Efficient energy

Combined heat and power plants are anything but new. However, evolving technologies are revolutionising their scope and HM government likes the sound of it. Brian Tinham reports

Combined heat and power (CHP) plants – which essentially comprise electrical generators, combined with equipment for recovering and using otherwise wasted heat – are all much of a muchness and based on engineering that has barely changed since the 1990s, right? Wrong: CHP is currently the darling of government energy policy – and among reasons for that position are the sheer scope of power and heating provision that the various technologies (including some new) can accommodate, the increasing efficiencies of those technologies and the variety of fuels that can now be consumed in the process, including waste.

Today, yes, we're still talking about CHP plants at the big industrial end, normally involving gas and/or steam turbines, often used in combination to provide the classic CCGT (combined cycle gas turbine) installations that were so popular during the 'dash for gas' era of the 1990s. With high-grade exhaust heat from the gas turbine fed to a heat recovery boiler, and its steam passed to the steam turbine to generate additional electricity – while lower pressure steam serves site heating requirements – these still provide for unbeatable efficiencies, in the 85—90% range.

But the term CHP also applies equally to urban and community district heating and power plants, typically harnessing boiler-fed steam turbines, burning all sorts of fuels (mostly natural gas, but also biogas, landfill gas, mine gas and non-commercial waste gases). Then again, think about site- and building-level CHP installations, normally based on reciprocating engines with attached

generating sets, plus exhaust gas and/or engine shell heat recovery – and often linked to existing or refurbished boiler plant to serve additional site steam and hot water requirements. And there are more: nowadays, there are also packaged mini-CHP variants of the above, as well as micro-turbines designed for offices and smaller factories, and soon to come micro-CHP equipment – using smaller reciprocating engines to replace conventional domestic boilers.

Official sanction

So what is the government's line? Late last year, Energy Minister Lord Hunt said: "Combined heat and power is going to have a key role to play in the future of the UK's energy needs, because it is more efficient, it should save money long-term, and it reduces carbon emissions." Speaking ahead of the lacklustre Copenhagen international emissions summit, at the Combined Heat and Power (CHPA) annual conference, he also added: "The UK is showing great leadership in tackling climate change... Demonstrating that the UK can make the shift to a low carbon future will be vital in striking an ambitious deal."

Well, we all know the history there. But, be that as it may, CHP is clearly now centre stage in government thinking, right up to the level of planning policy on new power plants. Look no further than the Department for Energy and Climate Change (DECC) national policy statement (NPS), published last November. It included the following: "In developing proposals for new thermal generating stations, developers should consider the opportunities for CHP from the very earliest point, and it should be adopted as a locational criterion… Substantial additional positive weight should be given to applications incorporating CHP… If the proposal is for thermal generation without CHP, [the operator] must justify the decision against a range of thorough criteria."

So when the government's new Infrastructure Planning Commission (IPC) looks at applications for energy developments, it's plain which technologies that body will be favouring.

And the approach is not unique to the current labour administration. Conservative Shadow Energy and Climate Change Minister, Greg Barker, also speaking at last year's CHPA conference, said: "A conservative government would show a new level of ambition to reduce the $C0_2$ footprint of the public sector and deliver cuts to a much more urgent timeframe. I am in no doubt that CHP will be a key part of the solution." And in the context of CHP at a community level and across the public sector, Liberal Democrat Shadow Energy and Climate Change Minister Simon Hughes added: "CHP locally ticks all the right boxes. It makes precious energy go further and delivers crucial reductions in $C0_2$".

As CHPA director Graham Meeks puts it: "Faced with the enormous challenge of decarbonising our energy supply, it seems inconceivable that we should perpetuate the profligate waste of energy that we see in our current generation of power stations. The requirements of the NPS serve as an unequivocal statement of intent that heat recovery should be a defining component of our future approach to energy." And turning to smaller heat and power projects, he adds: "Over the past year, the government has taken important steps to advance the uptake of CHP and district heating, extending the financial incentive presented by exemption from the Climate Change Levy and now strengthening the planning framework."

That being the case, it makes sense for plant engineers to wise up on the technologies and particularly more recent developments. So, looking first at the bigger end of the spectrum, CHP generators are typically the prime movers

Left: building- and site-scale combined heat and power plants are among the darlings of government emissions reduction strategy
Below: on a smaller scale, packaged CHP units can be dropped into all sorts of applications

themselves – such as gas turbines. But they may alternatively consist of steam turbines, generating power from high-pressure steam produced in boilers. In some cases, CHP schemes involve a combination of prime mover(s), boiler(s) and steam turbine(s) – and we're then into classic CCGT plant.

Gas turbines remain the most widely used prime movers for industrial CHP plants, with electrical power outputs currently ranging from sub 1MW to more than 200MW. Why? Because operating experience over many years confirms they are fit for purpose, with ultra-high reliability and minimal running maintenance requirement. Long-term availability is normally 94–98%, where plants are operated at optimum output continuously and efficiency is usually around the 75–85% mark.

Highest efficiency

In addition, although the most popular fuel remains natural gas (82%), other gaseous fuels now being used include biogas, mine gas, land fill gas and waste gases (by-products of upstream processes). Engine modifications capable of handling higher tar values and aggressive gas constituents are routinely in use – mostly involving front end cleaning and some material changes, in terms of seals and the combustion zone, as well as modified back-end emissions scrubbing.

Incidentally, gas turbines' high efficiency figures can be increased by approximately 2% when turbines are equipped with Sprint cooling technology, which lowers the high-pressure compressor inlet temperature and thus, in turn, its discharge temperature. That allows the compressor pressure ratio to be increased and additional air directed through the compressor to increase the turbine's output. Essentially, manufacturers, such as GE, add an inter-stage mist injection system that cools the low-pressure booster discharge air. In GE's case, water is injected into the airflow via a ring of air-assisted spray injection nozzles in the engine front frame.

As for the heating component, with gas turbine exhaust gas temperatures ranging from 400 to 550°C, we're talking about high grade energy, typically realised by passing to a heat recovery boiler that, in turn, produces hot water and/or steam – although, in some cases, the gases are used directly for plant processes, such as drying. However, where a site's heat requirement exceeds the heat available in the exhaust gases, or is variable, supplementary firing can be used, where an additional burner is incorporated in the ducting between the turbine and the heat recovery boiler to increase the temperature of the exhaust gases on demand, and thus improve the plant's heat output.

What about steam turbines? Peter Smith, research manager at the CHPA, argues that, although far from new, these are becoming increasingly important – partly because they can use the energy derived from any fuel (solid, liquid or gaseous), partly because they are so reliable and partly because of the range of power outputs – from 0.5MW upwards.

"The fuel is burned in a boiler and the resulting high-pressure steam is then let down through the steam turbine, generating electricity and providing lower pressure steam or hot water for site use," he explains – adding that steam turbines can achieve long-term availability figures up to 99% and efficiencies around 60—70%.

"Steam turbine CHP is usually the technology of choice when a cheap, non-premium fuel, such as waste material, is available that can only be used once the energy it contains has been released and turned into steam," he continues. "That's because it's one of the only technologies that can utilise waste in this way – and, with gas and other fuel prices still rising, it makes sense to look for ways to save money. However, steam turbines are only suited to sites where the heat requirement is high [around five to one] in relation to the power demand."

Incidentally, waste gas burning – including that using anaerobic digestion from food waste – is a growth area, particularly given the financial incentives under the Renewable Obligation Certificate (ROC) scheme. From a practical plant perspective, issues such as sour and aggressive gases need to be addressed, with scrubbers and attention to materials and seals, but this is known and proven technology. Just as important is the fact

Pointers

- CHP is not only about big plant, but also district heating, packaged units for buildings and micro CHP
- Gas turbines remain the most widely used and efficient for big CHP plant
- Steam turbines are ideal for burning waste fuel, where heat exceeds power demand by approx five to one
- Gas reciprocating engines remain the mainstay for urban and site CHP plants
- Tri-generation, including air conditioning, is growing
- Packaged units, micro turbines and domestic CHP systems are also on the rise

that many of the dedicated 'energy from waste' plants are inefficient – sometimes down at just 20%. That is because most of the useful heat energy is wasted since, given that there may be little or no local heat or low grade steam requirement, all the operator is interested in is electrical power for export. So heat is wasted to atmosphere.

Moving down scale a little brings us to the urban community energy level, where the equipment of choice is steam turbines and/or very large-scale gas reciprocating engines. From a plant engineering perspective, the interesting aspects here are not so much that a decade of innovation has improved overall generating and heat recovery plant efficiencies (notably enabling efficient lower temperature operation), but that downstream distribution plant has evolved to the point where insulation, monitoring and control make CHP far more widely viable.

Distribution solution

CHPA's Smith points, for example, to pre-insulated pipes that are now enabling thermally efficient networks to distribute heat as hot water, rather than steam. He also refers to internal pipe pre-wiring, designed to pinpoint leaks by sensing temperature changes on the supply side. And he alludes to low-cost, accurate heat metering equipment for installation at the point of use. "Together, these are transforming the image of old inefficient district heating projects into economical, responsive and low-carbon solutions in the public and private sectors," says Smith.

And there's another development – air conditioning, which is now the third component of what's termed tri-generation. "Offering cooling, through absorption chillers, is an important development for district heating and building-based CHP projects, primarily because it means that generating plant can be operated at its most efficient – flat out – throughout the year. It also means that, whereas these projects have usually been sized to match minimum sensible heat requirement, now designs can move up to service greater heating and cooling demand."

So what about CHP plant for single buildings? Equipment at the bigger end here is almost invariably based on gas reciprocating engines equipped with gensets for electricity generation. As with their larger cousins, these units recover heat from the exhaust gases and the outer shell of the engine, using a heat transfer jacket – usually to provide for hot water distribution or space heating. Again, hot water can be cycled through an absorption chiller for seasonal air conditioning.

However, what users see at the smaller end – in the sub- and low-MW range – is the acoustic packaging and telemetry for remote monitoring and control, which together mean that quiet, efficient, maintenance-free (as far as the user is concerned) CHP plant can be installed almost anywhere – in existing boiler houses, external enclosures, you name it. One example is at the Natural History Museum in London, where two Jenbacher engines have been providing for electricity, heat and cooling since 2006, courtesy of Vital Energi, under a public-private partnership (PPP) finance deal. Other companies offering similar services include Cogenco (Dalkia's small-scale CHP subsidiary) and ENER-G. For plant operators, the offering is not just the plant itself, but specification, installation, maintenance and finance all rolled up.

But there's more: Damian Shevloff, sales director for Cogenco, makes the point that, in the 30–65kW range, his organisation offers Capstone micro-turbines, in place of reciprocating engines. "Advantages with these machines include low emissions, low weight and very few moving parts – which means vibration and noise are also low for more sensitive areas," he explains.

Cogenco's micro-turbine range is natural gas-fired, although Shevloff insists that his organisation can also convert the equipment for biodiesel and diesel. The downside, he warns, is that maintenance requirements are then "much higher", but the upside is the option of a ROC, which, even below 400kW, can provide some payback. PE

Above: construction work at Kingston Hospital, with its Dalkia-managed CHP Left: Another Dalkia CHP installation – this also based at Kingston

Is your CHP technology viable?

When sizing a CHP project, the first task is to examine site heating profiles at the location, advises Damian Shevloff, sales director for Cogenco. "You need to size your project against the base heating load in the summer, not winter, otherwise in the summer months you'll be dumping a lot of heat and generating very expensive electricity," he explains.

Once heating requirements have been matched to the site, it's time to look at the half-hour power profile. "We can look at sites that export power, but the success of that strategy is very dependent on export prices and, in some areas, it's not an advantageous proposition. That's why the majority of our smaller CHP installations involve all energy being consumed by the plant location."

But that's just the start: every project is different. Take a 1MW CHP installation. The power unit could be packaged in an acoustic package (containing the engine, generator and balance of plant, such as heat exchangers, pumps, absorption chillers etc) or housed in part of an existing site boiler house.

"Very often, an existing location may have additional capacity, with one or two additional boilers, any of which may have been mothballed," comments Shevloff. "We might then encourage the operator to think about not using one of the top-up boilers, and instead removing it and replacing it with a custom CHP unit, which can then be interfaced with the rest of the heating network in the boiler house. As part of that kind of installation, we would then connect it to the local gas supply and the power supply, which could either be local or connected via an LV panel or stepped up on a transformer."

And that's just the plant configuration; then there is the whole issue of precisely how heat recovery is managed and utilised. In certain applications, it's only sensible to use the high-grade engine exhaust heat to produce steam, via flash vessels and heat recovery boilers. In others, low grade heat from the engine jacket can be utilised – for cooling, chilling, pre-heating feedwater or the condensate return line, or simply providing a local hot water circuit. "Ideally, any CHP installation should use both heat circuits to maximise the heat recovery efficiency, but it's all about the project – and electrical efficiency is another debatable issue that requires painstaking specification."