EXPLOITING WASTED HEAT

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It's something we've all thought about. One day we notice a source of heat going to waste, perhaps a flare stack or a giant cooling tower, and the thought occurs. "There should be a way to use that heat." Now, with Freepower's newly-launched generators, there is. But those behind Freepower are thinking further. They've proved electricity from wasted heat works; now they are targeting electricity production from waste – domestic, industrial and commercial, and from sustainable heat – solar and geothermal.

Pondering how to exploit wasted heat led to the formation, nine years ago, of a small team with a big dream. They were determined to find a way to extract power from wasted heat. They wanted not to create one-off custom solutions for particular sites, but to design a production-line answer to the global opportunity that wasted heat provides. That team became Freepower Ltd, a company based in Southern England. That dream, which has absorbed over £3 million in direct research and development costs, has created machines now being delivered to, and operated by organisations in Australia, Austria, Britain, Germany, Italy, Sweden, and the USA. Mym Simcock, CEO of Freepower, explains "The life we lead demands power and generates unwanted heat, which we dump. In an energy-conscious age, that really is conspicuous consumption. Our view is that wasted heat is a huge, untapped energy source which we want to exploit. If we could use one percent of it we'd make a difference. If we could employ ten per cent of it, we'd revolutionise the energy-centric economy."

Turning to renewables

Freepower has succeeded in its objective. Affordable electricity is being generated in meaningful quantities from a variety of heat sources albeit, currently, on a small scale. Now, Freepower has revealed the next target for the technology it has created, electricity from renewable heat sources. First though, let's take a brief look at the story to date.

When the Freepower team first coalesced nine years ago, its initial task was to identify and quantify sources of exploitable wasted heat. There were more than they'd imagined. "For us, 'exploitable' imposes several filters. The heat source has to be available over useful time periods. It has to provide sufficient thermal output,

and it has to be sited in an environment where use can be made of the recovered energy. We thought," Simcock explained "that those criteria would reduce sources of supply. But they didn't.

The Turbine Alternator

The more we looked, the more we found. Even our local pizza parlour is a candidate. It fires up gas ovens at 6 am every morning and leaves them running until midnight. That's 18 hours a day of wasted heat, at times when local energy demand is highest." Freepower's search for suitable energy sources didn't stop with a Quattro Formaggio with extra olives. The more they looked, the more they found - see the sidebar.

Recycling heat as power

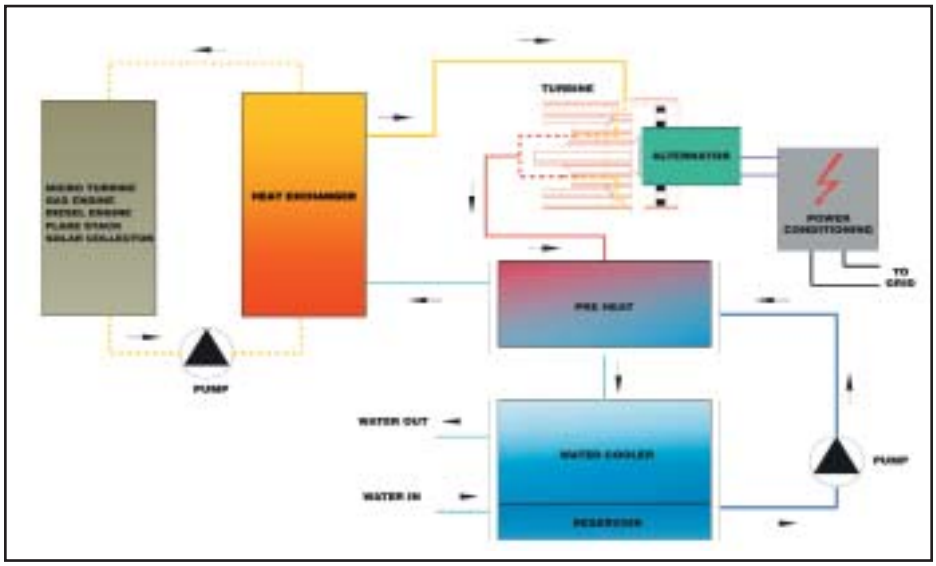
Having identified multiple sources of potential energy, Freepower considered what to do with it. Because wasted heat is exactly that, wasted, collecting it and extracting more heat from it would have been easy but nonsensical. Why supply more heat to an environment which is already dumping it? What the market requires is electricity. Currently 81.5% of the world's electricity is generated by heat from fossil fuels (64.5%) or nuclear fission (17%). Why shouldn't electricity from wasted heat supplement or displace some of that centrally generated power?

Large-scale electricity generation uses fuel to convert water to superheated steam, which drives turbines. Generating power like this was not the brief Freepower set itself. "We were looking for an innovative micro engineering solution, not a civil engineering one," says Simcock. "Our vision was a system that could be delivered by van or small truck to micro heat production sites and installed within a few hours. What we had in mind was something that looked like a domestic fridge, with extra connections."

Spin doctors

Freepower realised that generating electricity by rotating a turbine which spins an alternator dominates the power production market for a very good reason: it's the easiest and most cost effective way of doing it. Consequently, it set out to develop a turbine and an alternator which will produce 6kW of electricity from a pizza oven's worth of wasted heat.

Freepower's Director of Engineering, Richard Biddle, takes up the story. "Once we identified heat sources, we started measuring them, both for volume and temperature. We realised that to build a universal solution, we shouldn't anticipate high thermal inputs. Wasted heat temperatures vary widely, depending on source, but at their lowest they're barely sufficient to boil water. The conventional power generation medium - superheated steam – wasn't available to us. We



An external heat exchanger extracts heat from the energy source and transfers it to the working fluid. The fluid vaporises and expands, flowing as gas at high speed into the turbine. The turbine spins, turning an integral alternator. The alternator generates current which flows through the power conditioner into the local power supply, or out to the grid. The vaporised gas, having transited the turbine, preheats the working fluid, and then passes into the condenser to re-liquefy. It is pumped from the condenser through a water-cooled heat exchanger. The fluid is cooled sufficiently to return to the upstream heat exchanger and begin the cycle again.

concluded we'd have to spin a turbine with input temperatures as low as 125˚C. That dictated several choices. Firstly, we'd need a turbine that would operate at relatively low gas flow rates, and we found nothing suitable available commercially. Secondly, we'd need a working fluid that would vaporise at low temperatures but deliver significant efficiencies. And thirdly, using a working fluid requires a closed circuit system because - unlike water – it introduces a cost which Freepower wanted to minimise over equipment life."

Going organic

The choice of a suitable working fluid, one which would vaporise at low temperatures, and not cause health or environmental problems was solved by using an organic product that's non-toxic, non-flammable, non-ozone-depleting, and acceptable under Kyoto's terms. The challenges of designing, building, testing and productionising the technology took much longer to solve.

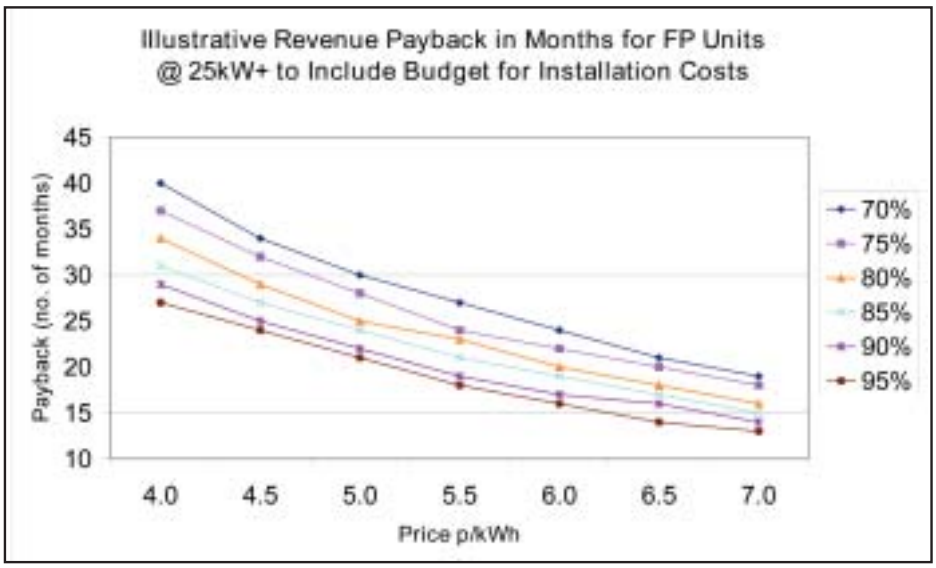
Biddle continues. "The Freepower solution uses an existing process, the Organic Rankine Cycle (ORC). The plain-vanilla Rankine Cycle is the superheated steam cycle. Replacing water with organic fluids that vaporise at lower temperatures results in higher efficiency and this is the ORC. The problem from our point-of-view was that we were aiming at a maximum output of 500kW from a single installation. To achieve that using conventional ORC technology would mean a machine weighing in at around 25 tonnes, whereas our target weight was 2 tonnes. Obviously, we had to think radically. And the more we thought, the more we came back to the turbine being the point where we could revolutionise conventional ORC thinking."

The heart of the machine

Freepower is reluctant to talk in detail about its turbine and other enabling componentry. Covered by 6 patents, with more going through the application process, it's obvious that it has come up with something radical. Depending on the model, its turbine is either two or three stage,

and rotates in the range 30,000 to 50,000 rpm. Ideal thermal input is between 180˚C and 225˚C, but the technology will still operate successfully at temperatures from 125˚C with varying degrees of efficiency. But, maintains Biddle, it makes little sense to focus on efficiency when you are capturing something being wasted, provided the electrical output is sufficient. The turbine drives an integrated alternator capable, depending on the output rating of the particular model, of producing between 2kW and 500kW.

Biddle picks up the thread. "Having conceived the miniature turbine at the heart of the Freepower solution, we had to



continue the 'small is beautiful' philosophy to achieve our transportability target. Essentially there are five main components to our products. We have heat exchangers, one to heat our working fluid from the energy source, and one to cool it post-turbine so that it can cycle back. Then we have pumps, to circulate the fluid through the heat exchangers. We have the turbine itself, driving an integral alternator which outputs unconditioned electricity, and so we incorporate a power conditioner to convert the alternator output to grid standards. We've integrated several proven technologies together in a unique way"

Improve, lighten, simplify

"We've rethought the role and design of those key components many times during the development period, seeking to refine, lighten, miniaturise, improve reliability and equipment robustness. We've achieved our current targets for size, weight, maintenance costs and mean time between overhauls. For example, our rotating components are cooled and lubricated by the elements they work in, avoiding the need for separate lubrication systems which add weight, complexity and unreliability. From an engineer's point-of-view a Freepower machine is very pure, very elegant, and very satisfying from the simplicity of its presentation to the 'plug and play' nature of the design."

We go back to Mym Simcock. "In a sense, to me as a business person, the engineering is interesting, but it's the result which counts. We've reached a point where we can deliver fork-liftable power generation equipment to any site that light transport can get to. Our machines are minimally disruptive for site operators and don't impact the host heat creation process in any way. They consume no fuel and create no emissions, but produce significant amounts of electrical power."

Putting the business case

Simcock likes to put herself into the Financial Director's role of almost any organisation you can imagine. "I'm sitting in my office and someone comes in and tells me that, for not very much money, for not very much time and for not very much manpower, I can install a self-contained box the size of a big fridge on every site I operate. They tell me that the box will produce significant amounts of electricity that cost me nothing but which will reduce my power costs, or which I can sell back to the grid to generate income from something I am currently wasting. They say that the box might even make me energy self -sufficient. Finally they add that it will pay for itself in between 12 and 48 months, let me claim environmental and tax incentives, and reduce my concerns about the impact of that new boy on the block, carbon trading. Why would I say no?"

Life is, perhaps, not that simple, but Freepower's argument is compelling. The technology, albeit in its smallest version at 6kW, is out there and running, proving itself in daily service. A range of models is planned, and testing of the first 120kW models is due this year, with first production shipment to a network of worldwide distributors in the first half of 2006.

Green, greener, greenest

With the wasted heat market for Freepower technology in hand, the company's attention has focused on the potential for generating electricity from waste, something which seems an almost infinitely renewable resource. One of the initial stimuli for Freepower was the potential to significantly increase the efficiency of methane gas generators, and do away with the sight of methane flaring from landfill. With technical R&D underway, the team began to look in detail at landfill heat sources. Freepower's Sales Manager Tom Gerson was tasked with researching landfill, and relates what he found.

"It quickly became clear that landfill is an unsustainable method of waste disposal. There's no question that landfill will continue for years to come and that it will produce enough methane to let Freepower generate gigawatts of power. But the waste management industry is on the cusp of significant change. Landfill volumes must be reduced by quantum amounts or we'll be buried by our own rubbish. Recycling plays a major part in this, but recycling can't do much more than halve waste volumes. That leaves a lot of rubbish which the industry needs to treat in new ways. For us, the good news is that whatever route is taken to reduce landfill volumes, there are by-products we can convert to electrical energy.

Renewable rubbish

Gerson's enquiries found there are several potential ways of treating domestic, agricultural and industrial waste in consideration. Firstly, there's autoclaving. "The plan for autoclaving," Gerson explains, "is that large ovens will take rubbish to a medium temperature - around 160˚C – for period of perhaps 60 minutes. That temperature won't cause combustion, but is high enough to dry out wet waste, to shrink but not char plastic, and to sterilise leftovers in bottles and cans. The effect, once recyclable materials have been recovered post-autoclaving, is to reduce output volumes to circa 15% of input volumes. What's left, the industry is calling "flock"; a dry, sterile product with several uses. One is to be pelletised, as fuel, which could be used on-site as a heat source for the autoclaving process. Trials indicate that more flock will be produced than the site needs as autoclave fuel. Our vision is that, rather than transporting the flock off-site, it will be burnt there to generate Freepower electricity."

The next area being examined is biomass. Power generation from biomass is an established process, using organic fuels which are either agricultural by-products, like straw, or which are specifically grown as fuel, like willow coppice. However, much of what arrives at today's waste disposal plants can be considered biomass, material like garden and kitchen waste, paper, card and certain textiles. "This material is too heterogeneous and, relatively, too small in volume to warrant extraction and despatch to any conventional power station, says Gerson, "but it is an ideal on-site fuel for a Freepower installation"

A relation of biomass is biogas. A United Nations Report, Energy After Rio: Prospects and Challenges identified community biogas as one of the most useful

decentralised sources of energy. Biogas plants don't require major funding, and don't excite public opposition. The organic material – like agricultural, human and animal wastes – needed to produce biogas in anaerobic digesters is readily available in developing and developed countries. The process yields fertiliser and biogas, mostly methane.

Then there's syngas, resulting from pyrolysis of waste. Pyrolysis breaks down waste materials through heat and combustion in the absence of oxygen, or restricted oxygen. It creates three main products; char, oil and gas, whose proportions vary depending on waste composition and oxygen levels. Gasification converts most of the pyrolysis products into steam and a combustible gas – syngas – a mixture mostly of hydrogen and carbon monoxide.

Gerson concludes "Whichever way waste disposal goes, there's potential for Freepower to transform the industry's economics. The general view is that waste should be handled locally, to obviate the environmental downside of long distance haulage. Local treatment means smaller-scale treatment, where major capital investment to recover energy from waste is not viable. Freepower makes it possible to equip small sites, maximising the benefits from waste, and minimising environmental impact. Our sums suggest that tomorrow's waste treatment plants have the potential not only to become electrically self-sufficient, but also to generate revenues through grid-injection of surplus power. In doing so they will slow the depletion of fossil fuels, and delay greenhouse gas build-up"

Natural energy

Apart from wasted heat, and heat from waste disposal by-products, there's also natural heat for Freepower to make use of. One intriguing source currently being investigated is capturing solar heat and storing it in hot rocks, to provide 24x365 electrical production, something not possible using photovoltaics unless the major overhead of battery banks is incurred. Freepower is also investigating the potential to generate electricity from geothermal heat.

Kyoto, Rio, G8

Freepower is not a bunch of sandal-wearing, vegetarian ecofreaks, but an experienced and hard headed team of engineers and business people. "Of course," says Simcock, "we embrace the global warming arguments, the need to reduce emissions, the requirement for stewardship of the planet. But primarily, our driving philosophy is that we live in an energy economy, and nothing we can do as the human race is likely to change that. Therefore, for us, the challenge is to create the energy we need with the smallest possible downside. Freepower is one element in that battle.

"Freepower is," concludes Simcock "as neat an answer to increasing the efficiency of energy production as any; a way of recycling wasted heat; a process for turning waste into a sustainable energy source; and a different way of creating energy from solar power. In a world where energy prices are consistently rising, and emissions are refusing to fall, there's a definite place for a technology which consumes no fuel, emits no pollutants and gives clean electricity." Zero fuel, zero emissions is the phrase which Simcock uses to sum-up Freepower's case.

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