Environmental Analysis of the Use of Poultry Manure as Fuel for Combustion on Broiler Farms: A Case Study

A. Dimache, J. O'Connor, D. Kearney

Abstract:

Fluidised Bed Combustion (FBC) technology is not new. It has been used in power plants for the last three decades and is considered very efficient for biomass combustion. The novelty of the FBC application in BHSL's case consists of the combustion of poultry manure on farm with the same thermal efficiency (over 86%) as the combustion of biomass (e.g. wet wood chips). BHSL has successfully miniaturised the power plant design to produce up to 2 MWh heat in a unit which is small enough to locate on the site where the fuel is generated – ideal for agricultural and by product applications with high heat demands. BHSL's FBC 500 boiler is capable of 500 kWh thermal output, which is sufficient to provide hot water at 85^{0}C required for distribution to poultry sheds for rearing broilers from day-old to fully grown. A case study was conducted in order to measure the efficiency of the BHSL energy system for broiler production and also to evaluate its environmental benefits. Environmental benefits were measured using Life Cycle Assessment (LCA), which compared the environmental impact of 3 scenarios: (1) where the poultry manure is used for land spreading as a fertiliser and the broiler houses are heated with LPG; (2) where the poultry manure is used for combustion in the FBC 500 to generate heat, most of which is used to heating the broiler houses; (3) where the poultry manure is used for the production of steam and electricity generation with the residual steam used for heating the poultry sheds (combined heat and power – CHP). The results of the analysis show that when poultry manure is used for combustion, a reduction up to 95% in LPG use, as well as reductions in eutrophication potential of 26-32% and acidification potential of 31-40% can be achieved. An improvement in birds' welfare was also noticed as a result of the use of dry heat that can be supplied to the broiler houses by poultry manure conversion.

1. Introduction

Climate change and resource depletion (in particular fossil fuel) have been recognised in the past two decades as a serious threat at international, European and national level. In recent times there has been a surge in the number of policies established in response to these problems. The European Union is the leading organisation in addressing climate change, with numerous policies established to date. The "20-20-20" targets (European Commission, 2014a) for reduction in EU greenhouse gas emissions, improvement in the EU's energy efficiency and raising the share of EU energy consumption produced from renewable resources are well-known and have been recently revised by the 2030 Framework for Climate and Energy Policies (European Commission, 2014b). In order to deliver the 2020 targets, the Commission has adopted the Climate and Energy Package (European Commission, 2014a) that comprises of various pieces of legislation, including the Effort Sharing Decision (European Commission, 2014) – which establishes binding annual greenhouse gas emission targets for Member States from sectors not included in the EU Emissions Trading System (EU ETS). Agriculture, transport, residential and waste processing are the main sectors outside the EU ETS, and these contribute approximately 60% of the EU's total emissions (European Commission, 2014a). A recent EPA report (EPA, 2013) show that agriculture and transport are the key contributors to emissions in the non ETS sectors. The agriculture sector emissions are largely made up of emissions from enteric fermentation (45%) – this is when methane is produced by animals' digestive processes – manure management (27%) and nitrogen application to soils (22%) (EPA, 2013).

In this context, bioenergy technologies that convert biomass (including manure) into different forms of energy including power, heat and combined heat & power (CHP) can be a viable solution for agriculture, the contribution to the European targets being two-fold: (1) reduced emissions due to manure management and fertiliser application and (2) increased use of renewable resources to produce energy.

This paper presents an innovative use of Fluidised Bed Combustion (FBC) technology for combustion of poultry manure to generate heat, which is used for heating broiler houses. This novel and patented solution offers the opportunity to turn poultry litter which is currently a cost into an income stream by using it to generate heat (and thus significantly reduce the fuel requirement) and sell the by-product (ash) as high-potash fertiliser. The benefits that arise from this are positive environmental impact, energy security and turning a cost item into a profit item. The advantages of the FBC solution are proved by a case study conducted on a large farm in the UK by the originators of the FBC system, the Irish company, BHSL, as part of the SUPPER European project funded by the ECO Innovation programme.

2. Sustainable Heating for the Poultry Industry

Broiler farming is a low margin business where propane is a significant proportion of the overall cost; this cost is likely to increase over time in line with other fossil fuels. Each broiler produces approximately 1.2 kg of poultry manure that the farmer is responsible for disposing of (Moore, 2013). Currently, the principal methods of poultry manure disposal are:

- Land spreading as fertiliser. Poultry litter has long been recognised for its beneficial fertilising impact on crop production as it is considered a relatively cheap source of nutrients. Poultry litter increases the soil organic carbon content, increases soil porosity and enhances soil microbial activity (Nyakatawa, Reddy, & Sistani, 2001). There are different approaches in place depending on national policies (e.g. a poultry farmer in Ireland has to pay to get it removed from his farm; in contrast, farmers in the UK are paid for their poultry litter to be used as a fertiliser).
- Re-use as compost material for mushroom growers. This is a viable solution when there are mushroom growers in the vicinity of the farm.
- Stock piling of manure. This is done when the weather is not suitable for land spreading or there is insufficient available land or it is restricted by regulations. Stock piling can lead to leaching of nutrients and bacteria into the groundwater. Loss of nitrogen is a problem here and reduces the commercial value of the product as a fertiliser (Kelleher, Leahy, Henihan, & O'Dwye, 2002).

The alternative to disposal is the use of bioenergy technologies to convert biomass into different forms of energy including power, heat, combined heat & power (CHP) and liquid biofuels. One of these technologies is fluidised bed combustion (FBC). The calorific power of poultry litter when used as a fuel is about half that of coal (Moore, 2013).

2.1. Fluidised Bed Combustion (FBC)

Fluidised bed combustion (FBC) technology (Oka, 2004) is a form of combustion which became commercial in the 1970s. It offers high thermal efficiency and low toxic emissions (CO, NO_x) due to good control over combustion conditions. Fluidised bed technologies also offer the advantage of a high tolerance of moisture content and type of biomass used.

One emerging application of FBC is the potential to couple an Organic Rankine Cycle (ORC) power generator to a biomass hot-water source (Peterson & Haase, 2009). ORC technology uses hot water to heat a compressed working fluid that has a lower boiling point than water. In this manner, electricity can be produced from low-temperature (approximately 85°C and greater), low-pressure sources such as biomass hot-water boilers (Peterson & Haase, 2009). (Kelleher, Leahy, Henihan, & O'Dwye, 2002) identified some advantages of the FBC technology used for manure combustion:

- It can facilitate the use of poultry litter close to where it is produced.
- It can use fuels with a relatively high moisture and ash content.
- It incurs low cost of fuel preparation.

Until March 2014 poultry litter was categorised as waste. As a result, it fell under waste regulations: any burning of waste requires the flue of the boiler to have a Continuous Emissions Monitoring System (CEMS) connected to it and it has to monitor more items (HCl, CO, NO_x, SO_x, dioxins and particulates) than if it was considered a by-product (Environment Agency, 2011). In March 2014 a major change in Regulation 142/2011 regarding "the use of animal by-products as a fuel in combustion plants" was achieved. This opened the way for on-farm processing of poultry manures – and potentially other manures in the future.

2.2. The BHSL solution

BHSL is a small Irish company with a history in the poultry sector since 1960. BHSL supplies and operates Fluidised Bed Combustion heating systems suitable for low-value biomass such as poultry litter, wet wood chips and spent mushroom compost. The multi fuel biomass Boiler FBC 500 offered by BHSL has greater than 87% thermal efficiency while running at 75% maximum continuous rating with wet wood chips (49% moisture content). The FBC 500 is certified by the Carbon Trust and qualifies for Enhanced Capital Allowances (ECA). BHSL has successfully miniaturised the power plant design to produce up to 1 MWh heat in a unit which is small enough to locate where the biomass fuel is created – ideal for agricultural and by product applications with high heat demands. These on-site units are suitable for a range of biomass including wet wood chips, poultry litter, spent mushroom compost and other manures and sludge, with the same high thermal efficiency (over 86%).

The BHSL solution for applications in broiler farming is presented in Figure 1.

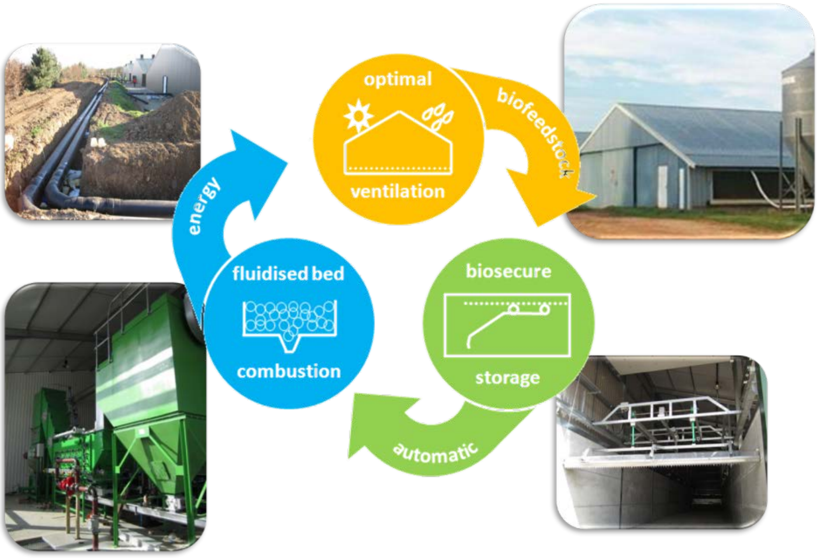


Figure 1. The BHSL solution for applications in broiler farming

Litter from one batch provides clean, dry, renewable heat to sustain the next batch. Poultry litter is a valuable fuel – the litter from one chicken can provide the heating needs of 3 chickens, leaving a surplus which can be used for electricity generation. Once a house is cleared of birds the litter is loaded into a bio secure fuel storage and handling system called a Toploader (see Figure 2). The air required for the FBC is drawn from this storage structure, creating negative air pressure and ensuring no leakage of odours or pathogens. Fuel handling is fully automated so farm staff have no further contact with litter after loading it in. Litter is conveyed to the FBC unit at the rate of 5 tonnes per day. The FBC 500 provides 500 kWh hot water which is pumped to fan-controlled radiators in the poultry houses. The system applies strict emissions controls.

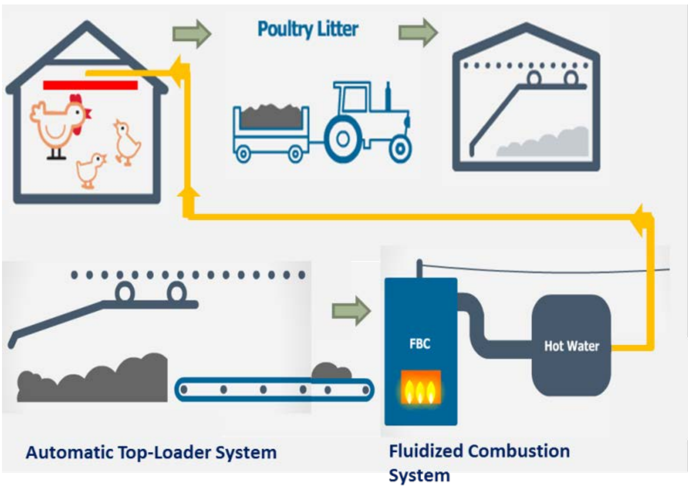


Figure 2. How the BHSL solution works

The system is remotely monitored and managed 24/7. A daily report (see Figure 3) is generated for the farmer, containing detailed information such as:

- Daily House Information:
    - Temperature
    - Relative humidity

- Bird weight
    - Water litres
    - Feed kg
- Crop Information
    - Litter sample analysis (e.g. uric acid and moisture)
    - Bird performance & welfare (e.g. pododermitisis).

Uphouse Daily Report for 14/08/2013 bhsl

Operations Summary

Date	Uphouse Unit 8	Uphouse Unit 9	Unit Total kW	Avg Unit Avail%	Short Fall kW	Total Farm kW	Farm1 %	Farm2 %	LPG kW	Total Diesel Litres	Elect. Kw	RHI Tier 2 Value £
14/08/2013	59	393	451	100%	0	451	18%	82%	0	-1	60	227

Poultry Summary

Farm	Bird Age	Temp C	Humidity %	Valve %	Flow C	Return C	Outside Temp C	Outside RH%
Uphouse Farm 1	20.9	25.4	55.5%	0.0%	86.4	85.2	19.4	62.9%
Uphouse Farm 2	45.6	28.5	40.4%	10.9%	86.5	84.4	19.4	62.9%

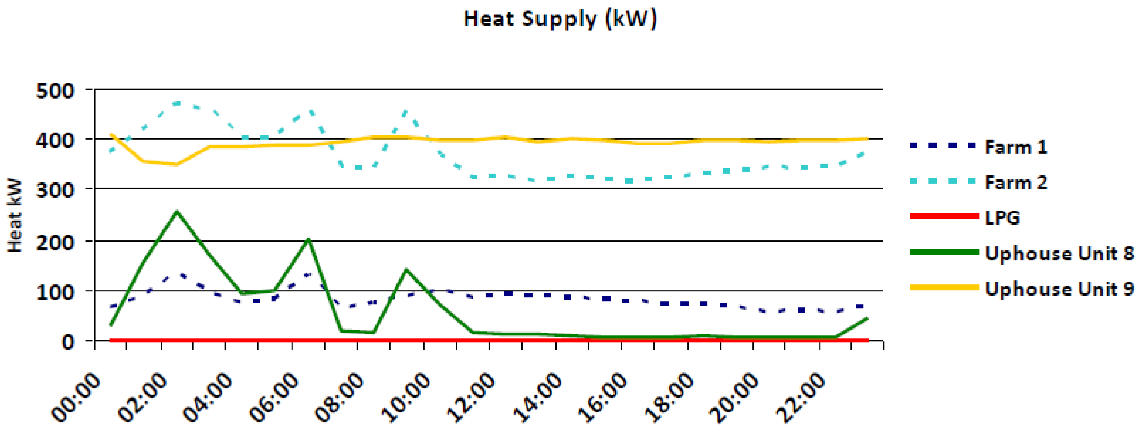


Figure 3. Daily report sample

3. Case Study

BHSL has worked closely with two leading British poultry farmers to fine-tune the technology and also to build up a bank of performance data. A case study was carried out as part of the ECO Innovation project SUPPER, involving Uphouse Farm in Norfolk, which grow 850,000 birds in 16 sheds and had installed two FBC 500 (500kW) burners to provide heat. The farm uses about half of the poultry litter produced, stored in an enclosed, automated system provided by BHSL.

3.1. Environmental Benefits

A Life Cycle Assessment (LCA) study was carried out to compare the environmental impact of three scenarios:

1) *Fertilizer use scenario (Baseline)*. In this scenario, all manure was assumed to be used as fertilizer (with credits given for the value of N, P and K in manure). With this application, the manure has both environmental credit (replacement of synthetic fertilizers in crop production), and environmental burden (emissions to water and atmosphere and energy use from manure management).
2) *Heat only scenario*. In this scenario, it was assumed that part of the manure is used as a fuel to produce heat and the remaining is used as fertilizer (as in the Scenario 1 above). The heat offsets the need for fossil fuel, in this case LPG. Also, the ash from the BHSL energy system is used as fertilizer with only P and K as valued plant nutrients.
3) *Combined heat and power scenario (CHP)*. In this scenario, it was assumed that all the manure is used as a fuel to produce heat and electricity. Some electricity may be exported and so displaces the need to generate it elsewhere. The ash from the FBC 500 energy system is used as fertilizer with only P and K as valued plant nutrients.

All the data for the environmental model were provided by BHSL:

- The total amount of manure produced and the amount used as a fuel per year
- LPG and electricity use for the baseline system
- The amount of LPG used and the amount avoided when using the BHSL systems
- Electricity use, including the electricity requirement for running the system
- The amount of electricity and heat produced by the BHSL systems
- The amount of ash produced per unit of manure used as a fuel
- The plant nutrient concentration of ash
- Total quantities of trace combustion gases released (NO_x, SO_2, CO)
- Weight and main constituents of the equipment.

In addition, data on bird performance (including body weight, feed conversion ratio and mortality) were provided by BHSL. These data were collected from three farms applying the BHSL heating system and included several production cycles before and after installing the BHSL system.

In the Fertilizer use scenario (baseline), the final age of the birds was assumed to be 36 days, the final weight 2059 g and the feed conversion ratio 1.72 kg/kg. For the other scenarios, the bird performance was adjusted based on the provided data. The structural model for the broiler production system calculated all of the inputs required to produce the functional unit of 1000 kg of expected edible carcass weight, allowing for breeding overheads, mortalities and productivity levels.

The results of the LCA analysis were grouped under the following categories of impact:

- *Global Warming Potential (GWP)* - a measure of the greenhouse gas emissions to the atmosphere.
- *Eutrophication Potential (EP)* - used to assess the over-supply (or unnatural fertilisation) of nutrients as a result of nutrients reaching water systems by leaching, run-off or atmospheric deposition.
- *Acidification Potential (AP)* - an indicator of potential reduction of soil pH (and causing damage to some building materials, like limestone).

- *Primary Energy Use* - quantified in terms of the primary energy needed for extraction and supply of energy carriers, including gas, oil, coal, nuclear and renewable.
- *Land Occupation* - the area of the land required to produce a unit of the product. In the case of poultry production, this mainly consists of the arable land for producing crops for feed.
- *Abiotic Resource Use* - the use of non-renewable raw materials, such as fossil fuels and minerals.

The results show that generally there are environmental benefits from using manure as a fuel on a farm compared to the fertilizer use scenario, as the environmental impacts were reduced in most of the main categories. The main reductions occurred in the categories of Eutrophication Potential (26-32%) and Acidification Potential (31-40%). This is a result of considerable reductions of ammonia emissions and, to a lesser extent, nitrate leaching when the manure is used as a fuel instead of as a fertilizer.

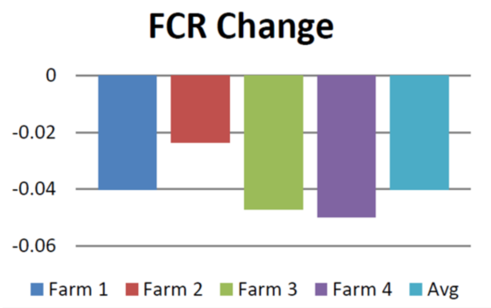
The main benefits of the BHSL system are in reducing ammonia emissions from manure management (storage and land application), rather than from housing itself. The differences between pH or the proportion of total ammoniacal nitrogen (TAN) that is present in ammonia form (which is potentially volatilised) was not statistically significant. Hence, no differences in emissions from housing could be assumed based on the litter samples provided.

In general, when using manure as a fuel, the farm LPG use is considerably reduced (by 89 - 95%), which also reduced the greenhouse gas emissions (Global Warming Potential). However, there is a need for extra electricity to run the plant, pump hot water to houses and deliver greater ventilation levels in the broiler house when the BHSL system is used and this reduced the potential GWP benefits.

3.2. Other benefits

One of the most important benefits of the BHSL system is optimal ventilation, therefore providing more heat and drawing a greater volume of air through the house in order to manage humidity, with the result of improved bird welfare. Gases associated with LPG combustion are no longer present, resulting in dryer litter and better growing conditions. As a consequence, the farm can experience advantages such as:

- Improvements in Food Conversion Ratio (FCR) (see Figure 3)
- Reduced mortality of the birds
- Reduction in common skin irritations such as hock burn and footpad dermatitis
- Reduced ammonia emissions as litter is dryer
- Improved working conditions for staff
- Less time spent managing litter.



Average FCR Change with BHSL: - 0.04

Figure 4. Improvement in FCR

Another benefit of the BHSL system is reduction of operation cost. As the owner of Uphouse Farm mentioned, "the energy output through my two 500 kW burners is just the same as with woodchip, yet the cost of my raw material is just £12-15/t (based on its sale value) compared with £70/t for woodchip and approaching £200/t for pellets. So long as people buy my chickens, I will be producing my own fuel for almost nothing –so it's incredibly sustainable". Supplementary revenue can be created by selling the ash left over after the burning process as a high-quality fertiliser.

4. Conclusions

BHSL has proven that their solution for heat production by poultry manure combustion in an FBC unit is a viable environmental and cost solution for farmers. Providing basically free fuel for heat production, it is an economically sound solution. The BHSL solution is an integrated system that provides not only heat for the broiler houses, but also bio secure storage and automatic feeding to the FBC unit. The optimal ventilation offered by the system has a positive impact on the birds' welfare, which is another benefit for the farmer.

With reduced emissions to air and soil the BHSL solution is environmentally friendly. Also, it employs a proven technology that uses renewable energy sources. Considering the 6 billion per annum total EU production of broilers (BHSL, 2014) with a potential of 7.2 million tonnes of litter annually, BHSL's innovative FBC system can play a significant role in helping Europe meet its energy and emission targets.

5. References

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