-glamping concept that recently featured on Channel 4 TV's *Amazing Spaces*.

The Bedroam features 18 high-spec, Japanese-style pod bedrooms built on two decks and has two fully equipped bathrooms with shower, toilet and sink. Sinks and showers are supplied with safe, temperature-controlled hot water from two Rinnai Infinity 17e water heaters – working on liquefied petroleum gas (LPG), complete with MC91 controller – via motion-sensor taps.

Underfloor upgrade in Sandwell school

A fully integrated underfloor heating package from Upanor has been installed as part of the newly developed Sacred Heart Primary School in Sandwell, West Midlands. The 15-classroom project by Sunesis – a joint venture between Scape Group and Willmott Dixon that specialises in new school builds – featured an Uponor Tacker 16 underfloor heating system, using a heat pump as the main energy source. The configuration was chosen to maximise the low heat outputs of the energy source while giving a cost-efficient and controllable approach to heating the building.

Groundwork being laid for heat networks code update

CIBSE and ADE call for views from industry on current edition

CIBSE and the Association of Decentralised Energy (ADE) have initiated a project to update *CP1 Heat networks code of practice*, and are seeking feedback on the current, 2015 edition.

As part of a consultation on the revised CoP, the update team is looking for suggestions from industry members on changes they feel are necessary and reasons for them, including thoughts on the usability of the document. The team is particularly interested in speaking to anyone who has used CP1 from project inception through to operation.

It is also seeking recommendations on any guides or standards that CP1 should reference or that the authors should review (with links, where appropriate).

Phil Jones, chair of the CIBSE CHP-DH Group, said: 'Experience in using CP1 is providing important feedback that needs to be captured.'

The new guide, funded by the Department for Business, Energy and Industrial Strategy, is expected to launch in autumn 2018. A key issue is to make compliance with CP1 easier to verify/check. Jones said: 'The "draft" checklists need to be improved and fully integrated into CP1. It needs redesigning to strengthen CP1 compliance.'

Feedback should be submitted as soon as possible using a form on the CIBSE consultation website at **bit.ly/2Jk5noR** – this can then be emailed to **CIBSECoP1revision@cibse.org** Alternatively, post your comments on the LinkedIn feedback group at **www.cibse.org/CP1feedback**

Updating the Code of Practice

By Phil Jones, chair of the CIBSE CHP-DH Group

The CIBSE/ADE *CP1 Heat networks code of practice* (2015) has been highly successful in setting down minimum standards and improving the quality of district heating projects. It is also having a strong influence on the procurement of heat networks, and underpins much of the Heat Networks Delivery Unit (HNDU) and Heat Networks Investment Project (HNIP) work by BEIS. It was always recognised, however, that the code would need updating at intervals, to reflect new understanding, feedback from the industry, changes in regulations and results from research projects. We need to take heat networks to the next level by ensuring developers have increasing confidence in investing in these schemes.

New work over the past three years needs to be taken into account, including the BESA heat interface unit testing scheme and the Small Business Research Initiative (SBRI) research programme.

Confidence will only come through tighter standards and a clear process for checking that CP1 has been met. The client needs to set clear performance targets and be able to check, at each stage of the project, that these will be met. The goal is enhanced performance in use, satisfied investors/operators, and happy customers.

Phil Jones

New piping guide published

The British Plastics Federation (BPF) Pipes Group has released a new guide for the construction and utility industry – *Quality assurance with electrofusion jointing*. This aims to help project managers demonstrate the quality of installed fusion joints and the integrity of new polyethylene (PE) pipeline systems.

Available from **www.bpfpipesgroup.com/support-downloads/guidance-notes/**, the guide is a step-by-step approach – based on established, non-destructive examination and testing techniques – to offer assurance that good workmanship has been used throughout a project.

It builds on the best practice for jointing set out in the recently revised WIS 4-32-08 standard for the fusion jointing of PE80 and PE100 pressure pipeline systems.

HNIP grants and loans up for grabs in autumn

A £320m Heat Networks Investment Project (HNIP) will be launched this autumn, as part of the government's Clean Growth Strategy. It will offer grants and loans to the public and private sectors for networks that serve two or more buildings.

The government wants networks to deliver up to 17% of heat demand from homes – and up to 24% from industrial and public sector buildings – by 2050. 'The UK has led in the decarbonisation of electricity and we are just as committed to tackling heat,' said Energy Minister Claire Perry. '[The HNIP] creates a route to market for innovative projects and demonstrates a key objective of the Clean Growth Strategy – to help deliver technologies that can lower bills, cut carbon and improve the quality of life for communities.'

The pilot HNIP ran for six months and awarded £24m to nine local authority projects in March 2017.

Care home heating upgrade from Elco

Elco Heating Solutions has supplied five Thision L EVO 120kW boilers to Westhaven House care home, in Weymouth, Dorset, as part of a refurbishment of its heating and hot-water system. The aim is to reduce energy use, emissions and running costs.

The care home's ageing and very inefficient atmospheric boilers and direct gas-fired water heaters were replaced by a floor-mounted, cascade system, consisting of the five boilers and two 500L Gemini calorifiers.

In addition, Elco supplied a weather-compensation kit, while the boilers' built-in control is managing the system pumps and diverter valves for two heating zones and the domestic hot water.

Baxi Heating targets training in 2018

Baxi Heating's new Commercial Training Academy has opened its doors, offering heating engineers the chance to refine their skills and gain practical experience in a real-world environment.

All product training is free and course content is tailored to the audience. Sessions geared towards contractors are more hands-on and cover practical tips about installation, commissioning and maintenance, while distributor training focuses on identifying the correct appliance for customers' requirements.

In addition to an updated curriculum, a new online booking system has been introduced. Anyone who books and attends a course before 1 June will receive a complimentary Baxi-branded softshell jacket.

Regulatory approval for Stovkis HIUs

Stovkis Energy Systems' range of Econoplate H2 heat interface units (HIUs) have been granted overarching certification for water quality under the Water Research Advisory Scheme (WRAS).

The consolidated approval follows tests at WRAS-approved laboratories, which demonstrated compliance with regulatory standards. Certification remains valid for five years – until December 2021 – and covers the Stokvis Econoplate H2, H2-24/14, H2-24/24 and H2-24/40 HIUs, which are designed for use with communal or district heating applications.

Heating failure tackled at St Helens Millennium Centre

Corrosion in heating pipes caused by poor water treatment and oxygen ingress

Water-treatment specialist Sentinel Commercial has carried out a cleaning and protection programme on the commercial heating system at the Millennium Centre, St Helens, Merseyside. It restored heating to the building after severe corrosion had left the system practically unusable.

Sentinel and water-treatment expert Richard Cumber were called in by the building's maintenance company in late 2015, to try to address long-term issues in the multi-purpose, three-storey facility, which was built in 2001 and is home to more than 70 charities and statutory organisations.

The centre had been experiencing serious problems with its system since 2013, with heat output from the commercial heating system decreasing to virtually nothing at times, despite rising thermostats.

Sentinel discovered that the heating system had severely corroded and was almost blocked, with thick iron-oxide deposits inside the radiant panel radiators and connecting pipes, stopping circulation of water.

It diagnosed the chief cause of corrosion as a combination of poor water treatment and excessive oxygen ingress. To solve the problem, Sentinel applied best-practice water treatment, including: boiler manufacturer-endorsed chemicals to remove debris; inhibitor to prevent further corrosion; and a regular maintenance regime for system water.

The programme not only solved the Millennium Centre's long-standing heating issues, but also resulted in significant savings in maintenance and energy costs. For more information visit **www.sentinelprotects.com**

University challenge for Hoval

The University of Edinburgh's Mylnes Court student accommodation complex has had its ageing Hoval boiler system upgraded to the firm's high-efficiency SR Plus and UltraGas boilers. These were specified by Engright Engineering Consultants and installed by contractors Taylor and Fraser.

Mylnes Court, on the Royal Mile, includes three halls of residence, housing 176 postgraduate students in self-catered flats. A central boiler house provides space heating, domestic hot water and pre-heating of ventilation air in air-handling units.

'The original system was designed to operate with medium-temperature hot water, but this was later changed to a low-temperature hot-water system,' said Engright's David McNeill. 'The boilers were retained and adjusted to operate with lower flow and return water temperatures. However, as they got older, a decision was taken to upgrade them. We selected Hoval boilers again as they offer the required efficiency, and their compact design helped to address space issues in the boiler house.'

A++ EFFICIENCY FROM INTEGRATED BOILER AND HEAT PUMP

Sime has launched the Murelle Revolution 30, an integrated boiler and heat pump in a single-cased product. Aimed at the new-build, social housing and retrofit renewables markets, the unit uses an ErP A++ 30kW Murelle boiler and a completely sealed 4kW output heat pump, working in tandem. It is designed to be installed inside a building and mounted on the wall, like a conventional boiler. The unit is capable of an average seasonal heating performance of 134%, delivering A++ energy efficiency.


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Rising from the ashes

The Northern Irish version contributed to bringing down a government and the entire scheme has been branded a waste of taxpayers' money, but it looks as if the Renewable Heat Incentive is here to stay… and offering guaranteed returns for investors, writes Ewen Rose

Financing of the Renewable Heat Incentive (RHI) has come under intense scrutiny, not least because of the controversy in Northern Ireland, where the scheme contributed to the collapse of the power-sharing government in Belfast. It continues to be the focus of an acrimonious inquiry into alleged financial mishandling, with RHI claimants apparently incentivised to 'burn to earn'.

Despite this furore, financial incentives remain available in the rest of the UK for users switching from fossil-fuel plant to: biomass systems up to 1MW (thermal) in capacity; heat pumps (ground, water and air source); deep geothermal; solar thermal collectors; biomass combined heat and power (CHP) systems; and biomethane and biogas for heat. As this edition of *CIBSE Journal* went to press, parliament was expected to approve the RHI's next phase.

Set up in 2011 to encourage commercial users to switch from fossil-fuel heating systems to renewable and low carbon alternatives, the RHI scheme was later extended to residential projects.

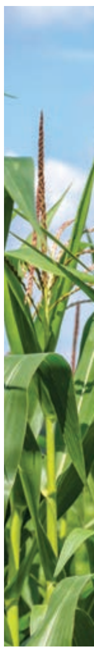
After detailed public consultations, which ended in 2016, the Department for Business, Energy and Industrial Strategy (BEIS) has agreed changes to the scheme. These are aimed at delivering better value for money, while still encouraging investment in renewable heat technologies – with particular emphasis on large-scale projects this time.

Guaranteed tariffs

Full details of the budget for the revamped scheme have still to be revealed by BEIS, but half of the money will be allocated to 'guaranteed tariffs'. This is a significant change, designed to give investors certainty about the rate of return they can expect at the earliest possible stage of their project. They must, however, have secured full planning permission before applying.

The tariffs have been set up in a way that should favour larger-scale projects. This is to address a perceived imbalance in the RHI, which has led to a large proportion of smaller-scale schemes. It also supports the widely held philosophy that bigger is better when it comes to renewables.

Without early-stage guarantees, there was a worry that much higher tariffs would have been needed to encourage investment in large-scale projects. In general, however, the



tariff levels have been held steady, with the exception of biogas and biomethane, which will benefit from improved payments.

There have been other changes for projects installed since September 2017. For example, the tier threshold for small and medium biomass has been raised and these, which will now be assessed on 35% of heat load – up from 15%. Large biomass will also move from a single, untiered tariff to a tiered tariff with the same 35% threshold.

Heat used to dry, clean or process waste will no longer be eligible for RHI payments and heating swimming pools will now only qualify if the pool is for public use. Single residential premises will no longer qualify; in the past, some large dwellings were eligible, but they will now have to apply to the domestic scheme, with lower tariffs.

The main underpinning rules remain, including that: no public grants can be used to fund any part of the installation unless it has been repaid; the plant must have been new at the time of installation; and it must use either liquid or steam to deliver heat.

Qualifying projects receive payments for 20 years – paid out quarterly – based on the 'actual' heat output of the installation; credits only accrue once the installation has been signed off by the RHI operator and industry regulator Ofgem. To calculate the output, installations must be metered, but it remains unclear how the regulator intends to improve policing to avoid embarrassing revelations of systems installed but never fired up. By its own calculations, Ofgem believes 4.4% of non-domestic schemes were non-compliant during 2016-17, but had received £3m in payouts.

Historic abuses are, however, just a small part of the scheme's financial issues, according to a National Audit Office (NAO) investigation, which claimed the scheme had 'not achieved value for money'.

Hitting the target

In its report, published in February, the NAO said the scheme was likely to deliver only 22% of its target number of new installations. Fewer than 80,000 had been delivered by the end of last year and the report estimates that around 111,000 will be completed by March 2021 – compared with the target of 513,000 by 2020.

Total payments to claimants between November 2011 and August 2017 were £1.4bn; the scheme is expected to cost the taxpayer £23bn by 2040-41. On the plus side, the NAO said the scheme saved 4.5 million tonnes of CO_2 equivalent last year and the government has avoided a Northern Ireland-style catastrophe by tweaking the payout system and introducing greater flexibility.

BEIS said: 'We have already taken major steps to prevent people from cheating the system and we welcome this further advice from the NAO to stamp out these practices.' It added that the RHI was playing 'a crucial role in reducing carbon emissions from heat and helping to make progress towards our legally binding renewable energy and carbon targets'. BEIS also said the UK was delivering a faster emissions reduction 'on a per person basis than any other G7 nation'.

The Renewable Energy Association (REA), meanwhile, pointed out that the RHI has led directly to 78,048 renewable heat installations and the production of 22.7TWh of renewable heat, enough to heat more than 1.8m UK homes for a year. It also claimed the RHI is crucial to creating 'low carbon' jobs, with more than 33,000 people currently employed in the renewable heat sector.

> "The government has taken a 'light touch' approach and resisted the temptation to make wholesale changes with this new iteration"

The REA's head of policy and external affairs, James Court, said the RHI was an 'essential policy tool that is supporting the decarbonisation of Britain's heating sector as necessitated by our climate targets'. The government has, therefore, taken a light-touch approach and resisted the temptation to make wholesale changes. It has looked to make the scheme more cost-effective by, for example, adjusting the tariffs for ground source heat pump systems to favour schemes that supply multiple buildings. BEIS has also said it will review the tariffs as the heat pump market grows and ensure the RHI underpins the 'quality of the supply chain'.

New biogas and biomethane plant will now need to produce at least half their energy from waste-based feedstocks to receive RHI support, in an effort to divert waste from landfill and make better use of available resources. There is also a greater focus on air quality; biomass applications made since 24 September 2013 have to meet specific emissions targets. In addition, BEIS has adjusted the tariffs to encourage biomass only where it can 'make the most effective contribution', such as in high-temperature industrial processes. The reformed scheme also introduces one level of support for all new non-domestic biomass boiler projects.

The government has changed the scheme to minimise the criticism that taxpayers have been subsidising ill-conceived, money-making schemes. It is a compromise that could hamstring the RHI and reduce its potential to revolutionise the low carbon heating market, but policy-makers might just have struck the right balance – time will tell. **CJ**

■ This article is focused on the non-domestic RHI.

TECH TARIFFS

Full details of the tariffs for individual technologies can be found at: bit.ly/2HIEwFQ

Ready to switch?

Heating is one of the topics that divides our industry. There are those who swear by the tried and tested methods of gas and associated technology, but we must prepare for decarbonisation of the Grid, says Cavendish Engineers' **Phil Draper**

When a building is designed, it must fall within an emissions target as specified in the Building Regulations. The calculation uses an outdated high figure for the carbon intensity of electricity, so the regulations tend to be more favourable towards the use of natural gas. So, for example, using this data, 1kWh of gas used by a boiler will provide approximately 0.8kW of energy and produce approximately 0.2kg of CO_2. In contrast, using an electrically driven heat pump to produce the same heat (and disregarding any potential cooling benefits) is likely to have an equivalent CO_2 impact of less that 0.1kg. Heat pump technology that uses electricity is at the top of the innovation list at Cavendish Engineers because of the energy and financial savings it offers.

Three years ago, we installed an air source heat pump at 350 Euston Road, replacing the roof-based chillers and creating new ways of reducing energy consumption for the owners. This technology has a power output of 7kW for each supplied kW of electricity. This is delivered as 4kW heat and 3kW cooling. It's a very efficient set-up because of the heat recovery the equipment supplies. The energy results back-up the use of heat pumps. The gas bill has reduced by 85% since installation in 2015, producing yearly bills of £5,000. The work was shortlisted at the CIBSE Building Performance Awards.

"We have cut the gas bill at 350 Euston Road by 85% since installation in 2015"

Despite the fantastic financial savings, heat pump technology has its critics. In designs with which I've been involved, people believed it was not viable because of the space required and the lower-grade heat involved. There is also a fear that you are adding load to the Grid, which is reportedly at breaking point.

Batteries can help with risk management and energy efficiency. Peak use for electricity happens in the winter months, generally when people are returning home from work, between 4pm and 6pm. This is the 'triad' period, during which the Grid penalises buildings for using electricity across the time frame – and, at £80 a kilowatt, it's big money. Greater visibility of batteries in the market would allow more renewable technology, such as heat pumps, to be installed, adding Grid support and a money-saving point. If you're producing more sustainable energy than you can use, batteries can store it for later.

In 2014, the EU introduced the Heat Network (Metering and Billing) Regulations, which stipulate that meters must be installed where there are two or more customers. The idea is to offer insight into energy use and make occupiers accountable. 350 Euston Road was designed to have two occupiers per floor, and so two sets of meters across heating and cooling. This data will help shape future energy efficiency in terms of sizing and control, and we have used it to improve building comfort by identifying and resolving the unknown issues.

System sizing

The design of heating systems was originally based on an outside air temperature of -4°C in peak winter. However, the average winter temperatures in the UK are closer to 8°C. In hindsight, systems should have been designed to cope with -4°C in a worst-case scenario, rather than using it as the base data. It would change the method used to size and select the equipment. Otherwise, for much of the year, the system would be well oversized and potentially more difficult to operate efficiently if it was based on a full-system sizing of air handling and fan coils. Preferably the whole design should focus on the building's heat loss and reuse the heat generated internally, rather than operating the fresh-air plant to meet heating loads and, in doing so, adding to your heat and load.

350 Euston Road was a 760kW system and a prime example of what can be done in a retrofit. Additional expenditure on the project was £70,000, to have the heat pump installed rather than a standard chiller, and

Controlled energy at 350 Euston Road has been cut by more than 70%

PHIL DRAPER MCIBSE is operations director at Cavendish Engineers

the payback in terms of financial savings on energy use was just eight months – a fantastic return. If you don't have a heat pump option to go on the roof, you can use a water-to-water unit, which Cavendish Engineers has just installed in a mixed-use development in London. The site has water-cooled chillers in the basement and they provide a heat source through a modification to the condenser cooling water system. That heat normally goes through the cooling towers and into the atmosphere. This would typically mean rejecting heat at 35°C to provide condenser loop water at 28°C.

Our solution takes that 35°C heat before it reaches the cooling towers and increases its temperature through a heat pump cycle, to put a much higher grade of heat for the building. We then return cooler water into the condenser cooling loop. This saves cooling tower energy use, and boilers are not used in any part of the process. There's an efficiency of 3.5 on that unit, so the energy intensity in carbon use benefits from this, and we can produce 75°C heat in the building.

Two heat pump units were installed with a capacity of 360kW each, but one of these will be enough for 80% of the year; this means the gas use will be reduced by around 50-60%. We understand it is the first time this has been done in a retrofit building in the UK. Some might consider it a risk, but we recognise the need within the building and know how the technology works and how to implement it, so there's very little risk in our eyes.

Controls

Ultimately, good efficiency comes down to controls. We can achieve a 20-30% gas reduction in many buildings simply by improving the control. Recently, we looked at a two-year-old building in which the combined heat and power (CHP) was failing. We found that the boiler system controls weren't installed and operating to suit the profile of the CHP requirements; the CHP was set up to operate as lead boiler, but the modulating gas boilers were operating in a way that didn't allow this. We changed the controls and fixed the problem.

I have helped British Land for eight years, working across 14 buildings that have automated meter readings. Analysis of the data has achieved a reduction of more than 40% in like-for-like energy. At 350 Euston Road, in particular, metering data has helped cut the building's controlled energy by more than 70% since 2008.

We wouldn't recommend installing a CHP system now, but there's no reason existing systems shouldn't be used because, on average, a CHP is 90-95% efficient, compared with a gas boiler of 80%. It also makes sense to use controls to operate it during the triad period and knock money off the electricity bill throughout the year.

Finally, we need to consider how technology might affect the amount of gas going into London and its impact on air quality. Gas combustion – for example, from boilers and cookers in buildings – accounts for 38% of the nitrogen oxide (NO_x) emissions in central London.

Why gas CHP still measures up

Despite the rapid decarbonisation of the UK electricity grid and lower wholesale prices, properly sized combined heat and power with thermal storage still offers an economic, lower-carbon energy option, explains director of Carbon Alternatives Martin Crane

Why choose combined heat and power (CHP)? With Britain generating more electricity from renewables (29%) and nuclear power (21%) in 2017 than from coal and gas, decarbonisation of the UK Grid is clearly advancing rapidly, while falling wholesale electricity prices are – for some – bringing into question the economic efficacy of deploying gas CHP applications.

Falling electricity supply emission factors may be reducing the relative carbon savings of gas-fired CHP, but correctly sized gas CHP systems with thermal storage are still an economic, cost-effective and lower-carbon energy option. In addition, its profitability can help fund the development of heat networks, which would allow a wide range of alternative renewable heat sources to be used in the future. This article looks at some of the main factors to consider to ensure CHP and thermal storage are sized correctly to optimise economic and emission-reduction benefits.

The economics of sizing

Gas CHP is a tool to reduce cost and carbon emissions, and most applications – such as in hospitals, industrial plant and hotels – are driven by economic returns. In many district heating (DH) applications, however, the driver for both the heat network and the CHP system is to allow the development to meet planning requirements – economic fundamentals are often less important or overlooked. Having reviewed a significant number of DH network feasibility studies and schemes for ESCO adoption – and through work for the Department for Business, Energy and Industrial Strategy (BEIS) on DH optimisation – it is apparent that these schemes often lack a rigorous economic assessment to establish the best size for the CHP system and thermal store. Commonly, the proposed size is based on a range of technical criteria, but these can fail to deliver the highest economic and carbon-reduction benefits.

However, to achieve maximum returns – and optimise carbon reduction – sizing CHP systems correctly before the design stage is critical. This requires the most robust economic and technical data possible, assisted by bespoke software – such as energyPRO – to enable techno-economic modelling.

In terms of £/kW output, larger CHP systems are cheaper than smaller ones, and have lower maintenance costs per kWh of electricity generated, as shown in Figure 1. Additionally, larger CHP systems tend to deliver higher electrical efficiency, which means more electricity is generated for each unit of heat supplied – leading to higher profitable electricity sales. The combination of these factors means the overall cost of heat from larger CHP systems is lower than for smaller ones.

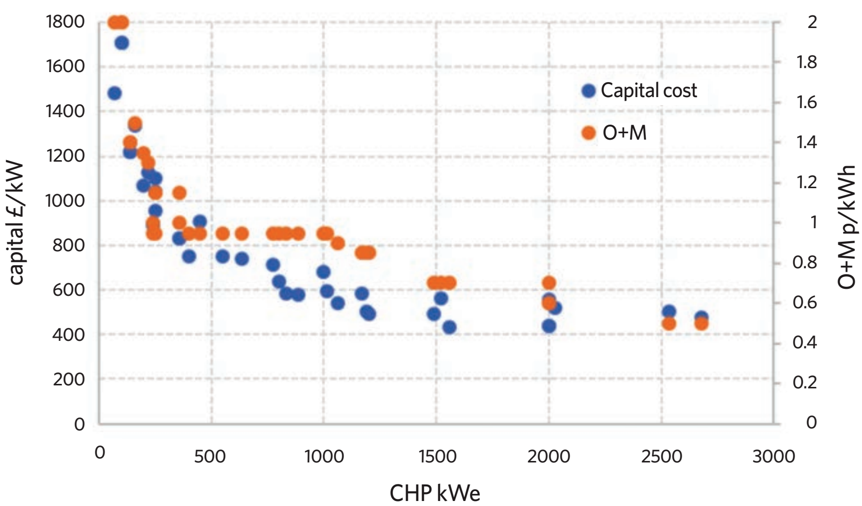


Figure 1: Larger CHPs are cheaper than smaller ones in terms of £/kW output and maintenance costs per kWh

"Larger CHP systems are cheaper than smaller ones, and have lower maintenance costs per kWh of electricity generated. They also deliver higher electrical efficiency"

CHP size		2 x 600 kWe	2 x 600 kWe	1,200 kWe	1,487 kWe	1,999 kWe	2,679 kWe	3,360 kWe
Thermal store size m^3		12	10	10	10	175	250	400
Electricity tariff		Flat	STOD	STOD	STOD	STOD	STOD	STOD
Heat-production cost	p/kWh	2.47	2.07	1.37	1.19	0.70	0.40	0.38
CO_2 emissions to supply heat load	tonnes/yr	1,230	1,240	770	610	100	190	270
CHP and thermal store capital cost	£k	910	940	770	870	1,340	1,520	1,900

Table 1: Economic and carbon-saving assessment of a range of CHP and thermal store sizes. Data for each CHP size, with most economic thermal store sizes presented

This analysis assumes all the electricity the CHP system generates is exported, rather than sold over private wire. When a small generator approaches an electricity supplier about selling its power, the supplier will typically offer a seasonal time of day (STOD) tariff for the power generated. This offers high prices in the winter between 16:00 and 20:00, low prices at night and medium rates outside of these periods (see Figure 2). Such tariffs offer great economic benefits to CHP applications with thermal stores, and so impact radically on the optimum CHP size. With such a tariff and a thermal store, the CHP system can operate more when the electricity price is highest and less when prices are lower. Yet, often, sizing assessments for CHP and thermal stores are based on a single, year-round electricity price.

Example CHP project

Using an example based on a DH project reviewed previously, an energyPRO model[1] was set up. This evaluated a range of sizes of CHP system and thermal store. The DH scheme modelled comprised new and existing residential stock, a college and a care home, with a total annual heat demand of 8GWh. The heat demands and profiles were predominantly based on monitored data, which the energyPRO used to generate hourly heat demands from the profile and the hourly CIBSE Test Reference Year temperatures.

The reviewed proposal was to supply these heat demands with two 600kWe CHPs and a $12m^3$ thermal store. The following analysis considers alternative CHP and thermal store sizes to maximise the economic returns. It uses the same »

» energyPRO model and changes only the size of the CHP and thermal store. The time-weighted average STOD electricity price is equal to the flat rate electricity price.

Figure 3 shows the results of the model runs, with every point on the graph representing one model run. For each CHP system size, the thermal store size has been varied to find the economically optimum dimensions for that CHP; the range of thermal store sizes includes a smaller and larger store that has lower net present value (NPV) than the optimum.

The results for the optimum economic store size for each CHP system are in Table 1. This shows the economic improvement of increasing the CHP and thermal store size, based on the output of the energyPRO model. All CHPs run only at full load, and no heat is dumped. For comparison, the cost of heat from 80%-efficient gas boilers is 2.75p/kWh, and the carbon emissions from boilers are 2,140 tonnes CO_2 per year.

Electricity tariff – indicates the tariff pattern against which the economic optimisation was done. A 'flat' tariff is the same all year round. The STOD tariff is similar to the example shown in Figure 2, with two prices per day in summer and at weekends, and three in winter weekdays.

Heat-production cost – is the cost of the gas used in the CHP and boiler, plus the CHP operation and maintenance cost[2], minus the electricity sales value. This is the cost of each kWh of heat leaving the energy centre.

The CO_2 emissions to supply heat load – the emissions associated with the gas burnt in CHP and boilers, minus the emission displaced because of the CHP electricity generation. These are calculated using the Part L UK Building Regulations values of gas at 0.219kgCO_2/kWh and electricity at 0.519kgCO_2/kWh.

CHP and thermal store capital costs – this is the capital expense of just the CHP and thermal store[2] – the CHP costs from all the other energy-centre plant costs will be similar for all the CHP sizes evaluated (the major exception being that the larger thermal stores need more space, as do the 2,679kW and 3,360MW CHPs).

The dramatic reduction in heat-generation cost and carbon emissions can be seen as the CHP system and thermal store sizes increase. The single 1,487kWe CHP system has a lower capital cost than the original CHP selection, generating heat at half the cost and with half the CO_2 emissions.

The modelling clearly shows the benefits of larger CHPs and thermal stores; heat

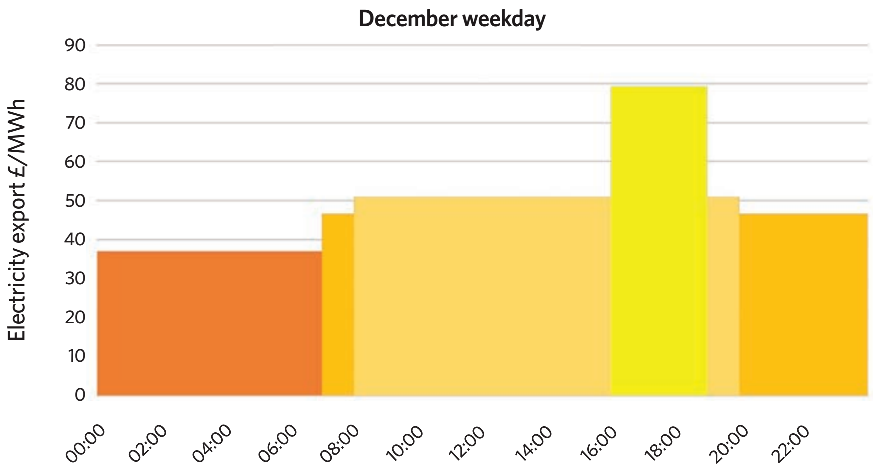


Figure 2: Typical winter weekday electricity price variation with STOD tariff

costs decrease as the CHP and thermal stores sizes increase because:

- More electricity is sold at times of highest electricity price
- More electricity is generated, because larger CHPs have higher electrical efficiencies and produce less heat for every unit of electricity generated
- The CHP operation and maintenance costs are lower per unit of electricity generated
- The bigger CHP system and thermal stores mean larger proportions of the heat load can be supplied with CHP heat.

The increases in carbon savings are a result of the increased CHP electrical efficiency and the increased amount of electricity generated for the same heat delivered. The carbon emissions increase for the 2,765kWe and 3,360kWe CHPs because their electrical efficiencies – at 41.6% and 40.8%, respectively – are a little lower than the 1,999kWe CHP efficiency of 41.8%.

Despite this, the trend is predominantly towards higher electrical efficiencies for larger units – for example, 4MW and 7.5MW CHPs have electrical efficiencies of 42.9% and 45.2% respectively. The required thermal store sizes are large, so the designer must be able to present a robust case for the economic and environmental benefits of the store.

Technical CHP sizing 'rules of thumb'

CHP utilisation – the CHP running hours divided by 8,760 (the number of hours in a year)

CHP hours run – the number of hours the CHP operates in a year

Proportion of heat from CHP – the proportion of the heat demand that is met with heat generated from the CHP; the remaining heat is from gas boilers.

It should also be observed, from Table 2, that some of the commonly quoted technical criteria 'rules of thumb' for sizing CHP – such as 'to achieve more than 5,000 (or 6,000) hours operation per year'; 'to select the CHP utilisation with highest utilisation'; and 'to cover the baseload DHW demand' – are all potentially »

CHP size	2 x 600 kWe	2 x 600 kWe	1,200 kWe	1,487 kWe	1,999 kWe	2,679 kWe	3,360 kWe
CHP utilisation	52%	51%	56%	51%	46%	32%	24%
CHP hours run	4,554	4,489	4,916	4,449	4,016	2,783	2,134
Proportion of heat from CHP	75%	74%	77%	82%	94%	91%	91%

Table 2: CHP utilisation, hours run and heat proportion

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poor selection criteria on which to achieve maximum carbon and economic benefits for DH heat loads. The more economic CHPs have far lower utilisation and hours run than the technical sizing 'rules of thumb'. The proportion of heat is higher – and the CHP far larger, than the baseload (the average demand in August is less than 500kW for the modelled scheme).

In addition, using emissions factors based on half-hourly Grid generation mix shows that CHP – sized as recommended in this article – achieves more than 40% higher savings in CO_2 emissions than is estimated using annual average emission factors.

Conclusion

Carbon savings from gas CHP will reduce as the Grid decarbonises, but this work shows there is a wide range of potential CO_2 and economic savings arising from CHP. System designers need to ensure their recommended solutions maximise the benefits of the technology – how they size and integrate low carbon technology has a very significant impact on the benefits arising from it. The full paper on which this article is based indicates that maximising the economic returns from CHPs very nearly provides the maximum CO_2 savings too.

Gas CHP applications with thermal storage – when sized correctly – still offer a cost-effective, lower carbon energy solution. To achieve this though, it is essential to consider that:

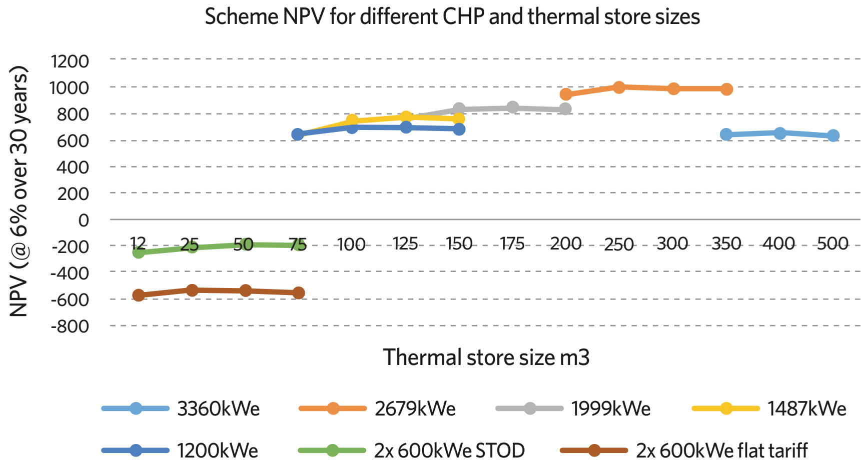

Figure 3: Economics of a range of CHP and thermal store sizes

- CHP and thermal storage is sized on an economic basis
- The assessment should be based on STOD electricity tariffs, as these are what suppliers offer for CHP applications, and they improve the CHP economics
- Part-load operation of the CHP increases heat cost and lowers carbon savings so consider the true part-load efficiencies and operation and maintenance costs in any analysis
- The analysis should show the economic optimum has been found, as demonstrated by larger and smaller plant (the CHP or thermal store being optimised) that is less economic. **CJ**

■ **MARTIN CRANE** is MD of district heating and energy efficiency consultancy Carbon Alternatives.

■ This paper was presented at the 2018 CIBSE Technical Symposium. All the papers will be available at **www.cibse.org/symposium**

References:

1 Information on the capabilities of software model energyPRO can be found at **www.emd.dk**
2 CHP O+M and capital and installation costs were from the Veolia CHP consultants' database and the thermal stores were costed at £1,000 per m³.

CHP PART-LOAD OPERATION

CHPs operating at part load have lower electrical efficiency, produce more heat for each unit of electricity generated, and incur higher maintenance costs. In studies, CHP operation and maintenance costs are commonly stated in terms of p/kWh of electricity generated, but – in operation and maintenance contracts – the charges are often on the basis of CHP operating hours; so a CHP operating at 50% output effectively has double the p/kWh(e) charge. Table 3 details how part-load operation increases the cost of heat and the CO_2 per kWh of heat. Where the CHP is not supplying onsite electrical loads, part-load CHP operation is detrimental to economic and environmental performance.

		Manufacturer's data	Calculated data					
CHP output electrical	CHP output Heat	Fuel	Heat	Electricity	Electrical efficiency	O+M cost	CHP heat emissions factor	CHP heat cost
		kW	kW	kW		£/hr	g CO_2/kWh	p/kWh
100%	100%	1,797	654	600	33.4%	6	117	2.4
50%	64%	1,089	421	300	27.5%	6	189	3.6

Table 3: Cost and CO_2 impact of operation of 600kWe CHP at part load


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Best laid plans

The government has committed millions of pounds to heat networks, but the long-term future of the technology will depend on the success of the generation currently being designed and built. Vital Energi's **Paul Kay** and **Lee Moran** look at the factors that determine best performance

It is a period of rapid growth for heat networks in the UK. Government grants are accelerating a shift towards decentralised heat. The Heat Networks Investment Project (HNIP) is set to allocate another £320m to schemes from 2019. The supply chain is evolving to ensure heat networks are optimised for performance, while the introduction of *CP1: Heat networks code of practice for the UK*, by CIBSE and ADE, has become a valuable document. Here are some of the key factors we believe need to be considered when delivering heat networks.

Hard lessons and soft landings

Large-scale developments often take years and changes in the market during that time may affect a building's end use. The shift from residential to commercial, or vice versa, will affect the peak load and, therefore, plant sizing. The energy profile may also alter, which could affect the viability of low and zero carbon (LZC) technologies.

In some cases, this can be addressed by building temporary energy centres of traditional gas-fired boiler plant instead of higher-value LZC technology, which is often not viable until an established load is connected to the network. Our networks evolve almost on a modular basis

For most of the time during build-out, networks operate at part load, and it is here that system inefficiencies occur if operational nuances related to part-load control, particularly pump control, are not considered. Collaboration with the developer throughout the build is essential to optimise system design.

Soft landings enables the transfer of knowledge between design, installation and operation, and maintenance teams. It requires design teams to stay on the project to fine-tune the plant, and ensure it operates at a high efficiency.

Extensive metering and data acquisition happens on most projects. Lessons learned from the data can be fed back into the design stage, which helps encourage lean solutions.

Demand and supply

District heating networks are in their fourth generation (4GDH), and are typified by low supply temperatures and wider flow and return temperature differences. Typically, 70°C/40°C flow and return temperatures are stated, and awareness is required to distribute these across the network efficiently. 4GDH allows for a wider range of heat-generating technologies, such as heat pumps, to be applied to networks with greater operating efficiencies. Temperatures need to be established and set at the concept stage – right from the point of use, back to the energy centre. (See Example 1). Flow rates in a heat network have a huge range – from <10% to 100% – so pumping systems need to be designed to operate at their most efficient at their longest running hours. Typically for DH systems, more than 90% of the operational hours is at less than 50% of the peak thermal load.

Connecting 4DGH networks to existing building stock with low-pressure hot-

Vital Energi's 2km Manchester Civic Quarter heat network features two gas CHPs and a 40m flue (right) designed by architect Tonkin Liu

water (LPHW) systems at 82°/71°C or 80°C/60°C is problematic because of a mismatch in temperatures. Great care with detailed surveys and analysis of the existing system is required, as the correction factors on existing heat emitters are lower than 0.5 because of the lower log mean temperature difference (LMTD – the fundamental basis of heat transfer). Traditional low-temperature hot-water (LTHW) systems are based on 82°C/71°C flow and return temperatures. District energy networks are trying to lower temperatures and widen the temperature delta – for example 80°C/50°C. Serving a system designed on historical temperatures via a district network with lower temperatures results in existing emitters – for example, radiators – having their heat output cut by 50% because of the reduced LMTD. This could result in existing systems being rendered inadequate.

Secondary systems connected to the DH network also need to be variable volume, and maintain low return temperatures as well as a wide flow and return temperature difference. Avoid any 3-port valves, bypass loops (unless thermostatically controlled) and anything that will increase system return temperatures. Compensated secondary heating or underfloor heating systems assist low return temperatures when adequately controlled.

Suppliers are keeping pace with the demand for optimised heat networks. For example, there has been an increase in the standard insulation thicknesses for pre-insulated district heating pipework – an improvement of about 20% across the manufacturing range. Prefabricated DH main pump skid arrangements can now encompass, for example, duty/assist/standby/jockey pumps, including sequence controls based on a quadratic system pump curve or multiple differential pressure-sensing index circuit control.

Quadratic control of pumps negates the need for additional pump controls. The pumps operate using a virtual quadratic operating curve programmed by the manufacturer into the onboard controls. This curve is based on the design system curve. Variable speed pumping to meet the changing system requirements is achieved by maintaining a minimum differential pressure at all flow conditions via the monitoring of the pump power and speed, to ensure all points of operation are maintained. Boilers have also evolved to extend operating parameters from a typical 20K ΔT across the flow and return, to 40K ΔT.

We see a strong business case for CHP, but – as the electricity grid decarbonises – its environmental benefits will diminish unless a fossil-fuel supply is replaced by renewable technologies, such as geothermal, air and water source heat pumps, and energy from waste. **CJ**

■ **LEE MORAN**, is associate design director and
PAUL KAY is building services and design director at Vital Energi

Example 1: Typical fourth-generation district heating network temperatures

Direct to customer HIU	
System	*Flow/return temperatures*
Network	70/40°C
Dwelling	60/35°C

Via block plate heat exchanger (PHEX) to customer HIU	
System	*Flow/return temperatures*
Network	70/45°C
Post PHEX to HIU	70/40°C
Dwelling	60/35°C

HIU – heat interface unit
PHEX – plate heat exchanger

DHW – domestic hot water (instantaneous) designed to be 60°C flow temperature

Vital Energi is set to deliver more than 200MW of district heating across eight major projects. Schemes range from 12MW to 60MW, and some will feature water source heat pumps and energy from waste

IS THE INDUSTRY READY?

Vital Energi's director of infrastructure, Ashley Walsh, has been involved in some of the largest district heating network installations in the UK and discusses the main challenges facing large-scale projects and how to overcome them.

- **Managing the quality of products:** There is an onus on designers to specify products that can minimise heat losses while maximising the design life of the network, and this balance is essential. Decisions made at this stage about the level of insulation, the jointing system and the manufacturer of pipework can have a big impact on the success and longevity of the network.
- **Managing the quality of the labour:** No matter how good a product, if it's installed poorly the network will perform badly. For us, the jointing process is so important that it needs to be undertaken by experienced operatives who have undergone a 12-month training process. Clear management and supervision is required to ensure the quality of the installer and the installation. Recruitment can be difficult in a growth industry where experience is scarce, so a long-term focus on training and development is vital. We have worked with a training provider to develop an NVQ for fusion welding technicians. Over the next two years, we will be building a District Heating Training Centre of Excellence at our head offices in Blackburn.
- **Ensuring good quality management practices:** An important element in the success of large-scale district heating projects is to make sure the knowledge and experience of in-house project management staff is cascaded through to new employees and apprentices. This should always be supported by a quality management system that tracks the installation of district heating systems, from day one through to completion and beyond.

This combination of training, mentoring and quality – when done correctly – can give confidence that installations will achieve a design life of more than 50 years.

Heat transfer

Tony Day, chair of the new CIBSE HVAC Systems Group, says radical advances in technology innovation can be achieved if industry can learn from academic researchers embedded in corporate R&D departments. Interview by Andy Pearson

'My focus is on research and innovation that will lead to the implementation of stuff that works,' says Tony Day, director of the International Energy Research Centre (IERC). The centre, based in Cork, Ireland, is responsible for promoting a €30m programme of collaborative research between industry and academia to help meet the need for secure, affordable and sustainable energy services.

Collaborative research was also the subject of Day's presentation at this year's CIBSE Technical Symposium. He spoke to *CIBSE Journal* in advance of presenting his paper: *Collaborative research in the building services sector: adding value and delivering impact*.

Day's involvement goes back more than 25 years. He was Professor of Energy in the Built Environment at London South Bank University (LSBU). In this role he was involved in research, teaching and consultancy in low carbon, renewable energy and energy-saving solutions in the built environment. 'At South Bank I set up the Centre for Efficient Renewable Energy in Buildings to showcase how renewable technologies and innovations were being implemented in buildings,' he says.

However, it was with his work with business at the university where Day saw first-hand the benefits of academia collaborating with industry. 'I led about 10 knowledge transfer partnerships (KTPs), which was Innovate UK's mechanism for embedding researchers into industry,' he says. 'I would pick a researcher and embed them into a company to solve a particular innovation problem that they had. For example, developing the next generation of software, hardware or system design.'

Day says all parties benefited from this industry/academia tie-up. 'For industry, the advantage is that it gets to develop the next generation of products that will give it a market edge or create a potential new business angle,' he explains. Participating in a KTP also helped industry 'de-risk' upfront investment, particularly for SMEs where up to 70% of development costs are met by government under the scheme – with the added benefit of businesses being able to claim research and development tax credits.

For academia, the advantage of the tie-up is that the researcher gains experience from working in a commercial environment. At the same time, the teaching staff benefit from interacting with industry, helping them gain a better understanding of its needs. It is knowledge, Day says, that is fed back into the coursework to help keep courses 'alive and relevant'.

After 20 years of encouraging collaboration between academia and industry, Day left academia for industry, joining energy management software developer Team. But, it was not long before he was headhunted to set up and then lead the new International Energy Research Centre (IERC).

The focus of the IERC is on improving demand-side energy efficiency and embedded energy generation at the building, community and city levels. The centre's broad remit means that many of the projects, by necessity, involve numerous industry partners. 'You have multiple business partners collaborating with academia on a single project,' Day explains.

Collaborative research between industry and academia is increasingly common in sectors such as micro-electronics or digital applications, where seemingly disparate industry players have a common interest in research results. But: 'What I've found in setting up the Energy Research Centre from scratch is that there is a complete lack of awareness of what research can do in the


The CIBSE HVAC Group aims to encourage knowledge transfer and best practice in HVAC

demand-side energy sector,' he says.

One reason cited by Day for this lack is that building services engineering systems are often highly complex and involve numerous players, which can mean that the value of the research results are thinly distributed throughout the supply chain.

'The building services sector is made up of manufacturers, distributors, designers, installers, operators and end users so there may not always be a single identified beneficiary from the research, or the potential returns are deemed to be too low to make it worthwhile for companies to invest,' Day explains. It is a situation he says needs to change because 'this sector could achieve a lot from whole system and supply chain research collaborations'.

So, what makes a project work? 'To be successful, a project will need to include assignment and valuation of the intellectual property arising from it, along with an early identification of routes to market and commercialisation options,' he says.

'However, this type of project is very difficult because each member of the value chain has different requirements and IP

"We haven't done collaborative research in the past because it is difficult... but the rewards could be fantastic"

aspirations, so we have to develop projects that have deliverables for each of the industry partners, and research outputs that are valid for the academic team.'

Day says he wanted to use the opportunity of presenting the opening paper at the CIBSE Technical Symposium to encourage the building services sector to embrace multi-party collaboration. 'What I have done with my paper is to say to the building services sector in the UK "guys we really, really need to have an aspiration to do multi-party collaborative research projects".'

He admits that this will not be easy because innovation in building services will involve dealing with architects, engineers, suppliers, contractors and end users.

'As it stands, the difference in vested interests means that those in the sector do not talk to each other and do not understand each others' needs,' he says. 'We haven't done collaborative research in the past because it is difficult, but just because its difficult doesn't mean that we shouldn't do it because the rewards could be fantastic.'

Day says that he would like the outcome from the Symposium to be 'an industry commitment to fund more near-market innovation research than it currently does and to do so collaboratively with other members of the value chain so that we can get more joined up thinking'.

Optimistically, he says the industry could even 'influence' Innovate UK to help with funding, as well as delivering an effective solution to improve its efficiency and operation. 'It's not credible that we deliver buildings that underperform by a mile,' he says. He thinks CIBSE would be an ideal body 'to promote a vehicle for collaborative research'. **CJ**

■ To find out more about the work of the IERC go to **www.ierc.ie**

CIBSE HVAC SYSTEMS GROUP

It was Day's quest to add value through collaboration in the building services sector that also led to him becoming involved in the establishment of the CIBSE HVAC group in November 2017. 'I don't think we pay enough attention to innovation in HVAC,' he says.

'What we want is for the group to focus on innovations and improvements in the technologies and how can they improve our understanding of how to heat, cool and ventilate buildings better,' he explains.

As with all special interest groups, its remit is to encourage knowledge transfer and best practice in HVAC. The plan is for the group to run four events a year.

The special interest group's short-term objective is to grow its membership, which will then determine its longer term agenda. 'A group like this will only be as good as its membership and how active it is,' says Day.

So, who should join the group? 'The whole supply chain,' he says. The committee includes manufacturers and designers, but Day says M&E contractors and others should join so the entire supply chain is represented.

The hope is that the formation of this group will help to bring about industrial-academic collaboration by identifying where pan-industry research is needed. 'Somebody has to look at what's outside the sector that we can learn from and bring into our industry,' he says. 'If we get a disparate and diverse membership then we can start to bring in more of these collaborative ideas.'

For more information on the CIBSE HVAC Group, visit: www.cibse.org/Networks/Groups/HVAC-Systems

Out with the old

Two in every three commercial boiler installations are replacements, so contractors often face the challenge of integrating the old with the new. Ideal Commercial's Chris Caton outlines the key issues to consider when planning a replacement installation

Quality boilers can run for a long time, but – inevitably – every boiler has its day. In fact, a surprising number of organisations unknowingly incur excessive heating bills because they continue to run a system that has been made outdated by more efficient, modern versions. Ageing boilers can cost more in repair and running costs than a replacement, burning money without giving out any noticeable heat.

Whether a boiler is no longer serviceable, or it's approaching that time of year when refurbishments are taking place, there are several things building services engineers need to consider to protect every level of the chain. For example, many schools will be considering upgrades at this time of year and, because they may require heating across buildings that span a variety of ages, layouts and uses, versatile solutions may be needed.

It sounds simple, but people rarely consider the building use. During the consultation stages, it is worth urging the client to think about using or creating a different space for any new boilers, which would minimise downtime from the old system being shut down. It's also important to remember that multi-use buildings can be heated by one system, but may need a control system intelligent enough to manage different areas at the same time.

New boilers have been installed at Duns Primary School, Berwickshire (top)

Another consideration for public sector buildings – particularly schools and healthcare establishments – is the appetite to install a heating system that can be backed up. No-one enjoys being without heat and hot water for long, but downtime in many commercial applications – whether for routine maintenance or because of mechanical breakdown – can be disruptive, expensive, and even damaging to reputation or health. So a cascade set-up could be the solution. For example, rather than two 300kW units making a total output of 600kW, six 100kW boilers arranged in cascade will give the same output and – in this scenario – an even greater modulation rate of 30:1.

The main risk with an old building is the sludge and dirt that accumulates in »

» its system over the years, which risks being deposited in the new boiler. Blocked waterways resulting from this debris can cause a premature failure of the boiler.

Costs on some projects can escalate, and levels of protection – such as plate heat exchangers and magnetic filters – can sometimes be taken out of a proposal. When looking at the life-cycle costs of boilers, however, this is a potentially risky move. System protection is the key to extending the lifespan of a boiler and, by communicating the long-term savings to an end user, you add value to your services.

Open vented v sealed

It is crucial to think of the whole system when installing new condensing boilers. Older heating systems will probably be open-vented, with a feed and expansion tank, which means pollutants can enter the system water.

Installing new boilers onto an old system that is clogged with debris and dirt will immediately reduce their effectiveness. If dirty water is transferred into new boilers, it will affect their ability to run efficiently and, potentially, lead to breakdowns and even failure.

Before installation, we encourage installers to consider treating the water within the existing system. This helps to ensure the boiler's longevity and can protect its internal parts from corrosion and the build-up of scale over time.

If introducing a new boiler installation to an existing system, another consideration is 'system separation' via a plate heat exchanger. This transfers heat from the primary circuit to the secondary without the system's potentially dirty water coming into direct contact with the circuit. It also maintains a constant water velocity, despite changes in the secondary circuits. This eliminates the need for a low-loss header, as the system's pumps won't have influence over the boiler shunt pumps. A heat exchanger will only function at its peak efficiency, however, when the water velocity passing through it is maintained within prescribed parameters. So accurate sizing of the plate heat exchanger is required before installation.

By taking a life-cycle costing approach to installing new boilers in an old building, a business can realise multiple financial benefits over the lifetime of the boilers – and while it's easy to win business on price, reputation lasts much longer. Key things to remember when approaching a boiler retrofit are: system preparation and ongoing water treatment; adding levels of protection, such as low loss headers, plate heat exchangers and filters; and understanding the needs of the occupants. If these are considered and clearly communicated to the customer, it's a win-win for all involved. CJ

CHRIS CATON is a product manager at Ideal Commercial

Boilers in situ at Duns Primary School

FREE COMMISSIONING

Ideal Commercial Boilers has launched a free commissioning offer for a range of its boilers. It says its engineers will ensure the boilers have been installed in line with the manufacturer's instructions and are working correctly.

Ideal says completed commissioning activates the warranty, which the manufacturer says can be up to five years.

The offer is available online and applies to all Evomax, Imax Xtra, Imax Xtra EL and Evomod boilers. Ideal says the offer could be worth up to £233 per boiler.

> "Ageing boilers can cost more in repair and running costs than a replacement, burning money without giving out any noticeable heat"

Comprehensive project solutions from Hoval

Underpinning its market-leading, environmentally friendly heating and cooling systems, Hoval offers a host of project support services, encompassing every aspect from initial design through the complete life cycle of the products.

Hoval's extensive product portfolio enables a wide range of solutions, including heating systems that incorporate a mix of low carbon and traditional heat sources. These include gas, oil and biomass boilers as well as combined heat and power, heat pumps, solar heating and heat recovery.

Design and project support

Hoval's engineers have extensive experience of designing heating and cooling solutions for a wide range of projects and are happy to assist specifiers and their planning partners in developing intelligent, tailored solutions.

Where required we will also undertake a project management role, co-ordinating delivery and onsite works with other parties to ensure that everything goes smoothly and on time. This support extends to commissioning and handover – and beyond with a selection of maintenance contracts to maintain optimum performance and reliability throughout the life of our products.

Lifecycle cost calculator

Hoval has recently launched a lifecycle cost calculator to help specifiers and end clients understand their project costs in more detail. By inputting key data such as the building's requirements, energy costs and product options the calculator will

provide detailed information on predicted running costs, as well as the heat and electrical demands on the system. It will also assist in correct system sizing and selection of the best plant for the project.

Pre-fabrication

There are many situations where the nature of the site imposes restrictions on the siting of plant – whether upgrading an existing system or designing a new system. In a plant replacement project, for example, access to plant room space may be limited, or the layout of the plant room may restrict working space – particularly where 'hot work' is required.

Or there may be restrictions on getting new plant into the site. Hospitals, for example, often only have limited time-windows where large vehicles can enter the site without critically disrupting the core activities of the site. So any such time availability needs to be exploited to the full.

Hoval's pre-fabrication services are designed to provide the project team with greater flexibility as well as mitigating many of the challenges that may be encountered on site. The key benefits include minimising onsite time, reducing the risk of errors and avoiding situations where different trades are trying to work in a confined space at the same time.

Pre-fabrication allows most of the work to be carried out offsite, at our Newark manufacturing facility, followed by dry run testing and witness testing if required. The entire assembly – typically mounted on a skid - can then be delivered to site and dropped into place, ready for quick connection.

Alternatively, if access to the plant space is restricted, the pre-tested assembly described above can be broken down to allow the elements to pass through doorways and then re-assembled in situ.

Packaged plant rooms

Packaged, self-contained plant rooms are becoming increasingly popular and Hoval works closely within its integrated supply chain to meet this demand. For instance, where space for extending plant is at a premium, pre-fabricated assemblies in weatherproof housings can be used to utilise space outside the building.

Thanks to partnerships with off-site locations we are also able to build full energy centres and plant rooms with multiple heat sources away from site – to any specification.

In all cases the time-savings and productivity benefits that can be achieved with pre-fabrication are significant., In addition, there are fewer workers on site and fewer deliveries to site, so less storage space is required for components awaiting installation. Plus, there is less hot working, which reduces health and safety risks.

For further information contact
■ **marketing@hoval.co.uk**

Hoval

Well-oiled machines

In the final instalment of his series, David Palmer focuses on conventional boilerhouse surveys, the results of system hydronic analyses and the measures needed to correct defects and shortcomings

Have you ever entered a boilerhouse on a warm, summer day to find all the boilers have been operating? This, and other common findings from boilerhouse surveys and analyses, are addressed in this article, which follows the first two instalments published in the November 2017 and February 2018 issues of *CIBSE Journal*.

Key issues covered relate to: the design and control of gas and oil boilers; their integration into boilerhouse hydronic systems; the implications of upgrading boilers without attending to the load circuits; and the need for a systems approach based on a thorough understanding of boiler-load circuit interactions.

Boilerhouse performance at low loads – analysis of a 70°C/40°C system

The most frequently observed issue is all boilers being online, and firing at low load.

Whether this is of concern depends on the part-load efficiency of the boilers and, in particular, whether the system return temperature is low enough to enable condensing operation in condensing boilers.

Surveys show that, not only is condensing operation seldom achieved, but very rare at part-load operation. If not operating in condensing mode, the efficiency of condensing boilers drops off with load as for high efficiency boilers (see Figure 1).

Current design practice advocates system flow and return temperatures of 70°C/40°C. Intuition suggests these temperatures would guarantee condensing operation but, with a boilerhouse controlled to produce a constant flow temperature of 70°C, it is not until the total load is >50% – producing return temperatures of <55°C – that condensing begins. These examples illustrate why all boilers may have to fire, and why condensing cannot occur under these conditions.

Here, it is assumed modular, low water content condensing boilers are employed, that the boilers are permanently in circuit – to maintain a constant primary circuit flowrate – and incorporate motorised flue dampers to minimise losses when offline.

If the maximum flow temperature on each boiler is set to the same value as the system setpoint flow temperature, it is impossible to achieve the system flow temperature using only one or two boilers (see Figure 2). It requires all three boilers to be online (Figure 3).

To produce the system setpoint flow temperature with a single boiler requires the maximum flow temperature on that boiler to be increased. A boiler flow temperature of 76°C is required for a system load of 10% (Figure 4), while a boiler flow temperature of 88°C is required at a system load of 30% (Figure 5).

Both conditions can be met within the 30K temperature lift of a single boiler, and with a system flow setpoint of 70°C. From dozens of systems analysed, the modal load is approximately 30% of the peak load. Figure 5 represents the most frequent operating condition that should be serviceable by a single boiler for most installations.

None of these situations produces condensing operation. Single boiler operation results in higher efficiencies, 80% in Figures 2 and 4, cf 72% when three boilers are

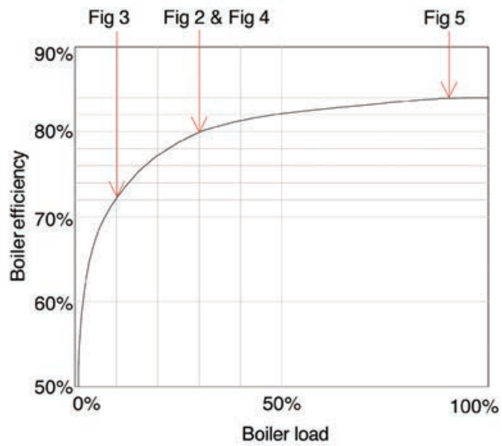

Fig 1: Boiler efficiency curve for a high-efficiency boiler, and for a condensing boiler operating in non-condensing mode

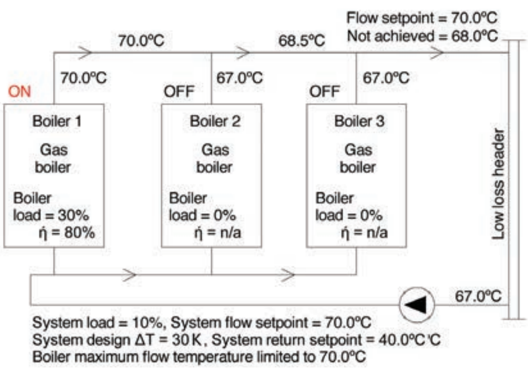

Fig 2: The intended operation using one boiler, but the flow setpoint temperature cannot be achieved with only one or two boilers operating when the boiler maximum temperature's set to 70°C

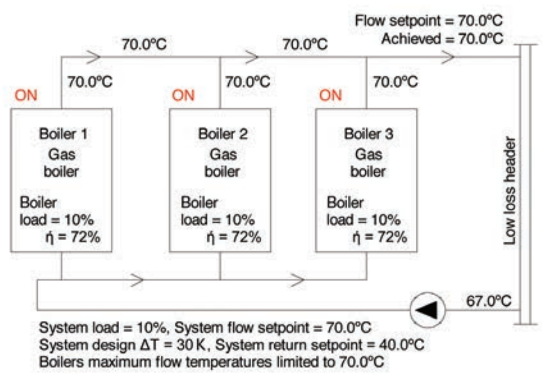

Fig 3: If the maximum boiler flow temperatures are set to the flow setpoint temperature, the flow setpoint is achieved only when all three boilers are operating

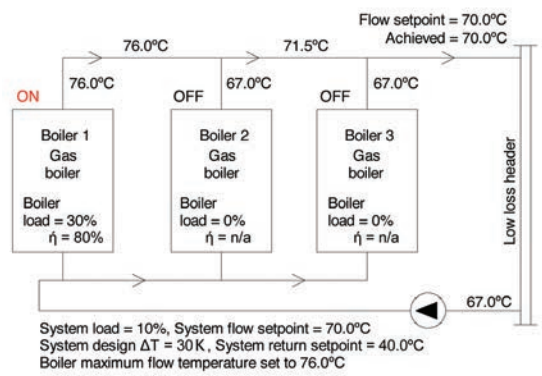

Fig 4: At 10% system load the flow setpoint temperature can be achieved with a single boiler only if the maximum boiler temperature is increased to 76°C

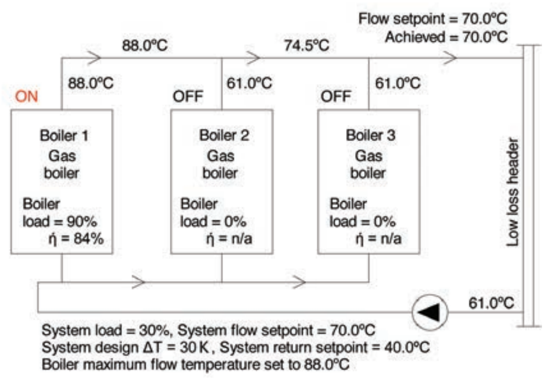

Fig 5: At 30% system load the flow setpoint temperature can be achieved with a single boiler only if the maximum boiler temperature is increased to 88°C

sharing the load (Figure 3). In summary, the boilers' temperature must be much higher than the system flow temperature to achieve optimally efficient boiler operation with a single boiler at low load, if the system is controlled on flow temperature.

To achieve condensing operation in these examples would require the system to be controlled on return temperature, as it is the aggregate load system return temperature that must be controlled to <55°C to return a temperature of <55°C to the boilers.

Retrofitting replacement boilers

Another common finding is boilers operating at 20K ΔT on systems designed to operate at 11K ΔT. Modern boilers are designed and marketed for use 20K ΔT or more, while operation at this temperature difference requires a lower flowrate.

If boilers designed to operate at 11K are replaced by those operating at 20K, a 45% reduction in primary flowrate occurs, making the secondary flowrate much greater than the primary flowrate, and causing reverse flow up the header (Figure 6).

This, in turn, causes temperature dilution to the load circuits because the reverse flow from the header mixes with the flow from the boilers to create a reduced flow temperature to the loads. This can then cause under-heating of variable temperature circuits and non-performance of circuits requiring a constant temperature, such as air handling units and wet radiant panel heaters.

Once 20K boilers have been installed, there are only two possible solutions to rectify the problem: either upgrade the boiler pumps, or common primary pump, to operate the boilers at 11K, or examine the load circuits to see if they can be made to operate at a lower temperature.

> "The boilers' temperature must be much higher than the system flow's for optimally efficient operation..."

Variable flowrate primary circuits

Another problem observed is the use of variable flowrate on the primary loop. This can occur either because boilers are individually pumped, with pumps switching on and off as boilers are brought on- and offline – as in Figure 6 – or the common primary pump (as in Figures 2-5) being speed-controlled by a variable drive to maintain constant dynamic pressure in the primary loop.

In either case, the use of variable flow on the primary circuit without commensurate flow control of the secondary (load) circuits can lead to massive flow temperature dilution to the loads, with consequent load circuit underperformance.

Load circuits

With the ever-improving performance of boilers, and the development of modular boiler systems with sophisticated integrated controls, mainly the result of European regulation, the importance of matching load circuits to boilers appears to be largely overlooked, especially when retrofitting new boilers to existing boilerhouses.

Specific considerations when retrofitting new boilers are:

- The original design ΔT of the load circuits must be established
- Could the design ΔT of the load circuits be increased to allow boilers to operate at a higher ΔT, and the primary and secondary flow rates reduced?
- Has the building undergone fabric upgrades that will have reduced the building loads? If so, it may be possible to operate the load circuits at a much lower flow temperature and/or at a higher ΔT
- Could any of the load circuits readily be converted to variable flow control? If so, would the maximum-minimum flow rate ratio achievable be large enough to make variable flow control of the primary circuit worthwhile?

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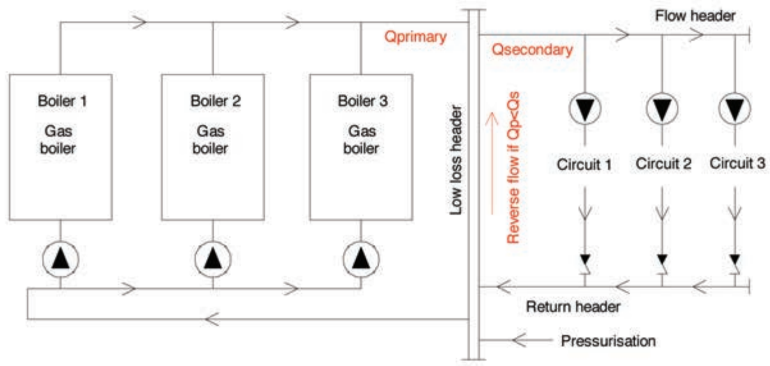

Fig 6: To avoid reverse flow on the low loss header, Qprimary > Qsecondary under all conditions

The answers will determine the ΔT required across the replacement boilers, and whether the system flow temperature and primary/secondary flow rates could be cut. If it is not possible to produce sufficient flow rate modulation of the load circuits, the primary boiler loop must be run at constant flowrate.

The need for a systems approach

It is not sufficient simply to model the building loads and ensure there is sufficient boiler capacity to meet the peak load. When designing or re-designing a boilerhouse, it is essential to consider the entire system, from load circuits back to the boilerhouse, and then to examine each combination that can arise during use. This is best carried out by mathematically modelling the entire system to enable a full understanding of performance.

Key considerations are:

- Understand the existing boilerhouse – take measurements of flowrates and temperatures on the primary and secondary circuits while the existing boilers are still in use, then model
- Do not oversize the replacement boilers
- Consider, carefully, the flow temperature and ΔT required across the replacement boilers
- Be wary of making the primary loop variable flowrate, unless you can be certain of providing matching reductions in flowrates on the load circuits;
- If condensing operation is required at low loads, the load circuits may need to be modified to ensure sufficiently low return temperatures under all operating conditions, not just peak loads. CJ

The material in this series has been delivered in training courses and seminars, but does not appear in its totality in any publication. Feedback is sought on whether there is demand for a book, which focuses on how to design and control boilerhouse systems so problems identified and analysed – and lessons learned – can be available to all.

DAVID PALMER is director at the Campbell Palmer Partnership and principal author of CIBSE AM15: *Biomass heating*. Contact him at **consultants@campbellpalmer.com**

Waste not want not with condensing boilers

Energy efficiency plays a critical role in balancing affordable, sustainable and secure energy provision. And when it comes to improving building efficiency, heating is a frequent starting point.

In the UK's existing buildings, cost-effective boiler plant replacement is the low-hanging fruit of energy efficiency. With many non-domestic buildings still relying on old or inefficient non-condensing boiler plant for their heating, the scope for efficiency savings is huge.

Just consider, while condensing boilers are capable of achieving near maximum efficiencies, ageing boilers typically waste around 30% of the gas input. Exact savings will depend on the original equipment, but a boiler upgrade can nearly halve gas consumption, as our examples show.

Condensing boilers generate more reliable heating, making our buildings more comfortable and productive places to live and work in. At the same time, they are engineered to meet ultra-low CO_2 and NOx emission criteria, helping reduce environmental impact and support the drive for improved air quality.

On every level – economically, environmentally and socially – the advantages of a cost-effective boiler replacement are clear. After all, why waste when you could save?

48% gas reduction for school

Ferndown First School in Dorset has nearly halved gas usage since refurbishing its heating system with replacement condensing boilers.

The old non-condensing boilers serving the school had come to the end of their working life. So consulting engineers Mabey Francis recommended replacing them with Remeha Gas 220 Ace condensing boilers which were fitted by Dixon Mechanical Services Ltd.

The result? An impressive 48% fall in gas consumption and a more comfortable, productive learning environment for the school's children and teachers.

"The project went extremely well and the new Remeha boilers will provide significant energy savings for the School for many years to come," said Andy Cope, Director at Mabey Francis.

University achieves 46% gas savings

Aberystwyth University is benefitting from outstanding gas savings after refurbishing the plantroom serving its William Davies research centre, home to the internationally-acclaimed Institute of Biological, Environmental and Rural Sciences (IBERS).

Since Aber Heating Engineers replaced the unreliable and inefficient boiler plant with Remeha Gas 310/610 Eco Pro condensing boilers and added a new building management system, gas usage has dropped by 46%. At the same time, the more reliable, efficient Remeha boilers have improved comfort levels at the Centre.

"The key aim of the University was to deliver reliable, energy-efficient heating and hot water throughout the Building, while reducing emissions in line with their environmental commitments. The Remeha boilers allowed us to do just that," said Sion Jenkins, Project Manager at Aber Heating.

40% fall in gas usage for Zurich

Zurich Insurance Services has also cut gas usage as a result of a boiler replacement. Heating at the company's Tri Centre 2 offices in Swindon was previously supplied by ageing, inefficient atmospheric boilers that lacked effective control.

R&S Building Services Engineers, appointed by Sodexo, recommended installing Remeha Gas 220 Ace replacement boilers to overcome space and access limitations and achieve the heating and hot water requirements.

Dan Yiend, Director at R&S Building Services Engineers, commented: "With the Gas 220 Ace boilers now commissioned and in full operation, Zurich can expect an improved energy-efficient system with reduced CO_2 and NOx levels. Early indications based on gas consumption show savings in the order of 40%."

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Reduction and prevention of limescale in continuous flow hot-water systems

This module explores what causes limescale and how it can be addressed in modern continuous flow hot-water systems

In many UK areas, the heating of water will lead to the accumulation of limescale. This can reduce the effectiveness of heat transfer surfaces as well as obstructing the flow of water in the system, and can practically lead to system failure. This CPD will explore what causes limescale and how it might be prevented in modern continuous-flow gas hot-water delivery systems. It will consider the potential for the application on electrolytic physical water conditioning.

Previous articles (including those in April and September 2017) have considered the application of such systems, such as those in Figure 1, to supply hot water efficiently. However, unless the incoming water supply is in a proper condition, the performance can degrade (as with all hot water systems), as limescale will accumulate.

Water hardness

Water absorbs carbon dioxide to create the relatively weak carbonic acid, H_2CO_3 and, as the water comes into contact with rock and sediment – the most likely being limestone and chalk – it acquires metal ions, most commonly calcium, Ca, and magnesium, Mg. So most water that comes from streams, lakes and boreholes can be regarded as dilute solutions of these – calcium bicarbonate, $Ca(HCO_3)_2$ and magnesium bicarbonate, $Mg(HCO_3)_2$.

Both calcium and magnesium are essential minerals that are beneficial to human health in several respects, and inadequate intake of either nutrient can result in adverse health consequences. Recommended daily intakes of each element have been set at national and international levels.[1] However, at elevated levels the water becomes 'hard'. Hard water can make tasty drinking water, as it contains many salts and minerals, but that hardness will also combine with soaps and detergents to create scum (and also reduce the lathering effect of soap) and precipitate as scale.

In hot-water systems, practically precipitation of calcium carbonate, $CaCO_3$, starts to occur at approximately 35°C to 40°C (or as pressure drops), and progressively worsens as temperatures rise. The carbonates are deposited as off-white solids on the inside surfaces of pipes and heat exchangers. Water hardness is expressed in terms of milligrams per litre as calcium carbonate. Temporary (carbonate) hardness is related to the bicarbonate salts of calcium and magnesium. Permanent (non-carbonate) hardness is related to other salts of calcium and magnesium – chlorides, sulphates, nitrate, and so on (see panel 'Water hardness' below).

There are no standard levels as to what constitutes hard or soft water. As can be seen from the example information for England and Wales in Figure 2, hard water is likely to

WATER HARDNESS

Temporary hardness **is removed by heating the water. The soluble calcium bicarbonate decomposes to form insoluble calcium carbonate, water and carbon dioxide:**

calcium bicarbonate → calcium carbonate + water + carbon dioxide

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

The insoluble calcium carbonate is the principal component of what is known as limescale.

Permanent hardness **is usually caused by the presence of calcium sulphate/calcium chloride and/or magnesium sulphate/magnesium chloride in the water, which do not precipitate out as the temperature increases. Unlike temporary hardness, it is not removed by heating the water.**

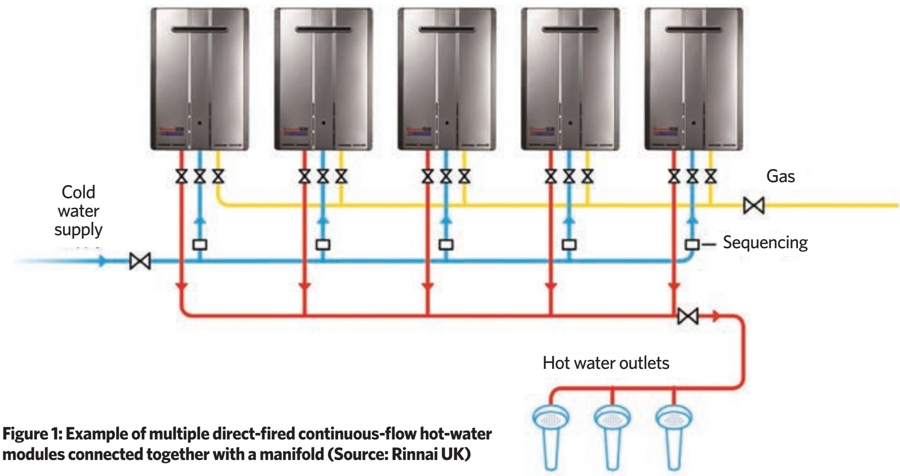


Figure 1: Example of multiple direct-fired continuous-flow hot-water modules connected together with a manifold (Source: Rinnai UK)

affect significant parts of the UK (water in Scotland is generally soft to moderately soft). When the total hardness is approaching and exceeding 200$mg \cdot L^{-1}$, water softening or conditioning would normally be considered. Specific water hardness data[2] is available from local water supply authorities and local testing.

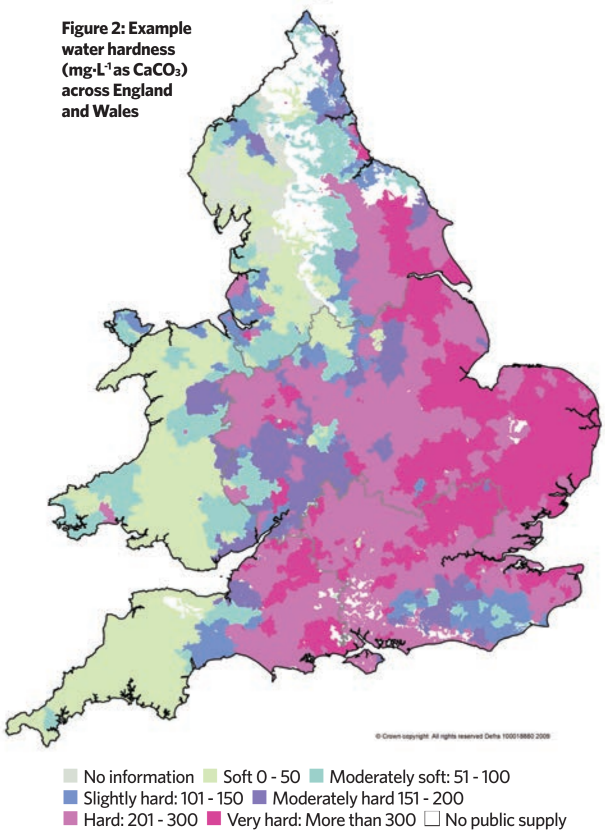
As the temperature of water is raised, the hardness will be cut as some of the bicarbonate dissolved salts (temporary hardness) comes out of solution and forms solids in suspension. Some of this will be deposited on heating surfaces to form an adherent limescale, reducing the heat transfer. Fuel consumption can increase, and the hot-water heating unit or system can deteriorate through the overheating of heat exchanger plates. The UK's Health and Safety Executive (HSE)[3] notes the importance of reducing the opportunity for scale accumulation, both for system efficiency and to reduce the supply of nutrients and breeding locations for bacteria, such as legionella.

The tendency to form scale – and the structure of that scale – is not just dependent on hardness, but also on the other chemical constituents and temperature of the water. So, scaling indexes such as Langelier Saturation Index (LSI) combine various additional factors to assess the likelihood of scaling (as well as corrosion). The LSI provides an empirical measure of the water system's likelihood to dissolve or deposit calcium carbonate, and is dependent on pH, calcium concentration, total dissolved solids (determining conductivity) and water temperature. An LSI of zero indicates balanced water, with an appropriate amount of calcium and dissolved solids, and stable pH. Negative LSI indicates that the water is approaching aggressive (and so will not deposit a layer of calcium carbonate), while positive LSI indicates increasing opportunity for scale formation. Indicative ranges of LSI are....

LSI > 0.4 → Calcite precipitation = scaling likely
0.4 > LSI > -0.4 → Practically no dissolution/no precipitation
LSI < -0.4 → Calcite dissolution and increasingly aggressive/corrosive.

The LSI was initially developed to quantify presence of a thin layer of scale that is usually beneficial in the prevention of corrosion of metallic piping.

Figure 2: Example water hardness ($mg \cdot L^{-1}$ as $CaCO_3$) across England and Wales



Reduction and prevention of limescale

There are two principal methods employed to control limescale in commercial hot-water systems: chemical water-softening and physical water-conditioner systems.

The most common water-softening process used for the protection of commercial hot-water systems is base-exchange (or ionic) softening. This process removes permanent and temporary hardness from water. It works by a simple chemical process – swapping the calcium, which forms limescale, for sodium, which is more likely to stay dissolved.

A typical water softener has a resin (or mineral) tank, a brine (sodium chloride and water) tank, and some form of control, as shown in Figure 3.

As water enters the system, it passes through an ion-exchange column filled with thousands of tiny resin beads. This resin has charged sodium attached to its surface, and swaps this for the more reactive calcium and magnesium as the unconditioned water flows over it. The resin can continue to do this indefinitely, as long as it is washed through with brine at intervals to remove the calcium and magnesium and replace the sodium.

During periodic regeneration cycles, the water is passed across salt in the brine tank and then pumped across the resin beads. As it flows through the resin bed, it exchanges sodium for the hard-water ions, regenerating the electrical attraction of the resin beads. Excess brine is then rinsed from the resin and sent to drain. It is important that the water softener should regenerate only when needed, according to the incoming water hardness and volume of water that has been processed. The resin bed will also need appropriate dosing to ensure that it does not accumulate bacterial material.

This whole process has a permanent effect on the incoming water, but will consume significant amounts of salt and water in the softening process. Since the softened water will have relatively high levels of sodium, a separate, untreated, water supply will be required for drinking water. Sodium salts are soluble, so the resulting water will not generate scum or scale.

Physical conditioners generally rely on electric or electromagnetic fields acting on the water to modify the physical structure and size of hard-water crystals. As a result, the ability of the crystals to cling to each other or to surface walls of the pipe or equipment is substantially reduced, so that limescale can be kept in suspension and discharged with the flow of water from the outlet. These systems do not use significant amounts of chemicals and do not change the composition

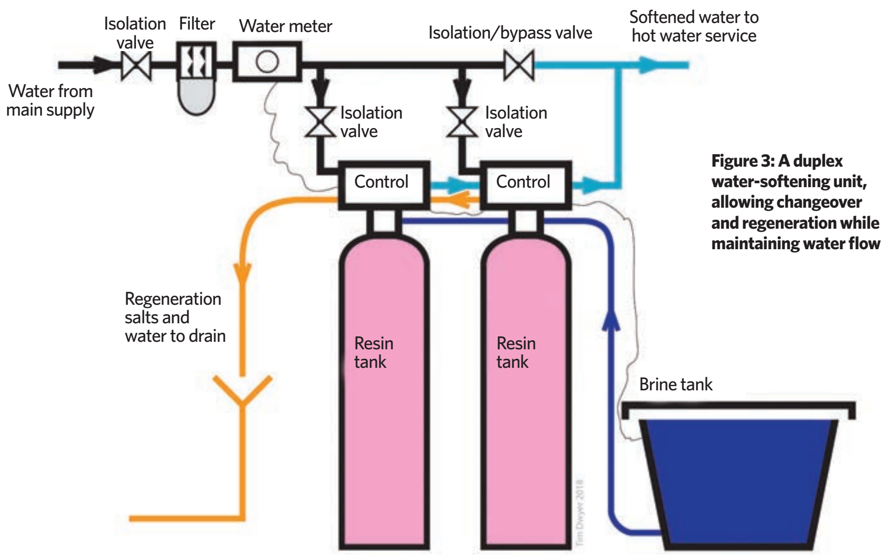


Figure 3: A duplex water-softening unit, allowing changeover and regeneration while maintaining water flow

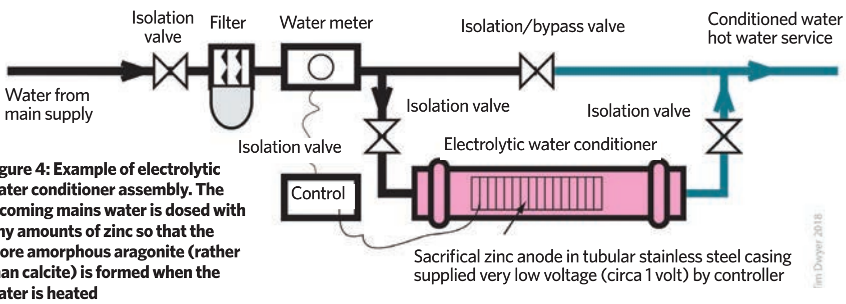


Figure 4: Example of electrolytic water conditioner assembly. The incoming mains water is dosed with tiny amounts of zinc so that the more amorphous aragonite (rather than calcite) is formed when the water is heated

of the water, so it still remains hard, but they reduce the rate at which the scale precipitates out. As listed in CIBSE Guide G[4], there are five principal types of physical water conditioner:

Magnetic: these use a magnetic field and alter the scale-forming minerals to combine with each other rather than form scale, but the effect is short lived.

Electromagnetic: a strong magnetic field is generated, which is much stronger than the simple magnetic devices.

Electrostatic: in these, an electric field is created by flow of water through the conditioner, which causes the ions to repel so that scale-forming minerals do not combine.

Electronic: by generating a low-power electrical current, controlled by a microprocessor, a variable electrical field is developed in the water that prevents build-up of scale by altering the shape of scale-forming mineral crystals.

Electrolytic: these prevent scale forming by the use of minute amounts of dissolved metal (usually zinc or iron).

If the water is conditioned temporarily through 'ionisation', this will be lost if the water is stored. In all physical conditioners the limescale is held in suspension and discharged at the outlet, so there will still be evidence of limescale where the water evaporates, such as shower heads and screens, and stainless-steel sinks and surfaces. Physical devices do not add sodium (or appreciable amounts of any chemicals) to the water, so it is still potable and wholesome. Significant turbulence can adversely affect performance and limescale formation – for example, where there are tight bends in the system that cause the pressure to drop.

While the theoretical and practical aspects of softening and chemical conditioning are well understood and established, the scientific principles behind physical conditioning are not fully understood.[5] However, it is reported by Yang[6] that, at least, electrolytic conditioners are 'consistent with established science. Dissolved zinc and iron and known scale inhibitors, impacting significantly on the crystal form, even at concentrations as low as a few ppb'.

There is much experiential reporting that physical – and particularly zinc electrolytic conditioning – has been successfully applied.

Example of application of a zinc electrolytic conditioner for continuous flow heating system

A zinc sacrificial anode is enclosed in an inline cylindrical pipe that is incorporated in the incoming water supply (as in Figure 4). This doses the water with tiny amounts of zinc (a few parts per billion) sufficient to alter the structure of any precipitating limescale from calcite to aragonite. These are polymorphs of mainly calcium carbonate – that is, they have the same chemical formula – but have different crystalline structures. The change in the shape of crystals reduces the adherence to surfaces as scale.

Incorporation of physical electrolytic conditioning systems (such as in Figure 5) have, reportedly, provided operational advantages over water-softening systems by virtue of their comparative simplicity. The reduction in installation space, very low maintenance requirements and, particularly having no need for salt or regeneration water, make them significantly cheaper to operate.

The use of both water softeners and physical conditioners can, if applied appropriately, maintain systems practically free of limescale. For hot-water systems with significant storage – particularly where stored longer than 24 hours – the changes effected by physical conditioners tend to subside, so the system may be increasingly likely to accumulate limescale. However, zinc-based electrolytic physical conditioners are well-suited to continuous-flow water systems where there is no storage – or even systems that incorporate short-term buffer storage. Such high-efficiency gas-fired continuous-flow systems are commonly used, for example, in hotels that deal with peak demand without storage, or with short-term buffer storage, and so present a good opportunity to investigate the application of zinc-based electrolytic physical conditioners.

Turn to page 38 for references. »

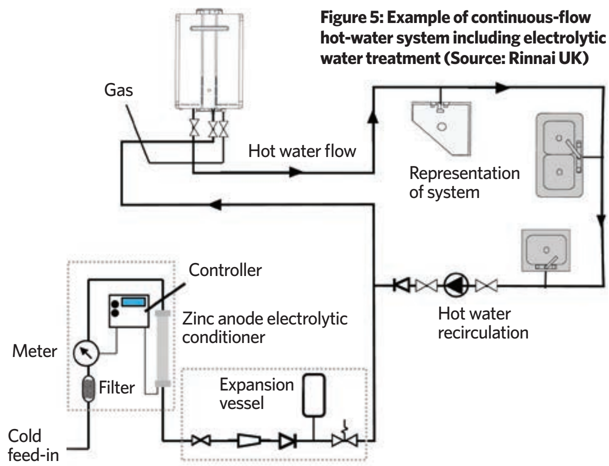


Figure 5: Example of continuous-flow hot-water system including electrolytic water treatment (Source: Rinnai UK)

Module 127

May 2018

1. Which of these is unlikely to be true for unconditioned hard water?

☐ A Contains minerals beneficial to health

☐ B Good for lathering soap

☐ C Likely to cause limescale issues

☐ D Likely to have been in contact with limestone or chalk

☐ E Potentially tasty to drink

2. In the article, what was given as the approximate temperature that calcium carbonate is likely to start practically precipitating out of water in a system?

☐ A 5°C

☐ B 15°C

☐ C 25°C

☐ D 35°C

☐ E 45°C

3. Which of these would be considered as moderately hard water?

☐ A 75mg·L^{-1} as $CaCO_3$

☐ B 125mg·L^{-1} as $CaCO_3$

☐ C 175mg·L^{-1} as $CaCO_3$

☐ D 225mg·L^{-1} as $CaCO_3$

☐ E 275mg·L^{-1} as $CaCO_3$

4. Which of these LSI values indicates that the water condition is likely to practically precipitate significant amounts of calcite?

☐ A -0.5

☐ B -0.15

☐ C 0

☐ D 0.15

☐ E 0.5

5. Which form of water conditioning was shown in the example of the continuous-flow hot-water system?

☐ A Electrolytic

☐ B Electromagnetic

☐ C Electronic

☐ D Electrostatic

☐ E Magnetic

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