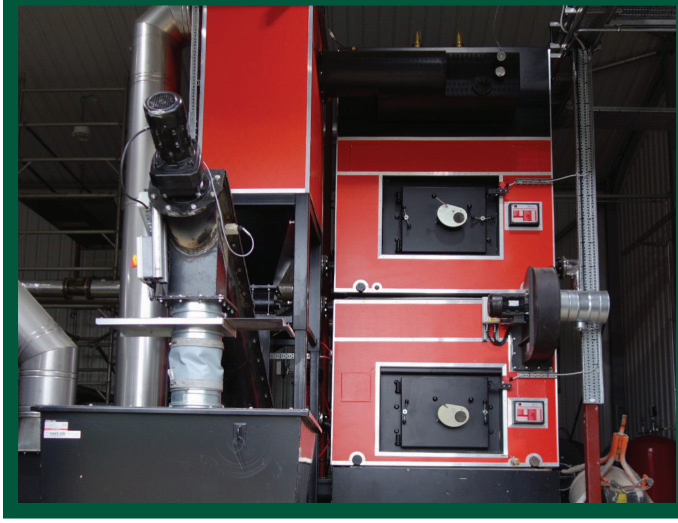
# ALTERNATIVE SOURCES OF $CO_2$

## INTRODUCTION

**This is the second part of a two-part update on $CO_2$. The first part covered the costs and characteristics of conventional $CO_2$ supply. Here, we look at the supply of $CO_2$ from biomass and anaerobic digestion and discuss how it has developed since the uptake of renewable-based heating systems.**

## $CO_2$ FROM BIOMASS COMBUSTION



Straightforward biomass combustion represents by far the largest proportion of new $CO_2$ source potential in commercial horticulture. Although anaerobic digestion, biogas production and gasification have also emerged as potential sources, biomass boilers have seen the highest level of adoption.

Whilst there is a broadly equivalent quantity of $CO_2$ in biomass combustion flue gases compared to fossil fuels, the cleanliness of the gas direct from the boiler is much more of a problem and this presents the biggest challenge to users. Therefore, gas cleaning equipment is required to produce the necessary quality of $CO_2$. The two approaches to this are to either remove the pollutants and leave clean $CO_2$, or to extract the $CO_2$ and discard the remaining pollutants. The ideas sound similar but, in fact, employ different techniques.

## REMOVING THE POLLUTANTS

The table below describes the major pollutants from biomass combustion and the techniques available to remove them. One of the biggest issues with selectively removing the pollutants is that the particulate matter can block other parts of the system, such as catalytic media, rendering them useless.

| Issues | Solutions |
|---|---|
| Particulates | A high standard of particulate removal is recommended. Bag or ceramic filters are best suited to this. |
| NOx | A good quality wood chip boiler might deliver acceptable NOx levels. A straw boiler will not. Ceramic filters impregnated with a selective catalytic reduction catalyst can be used. |
| SOx | SOx removal is advisable. Dry scrubbing with sodium bicarbonate is possible. |
| Ethylene | The worst case ethylene concentration is borderline acceptable, so should be checked. |
| Tars & other volatile compounds | Detailed flue gas analysis is required to determine if these are likely to be a problem. A flue gas condenser may provide sufficient removal. |

## EXTRACTING $CO_2$

The alternative to selectively removing the pollutants is to extract the $CO_2$ directly. The most common method is to use an amine scrubber. This was the principle introduced in a Canadian system, developed in late 2013 (ProCeed), and which has subsequently been adopted by a small number of companies in the UK and Europe.

For the system to work well, high temperature flue gas must be supplied by the boiler, substantially higher than the 95°C common to most hot water biomass boilers. This means that retrofitting the gas cleaning equipment on such systems is not viable.

The capital cost of this equipment is very high, but running costs are relatively low once installed. For example, a system capable of delivering 500kg $CO_2$/hr would cost approximately £1 million. Indicative running costs for this type of system are around £20 per tonne of $CO_2$.

With support for biomass boilers from the Renewable Heat Incentive, a biomass system with $CO_2$ recovery can be a financially viable alternative to a conventional heating/$CO_2$ system.

## $CO_2$ FROM BIOGAS

Biogas is produced from the anaerobic digestion of biological matter. Burning biogas to produce heating for glasshouses is eligible for the Renewable Heat Incentive (RHI). Biogas can also be used in CHP engines.

**Boilers**

Biogas is 30-60% $CO_2$, and can be burnt as long as the boiler is capable of doing so. Recovery of the $CO_2$ from the boiler is challenging, as it requires impurities and compounds to be removed, including $H_2S$ and water. High levels of NOx and SOx are also present.

**CHP**

Biogas can also be used in a CHP engine, where electricity is produced from a connected generator. Heat is available from the engine for use in the glasshouse. Value can be gained from the electricity generated, heat and $CO_2$. Subsidies on electricity production in the form of Feed-in Tariffs are available for burning biogas to produce electricity. However, unless you have already secured preliminary accreditation, any application submitted is subject to the rates available well into 2017 due to the recent introduction of quarterly capacity caps. Renewable Obligation Certificates (ROCs) are still available for generators until April 2017 and offer 1.8 ROCs/MWh for AD, with a ROC being worth £44.77; this relates to an effective rate of 8.06 p/kWh of electricity generated.

High levels of biogas clean-up are required if the gas is to be used in an engine compared to use in a boiler. This can be done using chemical or biological filters. See the table of impurities in raw biogas and their effect on engines below:

| Impurities in raw biogas | | |
|---|---|---|
| **Impurity** | **Common Name** | **Impact on installation** |
| $CO_2$ | Carbon Dioxide | Reduces overall calorific value and promotes corrosion of metallic parts by formation of weak carbonic acid. |
| $H_2S$ | Hydrogen Sulphide | Acts as a corrosive in pipelines, poisons the catalytic converter and causes increased $SO_2$ emissions. |
| $H_2O$ | Water | Contributes to corrosion in pipelines by forming acid with other compounds. |
| $NH_3$ | Ammonia | Leads to an increase in formation of NOx, but decreases risk of engine knocking. |
| $N_2$ | Nitrogen | Reduction in calorific value, but decreases risk of engine knocking. |
| Siloxanes | Treatment chemicals (e.g. antifoaming agent, washing agent, hydraulic fluid) | Mostly found in biogas formed from landfill or sewage sources and act as quartz of silica that grind motor parts. |
| Terpene | Essential oils (e.g. from plants, fruits etc.) | No impact. |
| Ester | Fruits, fruit aroma | No impact. |
| Particulates | Dust | Damages vents, catalysts and exhausts by clogging. |

## CROP EFFECTS

The effects of flue gases with impurities on plants are outlined below:

| Impurities in raw biogas | | |
|---|---|---|
| **Impurity** | **Common Name** | **Impact on plants** |
| NO | Nitric Oxide | Emitted as a result of combustion; the crop can handle a certain amount of NO, but beyond that it becomes toxic and the plant will use energy to break down the toxins – i.e. photosynthesis decreases. |
| $NO_2$ | Nitrogen Dioxide | A result of incomplete combustion. Same as above. |
| $C_2H_4$ | Ethylene | A result of incomplete combustion; at low levels will cause premature senescence, flower abortion and unwanted colouring of leaves. |
| CO | Carbon Monoxide | A result of incomplete combustion; not poisonous to plants, as it is rapidly oxidized to form carbon dioxide for use in photosynthesis, but is poisonous to humans so is undesirable. |
| $CO_2$ | Carbon Dioxide | The desirable component of combustion used to fertilize the crop. |
| SOx | Sulphur Oxides | Result of combustion; forms acid, which is corrosive. |

## GAS CLEANING

De-sulphuring equipment for biogas exhaust products is available and is in the region of £90,000/MW. Selective catalyst reduction (SCR) systems can be employed to reduce NOx, CO and a number of other pollutants and cost £300,000/MW. (Note: A 1MW system can produce about 500kg/hr of $CO_2$.)

## $CO_2$ FROM BIOMASS GASIFICATION

Gasification converts dry biomass into a combustible gas using heat in a low oxygen environment. The technology has been around since the 1800s and historically was used to produce town gas for lighting and cooking. Gasification can be carried out on any carbon source, either organic (biomass) or mineral (coal).

The gasification of biomass involves heating a biomass product (typically wood chips or pellets) to a temperature between 700°C and 1,600°C, depending on the application. This is done within a controlled oxygen environment to partially oxidise the feedstock. This breaks down the carbon source into carbon monoxide and hydrogen plus carbon dioxide. The resulting gas can then be burned in a boiler, or an engine, to produce heat and/or electricity. High levels of non-combustible $CO_2$ are contained in the gas and can be stripped out and used. Also, following combustion, flue gases of the combustion equipment can be cleaned to utilise the $CO_2$.

Gasification is a very scalable technology and has equipment available from quite small to very large in size. Its high temperature combustion lends itself to the production of high temperature water or steam, which can be useful for some heating/power applications. It is, however, a relatively expensive technology and requires a high quality and, therefore, high cost biomass substrate.

Subsidies are also available on energy production from gasification through the RHI (Renewable Heat Incentive) for heat and ROCs (Renewable Obligations Certificates) for electricity.

## $CO_2$ FROM BIO-METHANE CONDITIONING

$CO_2$ can be derived as a by-product of bio-methane conditioning, where raw biogas (straight from an anaerobic digestion (AD) plant) is upgraded to a grid quality gas before injecting it into the national gas grid.

Biogas from AD is typically anywhere between 40-70% methane, 0-2% trace gases, impurities, water and 30-60% $CO_2$. $CO_2$ has to be reduced to match mains gas quality and the required cleaning process can yield significant amounts of high quality $CO_2$, which can then be used for glasshouse enrichment.

$CO_2$ can be removed from raw biogas using a number of methods including:

- **Absorption** – in water at pressure, amine solution from which $CO_2$ can be released on heating.
- **Pressure Swing Absorption** – pressurised gas is led through an absorber bed, where molecules of varying sizes are removed from the gas.
- **Membrane** – pressurised gas is passed through a membrane system, which has selective permeability for $CO_2$.
- **Cryogenic separation** – biogas is cooled until $CO_2$ separates out as liquid form.

Electricity for the $CO_2$ extraction plant is the biggest use for the above options; 500kWh per 500 $m^3/h$ of gas injected into the grid, which would yield a similar volume of $CO_2$ post clean up – equivalent to about 1,000 kg of $CO_2$. Running costs would therefore be 5p/kg $CO_2$ or £50 per tonne.

## CONCLUSIONS

Novel methods of $CO_2$ recovery are emerging, such as $CO_2$ from biomass and biogas treatment. However, these technologies are in their infancy and will be constrained to certain sites. The renewable incentives associated with these methods of heat or gas generation are significant and could help bolster the uptake of the high capital cost, but relatively low running cost, of $CO_2$ recovery for these methods.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