Gadd's bottle and can interests enable reuse of excess carbon dioxide collected from fermentation

Carbon dioxide recovery

How small breweries can cut emissions – and save money

BY SOPHIE ATHERTON

I've always known brewers can get excited at the funniest things, but the glee on Eddie Gadd's face as he tells me "I'm capturing CO_2" still seems on the quirky side.

It is Green Hop Beer Day at Gadd's Ramsgate brewery, the occasion on which the first cask of this year's brew is tapped. Usually it would be the hops Eddie would be waxing lyrical about. He's still enthusiastic, and obviously looking forward to tasting the beer, but he wants to steal a moment before that to show me his CO_2 recovery unit.

Then again, he is the first small brewer in the UK to have one – and only the third overall. So I delay getting a beer and go to see the new machine. The fact there isn't a great deal to see makes it an even better story.

Gadds' Ramsgate Brewery is in an industrial unit on the edge of the town after which it takes its name (see profile panel for the Gadds' story). It produces around 5,000 hL of beer annually on a 25 hL kit and has eight fermentation vessels.

As we walk through the door Eddie tells me the brewery's CO_2 emissions are 17.5 tonnes a year. He then moves some bits and bobs aside for me to see this UK-first bit of kit. I'd have walked past it had it not been pointed out. It takes up floor space barely the size of a pallet. I recall my Nan telling me that good things come in small packages. Eddie begins to explain just how good a thing the unit is.

"Carbon dioxide is a by-product of the metabolism of glucose by yeast," he begins. "Alcohol is also the by-product – that's the bit we like – but the carbon dioxide, most of it goes up into the atmosphere, so for every gramme of alcohol that's produced by fermentation, 0.9565 grammes of CO_2 are produced. So for a regular strength beer it's virtually like-for-like by weight."

Now though, brewers can buy a cost-effective piece of equipment that makes their beer more environmentally friendly and will enable drinkers to avoid

eco-guilt when enjoying a pint but, what happens to the CO_2 that's been captured?

"You have this crazy situation where 30-40 grammes of CO_2 are going into the atmosphere from a brewery fermentation and then that same brewer would be buying up to 50g a litre to run their packaging plants, whether that be kegging or canning or bottling," Eddie tells me.

Cask beer, of course, needs no CO_2 when packaged but Eddie explains that for most of the UK's small brewers (those which produce less than 100,000 hectolitres annually) cask beer is about 50% of the volume of the market. Meaning half the beer in the sector is carbonated and has to go through filling machines that need CO_2.

Traditionally CO_2 has been a cheap by-product of other industrial processes, such as the production of ammonia, and historically it's been pretty inexpensive, so the economic arguments for capturing CO_2 from fermentation have never really stacked up before now.

Beer carbonation

Although Eddie's passion and focus is cask ale, in common with his fellow brewers, he also bottles and cans several beers. But unlike most, he has a business interest in a local bottling plant. Hence, he's perfectly placed to pioneer the use of this ground-breaking CO_2 recovery equipment and to explain not just how it works but the financial benefits.

"So we've got 30-40g of CO_2 coming off a fermentation per litre. We will use 5g per litre to carbonate the beer – that will come out of the beer if we don't take steps to keep it in there and those steps involve pressuring everything that the beer has to go through with carbon dioxide.

"So all your filling machines and your tanks, are all pre-pressurised with carbon dioxide and your bottle, or your can, or your keg, is pre-pressured with quite a lot of it in some cases, so that when the beer goes in the CO_2 doesn't escape.

"So to put 5g a litre of CO_2 into the beer, you can be using 45g a litre just to keep it in the beer depending on how efficiently you run your process."

I'm reminded of when I used to write about environmental issues for a local newspaper more than 20 years ago. The key to persuading people, espe-

Profile: 'Engineer turned brewer' Eddie Gadd, founder & head brewer at Gadds' Ramsgate Brewery

If it was as straightforward to set up your own tunnelling company as it is to start a brewery, Gadds' beer might not exist. Eddie studied mining and engineering at Imperial College, London and was already establishing an impressive CV (including stints on the Channel Tunnel and for London Underground) when he took some work in *The Flounder & Firkin* pub in Holloway Road, London while waiting for his next tunnelling contract to begin. It was here he spotted a way he could become his own boss and have an enviable lifestyle at the same time.

The pub was part of the Firkin chain of brewpubs, founded in 1979 by David Bruce (now better known for his work at West Berkshire Brewery) and had a brewery kit in the basement. Eddie noticed that although the brewer had a 6am start, by around 3 o'clock he'd be sitting at the bar enjoying his 'beer allowance', so he decided to find out how the beer was made.

He quickly realised he could bury any ideas about heading up a tunnelling company. Getting his own brewery kit would not only be much more affordable, it would be more fun too. Part-time work washing and filling casks led to him becoming a trainee brewer with the Firkin chain and an early achievement in 1994, just six months after he started brewing, was a portent of his future success and status as a brewer.

A cask of the now legendary Dogbolter porter brewed by Eddie was entered into the International Brewing Awards. Readers of *BDI* will be aware this is no ordinary

by professional, commercial brewers. Dogbolter won Bronze in the strong ales category (for beers between 4.7% and 6.9% ABV) and Eddie recalls being told that no brewery that size, or any brewer remotely that size had ever won anything at the competition before.

Over the next few years Eddie's role included opening a number of new Firkin pubs, setting up their breweries and making beer, before being sent to Holland to do the same there. By this time David Bruce had sold up and the Firkin chain was in the hands of drinks and restaurant industry conglomerate Allied Domecq.

Alas, it decided to sell the chain on in 1999 and the new owners immediately removed the brew kits and made all the brewers redundant. Fortunately, by that time, Eddie had several years brewing and business experience under his belt. He also now had the chance to buy the brewing kit he originally trained on and so, in 2002, Gadds' Ramsgate Brewery was born.

Appropriately, it began life as a cart

(before later expansion and moving to a larger site). Over the next few years Eddie 'plugged away', selling to local customers, and improving the quality of the beer until he reached a point where he says he understood what he was doing and his customers did too. After which he found the 'number of customers multiplied, really quite quickly, and suddenly we'd found our feet'.

Twenty years on, Gadds' beer is a local institution and Eddie a respected figure in the industry, including three years as Southeast chair of SIBA and work on Small Breweries' Relief. Classic cask ale remains the core of what the brewery produces. Beers like *No. 5* (4.4%) a traditional best bitter packed full of flavour and *No. 3*, (5%) a genuinely pale ale with crisp bitterness and pleasing lemon and lime hop character, from Eddie's beloved East Kent Goldings show his commitment to the traditional as well as being proof of consistent brewing excellence.

While brews like his East Kent Pilsner (4.8%) and the low alcohol gem No. 11 (1.2%) – which also won at the IBA in 2019, taking gold in the Non & Low Alcohol Beer Class 2 category – show he's a brewer able keep up with the times. Solar power at the brewery and now CO_2 recovery as well demonstrate environmental credentials and an understanding that innovation must be about provable improvement, and not doing things for the sake of appearances.

Gadds' then is a true beer success story, one which bucks the trend of 'craft' hyperbole; a satisfying case of local brewery makes fantastic beer and decides

competition. It is considered the Oscars of the brewing industry and judged solely

Appropriately, it began life as a sort of brewpub in an establishment called the Belgian Bar, close to Ramsgate Harbour

to keep doing what it's good at, but never gives up on aiming to be even better.

Dalum's skid-mounted CO_2 recovery unit in-situ at Gadd's Ramsgate Brewery with (inset) integrated controller

cially those in business, to do things that are good for the planet has always come back to how it can save money.

Given the uncertainty of CO_2 supply, because of energy prices, and add in rising surcharges, being able to capture and use your own CO_2 is incredibly useful right now. It also means that a CO_2 recovery unit is likely to pay for itself in a very short time – providing a brewer has a use or a market for the CO_2 captured.

Eddie tells me a brewery producing 10,000-20,000 hectolitres a year could see payback in less than three years – based on equipment prices ranging from around £45,000 for a small system, but more like £100,000 for a something larger and more sophisticated.

"I think at 20,000 hectolitres a year you could collect 80 tonnes of CO_2 and at current prices that's about

at £600 a tonne so that would be £48,000 - £50,000 revenue a year for the price of the electricity to run the CO_2 recovery unit which isn't very much."

A 'no-brainer' for small brewers

So, the capital costs are recoverable, but what about running costs? I quiz Eddie about what 'not very much' means in practice, mostly in terms of the environmental costs. After all it's not so good if supposedly planet-friendly machines create more green-house gases than they save because of the energy needed to run them. But apparently this is not the case with the Dalum.

At the time we spoke Eddie was still working on a full cost-benefit analysis, but said it was 'still looking like a no-brainer' for small brewers to invest in one of the machines.

For example, at the time of writing, the CO_2 recovery unit at Gadds' brewery used about one and a half kilowatts of electricity to collect 5kg of CO_2 per hour. Greenhouse gas conversion factors vary annually, depending on how energy is generated, but having consulted the Government-produced figures for 2022 Eddie reckons his CO_2 unit is producing the equivalent of 30g of CO_2 an hour and has the capacity to capture 15kg an hour.

Even capturing 5kg an hour it's preventing way more carbon dioxide going into the atmosphere than its energy use creates. In any case most of that electricity is used in cooling the machine (via glycol) – but there's even a way round that.

"This is beautiful," says Eddie with that excited look in his eye again. "It's some beautiful physics and elegant engineering: when you compress a gas it gets hot, so we stop the machine from over-heating by running glycol round it.

"The gas is turned into a liquid and it goes into a big tank. When we want to use it, the liquid expands into a gas and when liquid expands into a gas it gets very cold so what you do is you run the glycol past the expanding liquid, and it cools the glycol back down."

Eddie doesn't currently have that tech at the brewery, but plans to install it when putting the next unit in the bottling line.

It's green, cheap to run and it looks like a unit can pay for itself within a few years, but what about the quality of the

Tech specs & info:
Capacity: 0-15 kg/hour liquid CO_2 per hour at 35 - 45 bar.
Purity: 99.980-99.995% CO_2 purity depending on feed.
CO_2 supply pressure: Minimum 0.2 bar from fermenter.
Feed gas purity: Minimum 96% CO_2, maximum 0.6% oxygen from fermentation.
Room temperature: Minimum 5°C and maximum 40°C.

Utility data:
Connections: Electricity: 3x400V +N+P, 50 Hz, 10 Amp fuses.
Cooling media: -5 to 0°C, flow 0-15 l/min or max 2.5 kW.
Water and drainage: Both at 0-20 l/hour.

Features:
Dimensions: LxWxH: 1x1x3 meters and 1x2x3 including foam trap.
Noise level: Approx. 65 dB(A)
Materials: Stainless steel (exclusive motor, gearboxes, control cabinet) and selected electrical valves in brass.
Covers: These are optional, but recommended if module is placed in fermentation area with spraying with water and cleaning agents.

Controls, installation and use:
Fully assembled and tested unit ready to plug-in. No vendor installation and commissioning hours needed.
Needs only water, electricity, glycol and drain to be connected
Operated via PLC with colour touchscreen and fully automatic operation.

£200,000 or more – but that's with the surcharges.

"If the surcharges come down, or disappear altogether, then you're looking

The CO_2 module is outside PED and ASME regulation, so no approval needed. (Except for relevant liquid CO_2 storage tank approval/inspection). The equipment is delivered CE marked and with necessary manuals and documentation for use and maintenance.

Visitors to Gadd's Taproom can avoid eco-guilt with their beer

product? It is apparently much better than what you can buy.

"As it stands we're buying CO_2 from the production of ammonia, which none of us knows anything about! We don't know how they do it, we don't know what's in the gas, but we do know a lot about fermentation," enthuses Eddie.

"We know what's in there and we know it's good because we put it inside ourselves, so if you look at quality of CO_2, not only are we letting this free source of it go into the atmosphere, it's measurably better quality and it's from a known source," he explains, before telling me he's measured the purity at just 16 parts per billion oxygen, which is 'better than most CO_2 on the wholesale market'.

Early adopters

It sounds a lot like a green future for small brewers. Surely every brewery is going to want to snap up one of these machines? The missing piece though is that brewers need a use for the CO_2

Given the ongoing CO_2 supply issues and/or shortages and the problems it caused for pubs doesn't that mean there's a market ready and waiting?

"That will take a little bit more engineering…" says Eddie going on to explain that liquid CO_2 just needs to be kept cold in an insulated vessel. But the sort of CO_2 used by pubs is the gaseous kind and needs to be stored at extremely high pressure in order to fit a useful volume in a bottle small enough to transport and deliver easily.

"So for me to fill bottles for pubs I'd just need a pump that can take it from my liquid tank and pump it under very high pressure into those bottles – all the engineering's there, it's just finding it," he concedes.

In the meantime Eddie hopes the likes of Cloudwater, Northern Monk, North Brewing Co. and Five Points, small brewers producing a significant amount of packaged, carbonated beer, will be early adopters. They will need to

'almost overwhelmed' by the interest he received at this year's drinktec trade show and soon after – which he acknowledges will have been stimulated by the CO_2 supply situation. Nevertheless he's received about 30 orders already including from UK breweries Wiper & True, Stewart Brewing, Arbor Ale, 71 and Cromarty Brewing.

Eddie also believes that even larger brewers could make use of the unit. Giving the example of a regional brewery that makes 'a lot of cask beer but also has some on site packaging lines'.

"They're not going to be capturing all the CO_2 they produce, but could capture enough to become self-sufficient with CO_2 and if you do that then your payback is no time at all."

It's clear Eddie's something of an evangelist for CO_2 recovery and the potential of the machine Dalum has created. I ask if it's down to his engineering background. "I don't like seeing resources going up the chimney!" he

is that brewers need a use for the CO_2 they capture, or a market for it – and not all brewers also have shares in a bottling plant.

will be early adopters. They will need to join the queue.

Kim Dalum, the man behind the machine (see page 37), says he was

resources going up the chimney!" He laughs, before going on to clarify.

"I don't mind taking a risk when others won't, because I understand

what I'm getting into and, as an engineer, maybe I understand a bit more about this than perhaps some of my non-engineering brewing colleagues do. So it's my responsibility to take the plunge and I'm telling you it works – better than I ever expected."

Dalum's CO_2 recovery unit

In simple terms, Dalum's CO_2 recovery unit for small breweries works by fitting a hose to a fermentation vessel to capture the CO_2 produced, thoroughly cleaning and filtering the captured gas, then compressing it several times for storage. (At Gadds' the installed system consists of collection pipework, a foam trap, the capture unit and transport/storage vessels.) The result is very pure CO_2 ready to be used in the beer packaging process.

Collection of CO_2 from FV could not be easier!

How did it come about? Kim Dalum explains he approached several independent brewers with different ideas for new equipment and collaboration, based on his previous experience with large commercial breweries.

The independent breweries were interested in the creation of an affordable, small system to capture and liquefy the CO_2 from their own fermentation. In 2019 his new company started a partnership with the first Danish organic brewery, Ørbæk Bryggeri, to develop a piece of equipment, which would do just that *and* enable it to be stored and reused at a later stage.

He quickly realised that there was no existing technology available, so he needed to completely build everything from scratch, including the first stainless-steel and oil-free three-stage compressor for CO_2.

Unlike conventional CO_2 compressors, Dalum says its unit provides up to 45 bar pressure, hence the CO_2 condensation takes place at 0-5°C, which makes it unnecessary to use a separate CFC or ammonia cooling system, so a glycol, ice-water or alcohol coolant system can be used instead.

Raw CO_2 gas from the collection system is supplied to a foam trap (which can be optionally equipped with a foam detector, which stops the system if foaming is detected). After the foam trap, but before the CO_2 gas reaches the compressor, alcohol and aerosols are removed in a 'water scrubber'.

After second stage compression, CO_2 is led through activated carbon filters, removing any traces of sulphur and oxygenates. After stage three the CO_2 is dried in aluminium oxide-based dehydrators, which also removes traces of remaining volatiles. (The dehydrator is duplicated and regenerates automatically by heating.)

The dry CO_2 is condensed using an external coolant source and the liquid CO_2 is continuously distilled in the condenser coil to ensure low oxygen content. Liquid CO_2 is pushed with approximateely 35 bar pressure to a storage tank, where liquid CO_2

Brewery founder Eddie Gadd alongside his liquified CO2 collection tank

Dalum's small footprint (1m²) needs 3m of headroom for the incoming CO_2 washing column

expands to the storage tank pressure and temperature. Vaporised CO_2 from the storage tank is sent back to the compressor.

If an existing storage tank is available, it could in most cases be used. If not, Dalum can deliver a range of super-insulated storage tanks with vaporisers in different capacities. (In Europe, an inspection and a certificate from a notified body is needed before putting CO_2 storage tanks into legal use.)

Dalum says the unit is designed for continuous automatic operation and capacity can be adjusted according to the amount of CO_2 produced during different fermentation stages and the number of tanks engaged.

It adds that fully variable process speed is possible due to its proprietary sanitary stainless-steel compressor, which is 100% oil free, and delivers oil free CO_2. Materials used in the compressor, which are in contact with CO_2 are food contact materials (FDA). The compressor also runs at low speed to improve lifetime, efficiency and reduce noise.

The man behind the machine: Kim Christian Dalum

Kim Christian Dalum describes himself as having a passion for beer-making. He held managerial positions with various leading engineering companies at the global level, including Sander Hansen, Krones, Alfa Laval and Union Engineering (now Pentair) supplying process equipment to large scale commercial brewing companies from 1996 until 2017.

In 2018 he decided to establish DALUM Beverage Equipment ApS. with the aim of helping craft brewers save money and become more environmentally sustainable.

Of the first decade of his career Kim says, "I found the beer industry was the greatest and most giving business to be part of. I enjoyed this world-encircling and generous culture, the passion for beer, the hospitality, working with great people and you were allowed to have a good time and beer as well. It always made us suppliers walk the extra mile for our customers and it sparked great innovations."

He goes on to explain how things changed and what made him alter direction to work with smaller breweries: "Following the fierce consolidation of the international brewing industry, I saw this culture I enjoyed so much, and that I was part of, vanish a bit.

Kim Dalum (L) and Eddie Gadd toast the successful instillation of the equipment at Gadd's Ramsgate Brewery, August 2022

brewing. I now enjoy the new brewer's culture that matches my own innovative mindset and I have the vision to use my experience and innovative force to help independent brewers become more sustainable and efficient."

He outlines the challenge: "Due to the small scale of craft brewing, advanced technologies for improving efficiencies of raw materials, energy, water, and minimising waste streams and environmental impact which are used by large brewers have not been marketed nor affordable to craft sized operations.

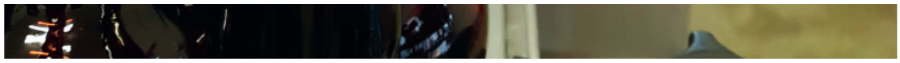
"As a result, craft brewer's production costs/hL exceed those of a large brewer and energy, water and raw material usage are higher, and CO_2 losses much higher. Some of this is due to the personality of the crafted beer and should not change. However, I took up the challenge to develop affordable small-scale process units to address the above."

Kim's hope now is that 'the wonderful craft beer keeps spreading volume and variety' and that his company can help it be even more sustainable and feasible to make.

"Craft beer quadrupled in a decade and could triple in the next decade," he says. "We strive to help recovering 1/3 of the potential million tons craft CO_2 and save small brewers £200 million per year by then. This is a crazy vision, but I think the potential and the need is there."

I was part of, vanish a bit.

"On the other hand, it has been a pleasure to see how the small brewers soar and develop a new spirit for



Half the beer in the small brewery sector has to go through filling machines that need CO2