Macdonald Reports

Biomass Heating for Improved Greenhouse Efficiency

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New research is providing greenhouse operators with an opportunity to convert exhaust gases from a greenhouse wood heating system into a useful resource. Conducted at McGill's Bioresource Engineering Department, this research is focusing on the use of renewable biomass combustion fuels. Professor **Mark Lefsrud**, who is leading this new research, is capitalizing on the recent explosion of interest in biomass. Often in the form of wood chips or pellets, biomass can be seen as a sustainable and economically feasible alternative to heat greenhouses.

Greenhouse industry directly affected by changes

The horticulture industry has received increased pressure to reduce greenhouse gas production and operational costs due to high energy consumption. This has been brought forward by the worldwide shift in energy policy requiring most industries and governments to reduce greenhouse gas emissions and dependence on fossil fuels. Greenhouse operators must address this issue by balancing energy efficiency through structural or fuel saving techniques, while maintaining optimal growing conditions in order to compete with an ever increasing competitive market. Heating represents around a quarter of operational costs depending on the energy source (oil, gas, electricity, or biomass) and so it is to the growers economic advantage to reduce energy costs and, consequently, their environmental footprint.

CO_2 emissions reduced with biomass options

Recent fluctuations of fossil fuel prices have increased the necessity to explore alternative systems and this has allowed biomass heating to become an economically viable option. Biomass resources such as wood residues, wood and grass pellets, agricultural residues or municipal solid waste are all options that are being explored.

The life-cycle carbon dioxide (CO_2) emissions from biomass are at least 90% lower than from natural gas, but still occur due to the natural thermo-chemical reaction of combustion. However, using waste exhaust gases from a heating system can be beneficial to greenhouse plants by providing a viable source of carbon dioxide. CO_2 enrichment is one of the commonly accepted techniques to enhance photosynthesis resulting in improved yields and income. Operators typically increase levels from 800 to 1000 ppm from an atmospheric level of 380 ppm. Enrichment is commonly practiced with pure CO_2 in bulk or from combustion of hydrocarbon fuel (natural gas or propane). Usually, these fuels are employed in dedicated burners to provide CO_2 while a separate heating system provides most of the heat to the greenhouse. CO_2 enrichment from the exhaust of a natural gas or propane heating system has proven to be feasible, but using renewable energy could have further benefits. In terms of enrichment applications, combustion of dry and clean wood biomass can produce two times more useful CO_2 than natural gas for the same energy unit.

The Quebec greenhouse research centre, "Centre d'information et de développement expérimental en serriculture" (CIDES, Canada), had begun promising demonstrations of CO_2 enrichment from corn based biomass. It was reported that 1.7 kg of CO_2 was produced from the combustion of 1 kg of corn. In comparison, propane yields 3 kg of CO_2 per 1 kg of fuel. The costs were approximated to be 0.11CAN$/kg for corn, 0.18CAN$/kg for propane and 0.17 CAN$/kg for natural gas.

Emission challenges

Since life cycle greenhouse gases of biomass are significantly lower in emissions than fossil fuels, they could be lowered further through enrichment and absorption of CO_2 by the crops growing in a CO_2 fed greenhouse. While the overall system would not be considered carbon neutral throughout its complete life cycle, CO_2 enrichment from exhaust gases could still be viewed as a means to reduce carbon emissions directly at the source. Such an initiative could be part of a carbon market and sequestration incentive.

PHOTOS: COURTESY M. LEFSRUD

Top: Macdonald Campus Horticultural Center Greenhouses; Bottom: Gasifier unit under maintenance.

In practice, CO_2 enrichment from the exhaust gas of biomass boilers is still challenging and expensive, considering the current equipment and exhaust gas composition. Many of the exhaust gases (carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxide (SO_x), ethylene (C_2H_4), other VOCs, and fine particulates) are toxic to humans and plants and must be removed or diluted before injection into the greenhouse. One possible solution is using membrane separation to extract CO_2 from flue gases. This technique has shown a lot of potential for large industries trying to reduce and isolate CO_2 emissions for sequestration and could be applicable to the greenhouse industry for enrichment.

Recent research at McGill University

Our research is focusing on comparing gasification and direct combustion. Gasification converts biomass into a combustible gas mixture (syngas, comprised mostly of CO and H_2) by heating the biomass under high temperatures and low oxygen. Through this process, far fewer fine particulates are emitted from the stack. By coupling a gasification chamber to a combustion chamber, the syngas is burned separately from the biomass fuel. With this design and an adequate level of air supply, fine particulates and undesirable gases can be reduced greatly. The energy efficiency for a gasification system is also higher than for combustion. Net conversion efficiency for biomass combustion is reported to be at 20 to 40%. Gasification coupled with combustion can provide 40 to 50% net efficiencies. Consequently, gasification, along with a proper system design, could be a first step at facilitating CO_2 enrichment of greenhouses with biomass.

We are enthusiastic about our MAPAQ (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation)-funded research project and the benefits it could have on the greenhouse industry in Quebec. We know that through leading edge research, we can help keep Quebec greenhouse operators at the forefront of the world while ensuring that the industry is able to meet new and emerging environmental standards for CO_2 emissions.

We welcome your interest.
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