

## Research Stimulus Fund

### Final Report

On-farm combustion and energy recovery from poultry litter

DAFF Project Ref No: **RSF 07 559**

Start date: Dec 1<sup>st</sup> 2007

End date: Dec 30<sup>th</sup> 2010

Principle Coordinator: *Dr J J Leahy University of Limerick*

Email: [j.j.leahy@ul.ie](mailto:j.j.leahy@ul.ie)

**Other Principle Collaborating Researchers:**

- *Prof Shane Ward University College Dublin*
- *Dr Kevin McDonnell UCD*
- *Nuala King Teagasc Athenry*
- *Dr Witold Kapwinski (University of Limerick)*

Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDAMENTAL 
→
 APPLIED/PRE COMMERCIAL

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**Key words:** (max 4) *Poultry litter, Fluidised bed Combustion*

## 1. Rationale for Undertaking the Research

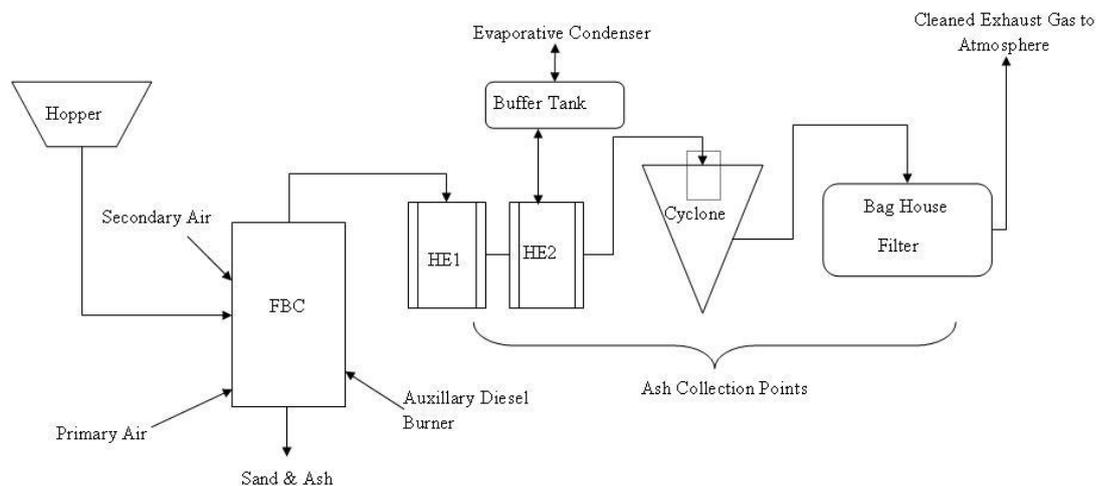
Agriculture is the single largest source of waste in Ireland. According to the EPA National Waste Database, of the waste generated annually approximately 70.6% is generated in a managed environment from agriculture. The Central Statistics Office indicate that approximately 103,400 tonnes of poultry litter were produced in 2009 (based on 1.4 tonnes of litter produced per 1000 birds) (CSO 2010), the majority of which is derived from chicken (broiler) production (SEI 2003). Current practices in Ireland for the disposal include spreading on agricultural land, stock-piling and re-use as a compost material in the mushroom industry. However, poor road infrastructure in rural Ireland and bio-security issues result in poultry litter being spread on local farmlands irrespective of the nutrient requirements of the soil and crops. This practice constitutes waste disposal as the organic waste is applied to agricultural land in quantities exceeding agronomic demands. This practice constitutes waste disposal as the organic waste is applied to agricultural land in quantities exceeding agronomic demands and results in serious negative implications for the surrounding environment. The Nitrates Directive (91/676/EC), the Ground Water Directive (80/68/EEC), the Local Government Water Pollution Acts 1977 and 1990 (Water Quality Standards for Phosphorus Regulations, 1998) and the Water Framework Directive (2000/60/EC) severely reduce the potential for land spreading. In addition, all poultry production facilities with greater than 40,000 birds require IPPC licensing by the Environmental Protection Agency which includes litter management plans. It is therefore evident that an alternative disposal/recovery route for poultry litter is needed.

A potential solution is the use of on-farm combustion which has the dual benefit of a cost neutral heat source as and reducing the litter volume to 10 % of the original. Poultry litter is recognised as a biomass in accordance with the EU Directive on Sustainable Electricity from Renewable Sources (2001/77/EC). The work reported is based on an Irish technology, developed from an ERTDI (Environmental Research Technological Development and Innovation) project and commercialized locally. The project was undertaken to address some outstanding regulatory and technical issues required to utilize this technology.

## 2. Research Approach

A 200kW<sub>th</sub> atmospheric bubbling fluidised bed combustion (FBC) unit supplied by BHSL (Biomass Heating Solutions Limited) was initially used on farm for the experimental studies and monitoring. During the course of the project this unit was moved to a dedicated research facility to enable discrete experiments to be undertaken without

impacting farm activities. Heat load was supplied and controlled using an evaporative condenser. A number of modifications were undertaken to allow more efficient control over the process parameters and emissions including integrating temperature and pressure sensors into a control facility allowing for continuous monitoring of combustion conditions and thermal output of the bed and optimisation the thermal output and efficiency of the unit. A second heat exchange section was incorporated to improve thermal efficiency. The project undertook experiments and modeling to optimize the thermal efficiency by matching heat exchanger output with heat load through the use of buffer tanks. Corrosion measurements were undertaken using coupons placed in the post FB process unit operations and changes to metal morphology were analysed chemically and using scanning electron microscopy.



The flue gases were sampled and measured by UL while a certified lab was used for monitoring for dioxin and heavy metals to assist compliance with national IPC regulations. Dioxin measurement was undertaken by a validated laboratory. The litter was monitored during storage and UCD undertook a risk assessment to establish best practice for its management and storage prior to combustion. UL measured NPK and solubility of the ash components to determine its value as a soil additive and the data was used to undertake an economic evaluation (Net Present Value) of the benefits of using this technology in terms of costings, financial benefits, health and welfare of the birds, environment potential of farmer to enhance his business because of better margins, alternative sources of on farm income with the free heat.

### 3. Research Achievements

The efficiency of combustion of poultry litter in a fluidised bed was found to be feasible for energy production and waste management. Under the combustion conditions optimised in the project it was possible to achieve sustained and self propagating combustion, >97% combustion efficiency, low NOx emissions with flue gas recycling and excelled dust abatement. Good temperature stability was maintained in the combustion zones and the feed system was able to be controlled sufficiently, without any negative impacts of varying

moisture content. Dispersion modelling of gaseous emissions generated from the actual combustion at a proposed poultry unit predicted that ground level concentrations for the set of emissions data would be below the TUV limits and guidelines

- Agglomeration and ash deposition were identified as key issues affecting its operation and further investigation into the routes of ash formation and agglomeration in this system was needed.
- Scientific Achievements: A model was developed to explain how major metals present in poultry litter agglomerate during combustion in a bFBC and how they deposit within the various unit processes. The bFBC bed agglomeration mechanism was determined to proceed with an initial molten  $K_2SO_4$  layer forming on the sand surface, which subsequently trapped a variety of solid mineral grains liberated from the burning char surface. Consequently, bed ash aggregated quickly and ash agglomeration increased the potential for de-fluidisation. Thermodynamic analysis indicated that the ash agglomeration reached 38-84 % of the equilibrated state, varying noticeably with individual metals. Further downstream in the heat exchangers, cyclone and baghouse, the evaporated metals and those entrained as fine particles remain mostly un-reacted from each other, signifying the slow condensation rate for the supersaturated metallic vapours in the low temperature zone.
- A protocol for the risk assessment of and best practice for storage and management of poultry litter was developed which emphasised avoidance of eutrophication, nitrate leaching, ammonia toxicity and pathogen contamination. The protocol presented details of optimum standards that should be met when storing litter for On-Farm Fluidised Bed Combustion. Safety measures such as prevention of leaching and spontaneous combustion must be adhered to, so too should the prevention and containment of possible diseases and pathogens to minimise the effects of contamination.

#### **4. Impact of the Research**

- 1) The work undertaken has provided experimental information on the processing conditions necessary to operate a boiler using poultry litter as the fuel such that it is compliant with the current regulatory standards.
- 2) The experimental data gathered during this project was essential to develop abatement technologies for control of flue gas emissions which has allowed the exploitation of the technology for boiler manufacturers.
- 3) The economic modelling of scenario options will provide poultry growers with real information on profitability and other tangible benefits and will allow them to make more informed investment decisions.

- 4) The overall improved thermal efficiency will provide marketing data for the boiler manufacturer but also allow growers the opportunity to exploit alternative sources of on farm income with the free heat.
- 5) The protocol for the risk assessment of and best practice for storage and management of poultry litter will be used by both Dept officials and growers to operate best practise conditions for on-farm storage of litter for any purpose. The implementation of the storage protocol and the flue gas recirculation option will have tangible environmental benefits through reduced odours and improved local water quality
- 6) The scientific community will benefit by an improved understanding of how the mineral matter in a high phosphate biofuel will behave with respect to agglomeration and ash elutriation under bubbling fluidised bed conditions.

## **5. Exploitation of the Research**

Arising from work undertaken during the course of this project and published in the public domain, BHSL developed a biosecure storage unit for the safe storage of poultry litter. The need for such a unit was not foreseen at the time of the original research proposal but was identified as part of the enquiry to develop the best practice guidelines for the storage of poultry litter on farm and reported in the literature. BHSL undertook the development, prototyping and construction of the biosecure unit independently of the RSF project. This unit maintains a negative air pressure by drawing the air required for combustion directly from this storage structure ensuring no leakage of odours or pathogens. It incorporates automated fuel so farm personnel have no further contact with litter after loading.

In addition, the work undertaken on improving thermal efficiency has allowed the company to improve the control system for their FBC unit incorporating flue gas recirculation to reduce NO<sub>x</sub> levels below the regulatory limits. Two of these boilers are currently licensed for use and operational in the UK. The work on thermal efficiency provided real data on actual heat outputs and has allowed the company to market their products based on actual thermal outputs and parasitic losses from the system and matching units to user requirements.

## **6. Summary of Research Outputs**

### **(a) Intellectual Property applications/licences/patents**

1. BHSL are in the process of patent application for a biosecure storage unit for poultry litter. Based on the work reported in an earlier report and published in the scientific literature BHSL built a number of prototype storage units. The development of this unit used information publically available and no UL/UCD researchers were involved in the development or the construction or testing of prototypes.

- (b) Innovations adopted by industry
1. Biosecure storage unit for the safe storage of poultry litter
  2. Flue gas recirculation to reduce NO<sub>x</sub> levels below regulatory limits
- (c) Number of companies in receipt of information: information has been disseminated through scientific publications and conference presentations and to our knowledge at least 1 company has used the information.
- (d) Outcomes with economic potential (2)
1. Improved thermal efficiency of boiler and reduced NO<sub>x</sub>
  2. Biosecure storage unit which has a market value separate from the combustion unit. This unit can be marketed as a stand-alone unit for on-farm storage of poultry litter or other biologically active waste streams.
- (e) Outcomes with national/ policy/social/environmental potential
- 1) The emissions abatement information can inform regulators as to the best available technologies for licensing of waste to heat operations.
  - 2) The protocol for best practice for storage and management of poultry litter can be used and adapted by Dept officials to operate best practise conditions for on-farm storage of poultry litter and other biologically active organic waste streams with environmental benefits through reduced odours and improved local water quality
  - 3) Reduction of greenhouse gas emissions will arise from a reduction in oil/gas use for heating
- (f) Peer-reviewed publications, International Journal/Book chapters.
- Acceptable Format: Walsh, D.R., Murphy, O., Cosgrave, J. (2008). Echinococcosis - an international public health issue. *Research in Veterinary Science* **774**, 891-902.
1. Bowen. B, Lynch. D, Lynch. D, Henihan. A, Leahy, J.J., McDonnell. K. (2010) Biosecurity on Poultry Farms from On-Farm Fluidized Bed Combustion and Energy Recovery from Poultry Litter *Sustainability* 2010, *2*(7), 2135-2143;
  2. Deirdre Lynch, Anne Marie Henihan, Barry Bowen, Declan Lynch, Kevin McDonnell, Witold Kwapinski J.J. Leahy; (2013) Utilisation of Poultry Litter as an Energy Feedstock: *Biomass & Bioenergy* 49 197-204.
  3. Lynch, Deirdre; Henihan, Anne Marie; Zhang, Lian; Kwapinski, Witold; Leahy, J.J. *Energy & Fuels* (2013) DOI: 10.1021/ef400744u. Ash Agglomeration and Deposition during Combustion of Poultry Litter in a Bubbling Fluidised Bed Combustor
- (g) Scientific abstracts or articles including those presented at conferences

1. Lynch D, Henihan A, Leahy JJ On farm Combustion of Poultry litter. 4<sup>th</sup>  
International Biomass Conference and Expo May 2011 St Louis, Missouri, USA

2. Lynch D, Henihan A, Leahy JJ "Closing the loop on farm fluidized bed combustion of poultry litter" Renewable Resources & Biorefineries June 5<sup>th</sup> 2013) Antwerp NL

(h) National Report N/A

(i) Popular non-scientific publications

(j) Workshops/seminars/ open days at which results were presented (excluding those in (g))

1. CLEANWASTE - 26th-28th October 2011 University of Limerick

## 7. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (months)	Average time contribution per permanent staff member
UL	1	5.4	5.4
UCD	1	4.8	4.8
<b>Total</b>	<b>2</b>	<b>10.2</b>	<b>10.2</b>

## 8. Researchers Funded by RSF

Type of Researcher	Number	Total Time contribution (months)	Average time
Post Doctorates	1	24.468	24.468
Contract Researchers	2	45	22.5
PhD postgraduates			
Masters postgraduates	1	15.276	15.276
Temporary researcher			
Other			
<b>Total</b>	<b>4</b>	<b>84.744</b>	<b>62.244</b>

## 9. Postgraduate Research

Total Number of Masters theses: 1

Author: Declan Lynch UCD:

Title: Systems analysis of best practice for biosecure of poultry litter on-farm storage.

Anticipated re-Submission date Dec 2013

## 10. Project Expenditure

Total expenditure of the project: €357,852

Total Award by RSF: €371,568

### Breakdown of Total Expenditure

Category	Uni of Limerick Institution 1	UCD Institution 2	Teagasc Athenry Institution 3	Name Institution 4	Total
Contract staff					
Temporary staff		97,756.55			97,756.55
Post doctorates	111,066.61				111,066.61
Post graduates		13,999.95			13,999.95
Consumables	28,530.47	1,471.76			30,002.23
Travel and subsistence	5,693.55	4,328.14	287.64		10,309.33
Sub total	145,290.63	117,556.40	287.64		263,134.67
Durable equipment	641.55	766.33			1,407.88
Other	14,610.55				14,610.55
Overheads	43,587.09	35,025.00	86.29		78,698.38
<b>Total</b>	<b>204,129.82</b>	<b>153,347.73</b>	<b>373.93</b>		<b>357,851.48</b>

## 11. Future Strategies

*Outline development plans for the results of the research.*

The work undertaken and the knowledge gained has significantly improved the profile of the research groups involved in this project and has resulted in invitations to participate in conferences and additional research projects including two successful collaborative

international projects (i) CLEANWASTE: A Danish Strategic Research Council project investigating innovative technologies for separation of pig manure and recovery of nutrients and energy from the separated fractions & (ii) RE-USEWASTE: an EUFP7 Marie Curie ITN training PhD researchers in the most promising technologies for the management of farm manures and recycling of nutrients.

At National level we have applied for and have been granted an IRCSET post-Doc to improve production systems in Irish Poultry Houses. We have built up a collaborative network of interested researchers including Teagasc, UL, NUI Galway and UCD.

As part of the SFI Research Centres Thematic Call we will be submitting a Centres proposal in the Thematic Area of Sustainable Food Production. This proposal will focus on the development of waste management technologies to support livestock production in line with the Nitrates and Phosphates directives.

## **12. Industry Collaboration**

*Summarise details of industry collaboration in the research project.*

BHSL were involved in the project and participated in some of the experimental work. Arising from this project they are also participants in RESUSEWASTE.