

REVIEW OF ALTERNATIVE TECHNOLOGIES TO FLUIDISED BED COMBUSTION FOR POULTRY LITTER UTILISATION/DISPOSAL.

EXECUTIVE SUMMARY

1. This review has examined the potential of a range of alternative technologies and options to fluidised bed combustion as a means of utilising/disposing of surplus poultry litter in Northern Ireland. The broiler poultry sector is a significant part of the local economy, sustaining on-farm employment for over 1400 people, with a further 4600 people employed in processing, and generating over 14% of the gross output of the local agriculture sector. However, the industry also produces a significant byproduct - around 260 kt (thousand tonnes) of poultry litter per annum and, given the scope for further industry expansion, a poultry litter production of 400 kt per annum may be a realistic possibility within 5-10 years (based on 50% expansion of current capacity).
2. The challenge for the industry is that, at present, only around 83 kt of poultry litter is managed sustainably (70 kt applied to arable land and 13 kt used for mushroom compost production). This review has shown that, given the 36% reduction in Phosphorus (P) content of poultry litter in recent years, there is potential to increase litter application to local arable land up to at least 100 kt/annum. However, litter use in mushroom compost production is likely to remain static or decline marginally over the next few years. Consequently, an alternative use/disposal is required immediately for 160 kt of litter per annum, potentially increasing to approximately 300 kt per annum in the next 5-10 years.
3. This review has examined a range of options for utilisation/disposal of surplus poultry litter including: export for land spreading or for further processing; a range of alternative processing technologies including anaerobic digestion (conventional and dry), pyrolysis, gasification, autoclaving and quick wash treatment. The key criteria against which these technologies were assessed included:-

- a) Suitability for a centralised/off farm approach, as bio-security issues preclude on-farm storage of poultry litter;
 - b) End product of the process results in a significant volume reduction with a potential export market;
 - c) Process generates added value through production of energy or recycling of nutrients and can at least achieve a cost neutral position.
4. When assessed against these criteria, the option/technology which currently best meets all three objectives is thermal treatment of poultry litter through a gasification process. Gasification converts organic materials into synthetic gases (syngas – carbon monoxide, hydrogen, carbon dioxide and methane) by reacting the material at high temperatures (>700°C) without combustion and with controlled additions of oxygen and/or steam.
5. In recent years, a number of gasification plants have been constructed throughout Europe, principally to deal with municipal waste in order to reduce the volume of waste going to landfill. In comparison to the fluidised bed combustion process, gasification plants are generally smaller (30-50 kt capacity per year) but this means that they can easily be scaled to meet the supply of fuel available. A modular approach can be used, with 2 or 3 modules located on the same site, giving the capacity to process up to 150 kt waste material per year through a centralised operation.
6. Whilst this review indicates that gasification may provide an alternative method to utilise surplus poultry litter, a number of key factors need to be taken into consideration:-
- (i) There is little experience of using poultry litter as a feedstock for gasification. The most detailed reports from a farm-based system in West Virginia, USA, found that the litter required drying before use;

- (ii) A major challenge for waste gasification technologies is to achieve an acceptable (positive) gross power efficiency given the high power consumption used in pre-processing feedstock and in gas cleaning. High energy efficiencies for gasification have resulted from being able to use the heat generated by the system;
 - (iii) There is little information on the properties of the biochar produced as an end product of the process. Consequently further work will be needed to identify and develop appropriate markets for this material.
- 7. Nonetheless, of the options/technologies reviewed, gasification appears to offer most potential as an alternative to fluidised bed combustion. In order to progress this option, consideration should be given to developing a prototype gasification plant to facilitate detailed investigation of the issues highlighted above.
- 8. Of the other options reviewed, export to Britain for land spreading on arable land also offers some potential, but this option will incur significant and ongoing costs due to high transport costs and the low financial value of poultry litter as a fertiliser. Estimated annual costs for this option are between £4 to £6 million (based on export of 200 kt poultry litter per annum). Alternatively, there is some scope for land spreading of poultry litter on local grassland (low P index soils only) by heat treating or autoclaving poultry litter prior to spreading – this sterilizes the litter and eliminates the risk of botulism. This option would also incur significant ongoing annual costs, due to the energy costs associated with heat treatment and/or autoclaving.
- 9. The key issue that remains is the challenging timetable which will be required to demonstrate to the European Commission that significant progress has been made in dealing with the issue of surplus poultry litter, before the end of the current Nitrates Action Programme (December, 2014). It may be that a combination of approaches, with a mix that may change over time, will be needed to satisfy the EU Commission in a way that is politically acceptable

locally. Depending on progress with a prototype gasification plant, other options may be needed to reduce the volume of poultry litter currently being land spread. Of the options reviewed, transport to eastern Scotland for land spreading is the lowest cost option. If this option is pursued, consideration will need to be given to reducing transport costs – for example use of baling and other approaches, and the logistics of shipping material for export will need to be investigated.

Key recommendations

10. The Review Group recommends that industry should consider the potential of gasification, including research to develop a prototype poultry litter fuelled gasification plant.
11. Of the remaining options, those which offer some potential, but with annual and ongoing cost, include: export for land spreading on arable farms in Britain; and heat treatment or autoclaving prior to land spreading on grassland (low P index soils only) on local farms. Consequently, the Review Group recommends that industry should also give consideration to options to reduce the transport cost of poultry litter for export, for example use of baling, and the logistics of shipping poultry litter for export should be further investigated.

11 January, 2012

BACKGROUND

12. This review was commissioned by the Minister of Agriculture and Rural Development and builds on a number of previous reviews that have investigated proven technologies and options for the utilisation/disposal of poultry litter, as summarised in Table 1 below. All of the previous reviews concluded that combustion of poultry litter for energy production was a proven technology that was widely used in other countries for the utilisation of surplus poultry litter. An alternative approach based on a pelletisation plant that processes litter into an organic fertiliser has been operational in the USA since 2001, but no further plants of this kind have been developed since then, indicating that the market for the product and/or the economics of pelletisation are not favourable. However, technology is continually developing and the value of the nutrients present in poultry litter has increased in recent years. Hence the objective of this review, as set by DARD Minister Michelle O'Neill, is to examine other processing/disposal options which may offer an alternative solution to fluidised bed combustion in dealing with the poultry litter issue.

13. The Review Group comprised:
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 - Bran Ervine (EPB)
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 - Martin McKendry (CAFRE)

14. Broiler Poultry Industry: The local poultry meat sector is dominated by broiler chicken production from around 600 farms that account for 3% of farm businesses, with the value of poultry meat production of £212 million in 2010 representing 14% of the gross output of agriculture. Local broiler poultry farms tend to be much larger than the EU average in terms of flock size.

15. The sector provides on-farm employment for over 1400 people, with a further 4600 people employed in processing. In this respect, and when compared to the other local food processing sectors, the poultry meat processing sector has the largest employee base, with 50% more employees than the beef and sheep meat processing sectors and over 100% more than are employed in dairy processing. The poultry meat processing sector had a turnover of £511 million in 2010, with 80% of product exported. Overall the poultry meat sector therefore represents a significant component of our agri-food sector and the local economy.

Table 1 Summary of previous reviews of disposal options for poultry litter

Study Title	Date Undertaken
InvestNI Study	2004
SNIFFER Report	2005
EGAUM Report	2006
DARD/DOE/ Industry Working Group	2008
AFBI Assessment	April 2009
DARD Research Update	December 2009
DARD/DOE/InvestNI/Industry Working Group	2010

16. Future Trends in Broiler Poultry Production: Broiler chicken production relies almost entirely on imported feedstuffs, largely cereal grains which account for over 70% of the farm output value. Given the high transport costs associated with the distance from the main cereal growing regions in Britain, cereal grain costs locally are comparatively high, but the industry is highly efficient. For example, only 1.7 kg of grain is required to produce 1 kg of poultry meat,

which compares very favourably to efficiencies of 2.4 for pigs and 5-10 for cattle. Consequently, in terms of meeting the anticipated doubling in world food demand in the next four decades, there is a strong case for encouraging increased consumption of poultry meat rather than ruminant livestock products.

17. Expansion in poultry production could have benefits in terms of improving farming incomes and employment. A poultry production unit can often be added to an existing farm enterprise as it does not require any significant additional land. In contrast, expansion of grazing livestock numbers is usually constrained by the land area available. Therefore, a poultry production unit combined with an existing cattle enterprise can help to maintain the viability of the farming business. Increased production is also likely to have consequent benefits for the poultry processing sector.
18. However, this historic business model of farms that are small in land area but capable of high output has become less sustainable due to the negative impact of intensive livestock production on water quality and the requirement to comply with EU water quality directives. The EU Nitrates Directive caps organic manure applications to land at 170 kg organic N/ha. Most poultry farms operate far above this limit and it is estimated that more than 90% of poultry litter has to be exported off the home farm. Poultry litter has a relatively high dry matter (DM) content, but is P rich. As this P originates from imported cereals it contributes to the P surplus of local agriculture.
19. Water Quality Regulation Eutrophication (nutrient enrichment) of lakes and rivers is our most widespread water quality problem. Excess P and, to a lesser degree, nitrogen from agricultural sources are significant contributors to eutrophication. Action to address nutrient enrichment is required by both the EU Nitrates Directive and the EU Water Framework Directive. The controls on farming practice applied under the Nitrates Directive are required to reduce and prevent water pollution from agricultural sources, particularly that arising from over-application of manures or application of manure in unsuitable conditions. The Nitrates Action Programme Regulations therefore includes a

range of controls to counter these risks. As well as limiting how much poultry litter can be spread, there are controls on when and where it can be spread and how it must be stored.

20. Measures have been implemented from 1 January 2007 through the Nitrates Action Programme Regulations and apply to all farms. In addition to a limit on the amount of livestock manure that can be applied to land of 170 kg/nitrogen/hectare/year, key Action Programme measures include: a closed period for spreading livestock manure during the winter months; and a minimum livestock manure storage capacity requirement of six months for pig and poultry farms.
21. Storage of Poultry Litter: Constructing on-farm storage for broiler litter is problematic on many poultry farms as current biosecurity regulations within the sector require that poultry litter cannot be stored at the poultry production site and the small size of farms require that it is exported off farm. Removing poultry litter entirely from the farm is the best way of reducing the risk of spreading disease amongst flocks, however, this has significant implications for the viability of on-farm alternative processing methods.
22. The Nitrates Action Programme Regulations currently allows poultry litter to be stored in field heaps during the winter. This was originally agreed with the EU Commission as a temporary measure in 2007 on the basis that an off-farm alternative to land spreading of poultry litter would be progressed by 2008. Subsequently, DARD secured EU Commission agreement to extend the use of field heaps to store poultry litter until the end of the Action Programme in 2010 and a further extension allows this to continue to March 2012. This temporary storage measure is a cost effective means of managing the process of land spreading while an alternative means of utilisation/disposal is progressed. It is, however, a temporary measure and proposals to extend it until December 2014 are currently being considered by the EU Commission. The EU Commission have indicated that it is committed to ending winter field storage.

23. Phosphorus Surplus in the Poultry Sector: The local poultry sector has a significant P surplus, as the P content of imported feedstuff greatly exceeds the P content of poultry production. In terms of the overall P surplus, the poultry meat sector contributes around 30% of the total. If the comparison is confined to farms with a surplus in excess of 10 kg P/ha, 47% of the surplus is associated with poultry meat production. Surplus P is contained in poultry manure and litter that is currently spread on land and this contributes to the high P status in soils.
24. Applications of manures and fertiliser to land over the years have led to a build-up of P levels in the majority of soils and this has contributed to higher P losses to water and ultimately to eutrophication. Therefore, action to reduce the P surplus is required and an objective of the Nitrates Directive Action Programme is that all farms should achieve a sustainable P balance by 2015. A series of actions on P have been implemented. Phosphorus Regulations have been introduced which prevent application of chemical fertilisers containing P, unless a crop need is demonstrated by soil testing. Phosphorus levels in animal feeds have been reduced by almost 26% from 2003 to 2010, through a voluntary agreement with the NI Grain Trade Association, whose member companies supply the vast majority of livestock feed. These reductions have been based on research carried out at the Agri-Food and Bio Sciences Institute (AFBI) at Hillsborough. DARD advisory support has also promoted best management practice and efficiency in relation to P. These actions, together with changes in farming practice in response to the Nitrates Action Programme and economic factors, have resulted in more efficient use of nutrients in agriculture here. Consequently, the overall P balance of local agriculture has reduced from 17.9 to 10.2 kg P per ha over the period 1995 to 2010.
25. Research has examined the potential to reduce P levels in poultry diets and adoption of low P diets has already lowered the P content of broiler litter produced here. For example, a recent study undertaken by AFBI (Ball and Foy, 2011) has shown that the P content of local poultry litter has declined from 25 kg P₂O₅ per tonne of litter in 1995 to 16 kg P₂O₅ per tonne in 2010.

The local industry has a very strong record of adopting low P diets, in part as they offer cost and production benefits, but there are limitations on minimum levels of P inclusion in the diet if acceptable levels of performance and welfare are to be maintained.

26. Whilst the reductions in P content highlighted above are very significant, poultry litter still contains the highest P content of all livestock manures. In addition, the poultry sector is still in a significant P surplus and the fundamental issue of the eutrophication risk associated with P build-up in soils receiving poultry litter remains.
27. The local broiler poultry industry produces 11.9 m broiler chickens per year, which produce around 260 kt of poultry litter. Current utilisation/disposal routes for this litter are summarised in Table 2. Approximately 83% of poultry litter is currently land spread, with the majority of the remainder used in compost production for mushroom-growing. In previous years a small quantity has been shipped to Fife for combustion at the Westfield Fluidised Bed Combustion plant, but limited spare capacity at this plant together with high and increasing transport costs mean that this option is no longer feasible.

Table 2 Current Utilisation/Disposal Routes for Poultry Litter

Utilisation/Disposal Route	Thousand tonnes per year
Land Spreading - Arable Land	70
Land Spreading - Grassland	130
Land Spreading - Export to south of Ireland	15
Mushroom Compost Manufacture	13
Mushroom Compost Manufacture - Export to south of Ireland	29
Other	2
Total	259

28. Currently, the need to land spread poultry litter and the problems associated with this practice represent an environmental constraint on production. The sector has a record of expansion, as poultry meat production by weight increased by 65% from 2000 to 2010, a similar percentage increase to that achieved in the previous decade. This expansion has slowed following the introduction of the Nitrates Directive, as in the three years since 2007 production has increased by only 7%.
29. Therefore a sustainable solution to manage poultry litter in a way that does not exacerbate P losses to water is necessary if local poultry production is to expand or, under certain scenarios, maintain current levels of production.

OPTIONS FOR DISPOSAL/UTILISATION OF POULTRY LITTER

Land Spreading

30. Land Spreading Locally: Land spreading locally currently accounts for 200kt of poultry litter per year, or 77% of total litter production. The need for an alternative to land spreading arises from the EU Nitrates Directive. Measures implemented through the Nitrates Action Programme Regulations include a limit of 170 kg organic manure nitrogen/hectare/year that can be applied to agricultural land on any one farm holding. The purpose of this limit is to prevent excess applications of manure which will result in nutrient losses to water and consequent pollution. Virtually all poultry farms exceed this limit and therefore need to export poultry litter to other farms to comply with the Regulations. On many other farms the manure from cattle and sheep uses up most or all of this allowance. Thus the organic nitrogen limit effectively restricts the area available for exporting excess manure from poultry farms.
31. The Integrated Pollution Prevention and Control (IPPC) Regulations implemented the EU Integrated Pollution Prevention and Control Directive (91/61/EC). The Regulations have extended an environmental permitting system to a range of sectors including intensive poultry rearing units above a

threshold of 40,000 bird places. IPPC farms which spread slurry/manure to land are required to demonstrate that they have sufficient land available to take the quantity of manure generated on the unit. New or expanded farms are being asked to demonstrate that they have either sufficient land to spread manure in accordance with crop requirements or have an alternative means for utilizing the material before they are permitted. For existing farms, a staged approach allows applicants until 6 months after the issue of a permit to come up with firm proposals to resolve any shortfall in available spreading land or to identify possible alternative uses. Approximately half of poultry production locally is on farms which are subject to IPPC controls. The fact that IPPC controls also apply to large intensive pig farms makes it even more difficult to source spread land with a crop requirement for P in future, due to the prevalence of fields here with high levels of soil P. There are additional constraints on the land spreading of poultry manure as, to protect against the spread of botulism from poultry litter to cattle, current DARD advice is that poultry litter should not be spread on land that will be grazed in the same year.

32. Given the prevalence of grass used for grazing and the small size of the arable sector (52,650 ha, 5.3% of farmed area) this is a significant constraint on finding suitable spread land for poultry litter. A further problem arises from the high P content of poultry litter, relative to its nitrogen content. This means that, where applications of poultry litter are targeted to meet crop nitrogen demand, the applications may over-supply the crop with P. Over the long term this over-supply can lead to appreciable increases in soil P, and this increase is regarded as a causal factor for the widespread occurrence of eutrophication in local lakes.
33. Effectively, the environmental problems and constraints highlighted above indicate that land spreading on grassland is not an appropriate disposal route for poultry litter. Therefore, an alternative use or disposal method is required for at least 130 kt of poultry litter currently used in this way.

34. At present, approximately 70 kt (approx 25%) of poultry litter is land spread on arable crops, primarily on the large arable farms growing over 50 ha of crops (total of 12,000 ha). These large arable farms only account for approximately 30-35% of local cereal production. The majority of arable crops are grown on mixed farms, which generally have an abundant supply of livestock manures and therefore do not have a crop nutrient requirement for additional nutrients from poultry litter.
35. Nonetheless, there is scope to use more poultry litter on large arable farms, particularly given the recent reduction in P levels in poultry litter which reduces the risk of over application of P to soils. This potentially increases the quantity of litter that could be applied to arable crops to around 100 kt per annum.
36. Export for Land Spreading: At present, around 15 kt of poultry litter per annum are exported to the south. The arable sector in the south is significantly greater than here, particularly when viewed in the context of the size of the poultry sector (11.8 m broilers per year and arable area of 395,000 ha in the south, compared to 11.9 m broilers and 52,650 ha of arable land in the north). Despite this apparent availability of arable land, further constraints arising from implementation of the Nitrates Directive in the south will severely constrain this route in the future. Indeed the southern poultry industry is itself currently reviewing alternative options to land spreading for disposal of poultry litter.
37. Currently, no poultry litter is exported to Britain, despite the significant land area cultivated there for arable crops (4.54 million ha in 2010). The majority of this arable land is in the south and east of England where rainfall is low, although this arable zone extends northwards to the east of Scotland. The rates of fertiliser used on arable agriculture are monitored by the British Fertiliser Survey and the mean values for the 2010 survey are used in Table 3 to quantify the potential demand for imported nutrients. It should be noted that the fertiliser values are for chemical fertiliser only. These values are then

compared with the plant available nutrients from local broiler production, based on 250 kt of broiler litter. It can be seen that the chemical fertiliser demand is many times larger than the potential broiler litter output of nutrients, which is approximately equal to 2% of the arable demand for P and potash in Britain and 0.4% of the nitrogen demand.

38. Theoretically, the nutrient value of local poultry litter should be worth around £32 per tonne. However, typical costs for farmers purchasing poultry litter in Britain are around £5 per tonne collected at the poultry house. The main reasons for the low financial value of poultry litter relative to its nutrient content include:

- the low nutrient content of broiler litter in comparison to chemical fertilisers makes it a more costly and difficult product to manage;
- compared to chemical fertilisers it is a less standardised and hence more variable product which can lead to yield losses;
- nutrients are only required once or twice per year (autumn and spring) prior to soil incorporation and seed/tuber sowing, so storage on importing farms is an issue;
- odour makes its use problematic near villages, towns and human habitations;
- issue of botulism and associated restrictions on grassland or near grassland;
- organic N content means that manure imports are restricted in NVZs which cover most arable production in Britain;
- the buyer sets the price in the knowledge that the broiler producer must, in most cases, clear the broiler house immediately.

39. The analysis above indicates that broiler litter in Britain is a low value product at best retailing at £15/tonne or 50% of its fertiliser value, before any allowance is made for transport costs and spreading costs. To achieve this

price the costs of transport and spreading will be borne by the poultry producer. Current transport costs to the east of Scotland are around £30/t. Even if the litter could command its full nutrient content price of £32/ tonne, transport to arable farms in Scotland would barely break-even in terms of transport costs to the farm. Road haulage costs of 10p/tonne/mile would mean that transport to the Vale of York or Lincolnshire, for example, are likely to incur further costs of around £10/tonne. Given that it is unlikely to command a price of more than £10/ tonne delivered but not spread, exporting of poultry litter is likely to incur a minimum net cost of around £30/tonne for transport to England and £20/tonne to Scotland.

Table 3 Comparison of chemical nutrients used in tillage in Britain and Ireland, with plant available nutrient output from local broiler production.

(References included in Reference Section)

	Nitrogen (N)	Phosphate (P ₂ O ₅)	Potash (K ₂ O)
Britain (Tillage area = 4.5 million ha^a)			
Fertiliser rates ^a (kg/ha)	149	30	42
Fertiliser used (tonnes /year)	677056	136320	190848
Republic of Ireland (Tillage area 0.35 million ha^b)			
Fertiliser rate ^c (kg/ha)	135	52	67
Fertiliser nutrients used (tonnes /year)	46612	17899	23262
Local broiler litter nutrient outputs^d			
Plant available nutrient output (tonnes/year)	2888	2400	4500
Broiler nutrient output as % of Britain	0.4%	1.8%	2.4%
Broiler nutrient output as % of Ireland	6.2%	13.4%	19.3%

40. Options to Reduce Transport Costs: An approach to lower the transport cost of broiler litter is to bale the broiler litter into bales, similar in size to those produced for grass silage. The rationale of the process is that the baled product is cheaper to transport over long distances as the trucks used to carry the bales do not require cleaning after unloading and so are able to carry and

charge for a return load on the return journey. This system was developed in Arkansas and reported in the press in Spring 2011 http://www.wattagnet.com/Baling_makes_poultry_litter_portable.html/ AFBI contacts with the University of Arkansas indicate that the plant has not been operational for much of 2011, having proved to be uneconomic due to the low price that even baled litter can command.

41. Consequently, export of poultry litter to Britain is a potential option, but with significant financial implications. For example, export of 200 kt poultry litter per annum would result in an annual cost to the industry of £4 to 6 million.
42. An alternative processing option involves sterilising broiler litter before pelletising the litter to produce a fertiliser. This process converts poultry litter into pellets that can be sold as a fertiliser and a commercial facility using this approach is in operation in the US, so the process is technically and practically feasible. The process is not a substitute for land spreading as the product will be applied to the land as a fertiliser. It would still be regarded as organic N under the Nitrates Directive and applications would be constrained by the 170 kg organic N/ ha limit and crop requirement. Previous reports by AFBI have noted that there is one plant of this type operated by Perdue Agrirecycle in the USA. The Perdue plant operates at around 70 kt per year and claims to dominate the North American markets with products targeted for use in golf courses and home gardening and vegetable production http://www.perdueagrirecycle.com/pdf/MS60_Broch.pdf
43. The plant has been operating since 2001 and remains probably the largest in the world. Notably it has attracted no competitors operating on a similar scale, suggesting that entry costs to production are high relative to profit margins. The limited scale of operation means that, even if a market for the fertiliser could be established in Europe similar to that in North America, it would only utilise around a quarter of the broiler litter produced here.

Alternatives to Land Spreading

44. Given the constraints on land spreading highlighted above, other options for the disposal/use of poultry litter are now considered.
45. Export of Poultry Litter for Processing Elsewhere: Export of raw poultry litter for processing abroad is a potential option, the main factor being costs of transport. A small quantity of poultry litter had historically been shipped to Fife for combustion at the Westfield Fluidised Bed Combustion plant, but increasing transport costs mean that this option would incur ongoing annual costs similar to those for export for land spreading. For example transport costs to Scotland are estimated at approximately £30 per tonne. Similarly, there is some spare capacity (around 50 kt per annum) at the Fluidised Bed Combustion plant at Moredijk in Holland. However transport costs to Holland are estimated to be around £90 per t. The cost of these export options is extremely high and, given the current low margins in broiler chicken production, would raise affordability issues for the poultry sector. If these costs had to be factored into the cost of production here it could make local production uncompetitive and increase the risk of transfer of production elsewhere. Furthermore, EU State Aid Rules prevent Government from subsidising transport costs, as a subsidy would be viewed as an operating aid and prohibited.
46. Consideration has also been given to exporting poultry litter to peat burning power stations in the midlands of Ireland where three Peat Power Stations burn a total of 3,150 kt peat per annum – details are provided in Table 4.

Table 4 Details of Peat Burning Power Stations in Ireland.

Location	Boiler Type	Output MW	Fuel kt pa
Edenderry	Bubbling Fluidised Bed	120	1,000
Lough Ree	Circulating Fluidised Bed	100	850
West Offaly	Circulating Fluidised Bed	150	1,300

47. These plants are based on fluidized bed combustion and potentially they could accommodate 220 kt of poultry litter per annum - in practice it is likely that poultry litter would be used as a partial substitute for peat, for example at a 5 -15% inclusion rate.
48. However, the plant operators have indicated a major reluctance to consider use of poultry litter as a partial peat substitute, due to serious reservations regarding the corrosion risk to the core systems in all of the plants. The major technical barriers are as follows:
- Compared to other fuels poultry litter has a high chlorine content that potentially results in severe corrosion of boiler heating surfaces. The lower chlorine content of peat allows higher steam temperatures of above 500°C and more standard materials of construction. The reduction in operating temperature to accommodate poultry litter would have a severe impact on plant efficiency.
 - Poultry litter has higher ash content than other conventional fuels and the ash residue after burning has a very high clogging potential. This would cause operational difficulties leading to additional shutdowns for boiler cleaning and increased operating costs. Normally, cleaning of boilers operating with poultry litter is considered and allowed for at the design stage. The designs of boilers operating on peat do not have the same considerations and features.
 - If a co-blended fuel of peat and poultry litter was feasible, this would require premixing of peat and poultry litter, but poultry litter is rarely as homogenous as the milled peat as the litter contains feathers, wood chips and excreta. This variability would represent a challenge to the fuel handling system and combustion.
49. In addition to these technical barriers there is a significant regulatory barrier in that inclusion of poultry litter as a fuel would bring the emissions of the power

plant under the remit of the Waste Incineration Directive (WID). Currently boilers operating on peat are not required to achieve WID standards for emissions and may not be compliant with these standards, particularly if poultry litter is included as a partial peat substitute.

50. Mushroom Compost Production: Currently it is estimated that 16% of local poultry litter is used to manufacture mushroom compost (13,000 t in the North and 29,000 t in the South). Since 2003, local mushroom production has been steady or in slight decline so there is no evidence of an increasing demand for compost. Compost manufacturers' have indicated that they would prefer to use alternative N rich materials rather than poultry litter and consequently, in the longer term, less poultry litter may be required in mushroom compost production.

Alternative Processing Technologies

51. Anaerobic Digestion: Anaerobic digestion involves a series of processes in which microorganisms break down biodegradable material, such as poultry litter, in the absence of oxygen. The process involves digesting feedstock material in a closed vessel maintained at a constant temperature. The digestion process produces methane gas which can be used as a renewable energy source. The major disadvantage of using poultry litter in conventional anaerobic digestion (AD) is that, in order to operate effectively, the dry and easily transportable poultry litter has to be diluted with large volumes of water, or other liquid waste. This means that, at the end of the process, a means has to be found of recycling to land the large volumes of liquid digestate created by the process. This digestate will also contain the same quantities of plant nutrients as in the original feedstock – a sustainable use of the nitrogen, P and potash in the digestate will still be required within the constraints on nutrient spreading highlighted above. On this basis, anaerobic digestion does not address the fundamental issue of excess nutrients in the manure, as it requires land spreading of the digestate. Therefore, it is not an alternative to land spreading.

52. Specific issues relating to use of poultry litter in AD are as follows:

- Poultry litter has a high nitrogen content, which can inhibit the anaerobic digestion process through production of excess ammonia. Consequently, the maximum inclusion rate for poultry litter in a conventional wet AD unit is around 6%. For a typical 500 Kw AD plant, this would equate to around 1000 to 1500 t poultry litter per year, or around 40-50 kt per year assuming 40 operational AD plants
- As highlighted above, conventional anaerobic digestion requires feedstocks in the range of 10-15% dry matter (DM) content (to facilitate pumping in and out of the digester). Poultry litter DM content is usually in the range 41-98% (overall normal average of 65%). Consequently large volumes of water or other liquid waste are required to bring the material to 10-15% dry matter. For example, 200 kt poultry litter at 60% DM will require 1 million tonnes or over 200 million gallons of water to bring it to 10% DM, or 600,000 tonnes water to bring it to 15% DM. One option could be to co-digest poultry litter with pig slurry (normal DM content of 4%). For example, 200 kt of poultry litter would require 1.5 million tonnes pig slurry to bring it to 15% DM. (The total slurry produced by housed pigs in Northern Ireland is approximately 1.4 million tonnes).
- Assuming poultry litter is diluted as above, the primary challenge remains; namely to recycle the large volume of digestate to land as the digestate volume is only slightly less than the volume of feedstock, and it still contains all the original nutrients.
- Addition of poultry litter to the feedstock used in AD plants could limit application of digestate to grassland as the risk of botulism will remain – this will greatly restrict the use of poultry litter in AD plants.

53. An alternative to conventional 'wet' AD is "high dry matter" (30%+) anaerobic digestion or dry fermentation (DF). At a dry matter concentration of greater than 10-12% it is difficult to pump a liquid or slurry, so the design and operation of AD and DF plants is quite different. DF technologies were pioneered in Switzerland in the 1980s, and while still used to some degree across the world today, it is less favoured compared to AD.
54. There are 3 recognised types of DF which achieve mixing in different ways, namely:
- Horizontal Shaft systems – used for total dry solids contents of 30-35%. These have high energy costs and are generally considered unsuitable for agricultural applications (Fisher and Krieg 2001);
 - Gas Injection systems- these are also considered by Fisher and Krieg (2001) to have too high an energy requirement to be suitable for agricultural applications; and
 - Percolation systems – In these systems, which are operated as batch rather than continuous processes, the solid substrate is placed in a chamber and showered from above with water or percolate. This liquid is captured at the bottom of the chamber and recycled.
55. Of the three approaches, percolation systems have the lowest energy costs. DF is a similar process to that which occurs when rain percolates through municipal solid waste at a landfill site, though the gas arising from DF tends to lack some of the hazardous trace gases present in landfill gas (Fisher and Krieg 2001). DF produces biogas using the same microbial processes as AD but will generally operate at a longer retention time (up to 50 days (Kaiser *et al* (2003)). Accordingly, gas is produced at a lower rate from a DF percolation process than from an AD system (Fisher and Krieg (2001)). Some commercial DF claim to operate with input material of up to 55% DM (45% moisture content) and there are a number of DF operating around the world typically

producing between 37Kw to 950Kw of power. Around 5% of the energy produced is required to maintain the function of the plant, and an average installation requires approximately 1 acre of land, with the prominent features being the fermentors which have the appearance of farm buildings.

56. Given the high DM content of poultry litter (65%), addition of water or other liquid feedstock material will be required prior to its use in DF systems. Though DF appears to offer opportunities to generate energy from poultry litter, the significant draw-back is that the phosphate level of the residue post DF is the same in mass as before, and still requires a disposal pathway. While a reduction in organic volume of up to 40% may occur as a result of the process, the fact that significant quantities of water are added to the feedstock at the outset may mean that the overall volume is similar to that at the beginning of the digestion. The product may be more saleable, in principle, but the transport costs to take it to market would remain similar to raw poultry litter as highlighted earlier, and concerns remain regarding the potential for spread of botulism to cattle when the digestate is applied to grassland. One option to overcome this would be to subject the digestate to further processing, using some of the heat or power produced during the DF process – this would have a very significant impact on the overall economics of the process.
57. Thermal treatment: Thermal treatment describes processes which apply heat to cause the thermal breakdown or decomposition of organic matter to produce useful products that can be used for energy production. Two main processes come under this heading, **pyrolysis** and **gasification** and there is considerable research and development interest in each. While many of the basic principles are known, they remain limited in terms of application on a commercial scale.
58. Most recent research and commercial development interest focuses on using the processes to:

- 1) manage municipal solid wastes as an alternative to land fill and incineration;
 - 2) utilise products such as wood brash and sawdust from forest and wood based industries;
 - 3) utilise organic waste products from agriculture of which the most common material is corn stover, which consists of the stems and dead leaves after maize (corn) harvesting.
59. Although poultry litter is an organic waste product and has been proposed as a feedstock for gasification plants, the amount of research and development is limited. It should be noted that the source organic material is not incinerated, burned or combusted, which would require oxygen, usually in the form of air, but rather oxygen is excluded or in the case of gasification sometimes added in a controlled manner. Therefore gaseous emissions from the process are limited to those involved in providing the heat that drives the processes. Thermal treatment processing plants are normally regulated under the Waste Framework Directive 2008/98/EC and the Waste Incineration Directive 2000/76/EC.
60. Pyrolysis: A fast pyrolysis system has been developed experimentally that heats poultry litter to approximately 400 C for 1 minute with the process producing a solid bio char, a liquid bio oil and gases. The bio-char residue is approximately 35% of the starting biomass and contains all of the P present in the poultry litter. The fate of the nitrogen in the litter is less certain. Biochar is promoted as having remarkable properties in that it appears quiet inert and so can remain for long periods, perhaps over millennia, when it is incorporated in the soil. Added in this way, it sequesters carbon and as such has been highlighted as a possible greenhouse gas mitigation strategy. In some soils it appears to increase soil fertility. Given the renewable energy yield generated in creating the biochar, its role in carbon capture through sequestration and potential contribution to improved soil fertility, the process has been characterised as win-win-win. BUT

61. Bio-char derived from poultry litter remains virtually untested as a fertiliser or soil amendment either in terms of nutrient availability or effects on soil fertility. Most of the literature reporting beneficial effects of biochar as a fertiliser come from additions of wood derived biochars to the highly weathered soils of the tropics, such as in Amazonia. Achieving benefits of similar magnitude from addition to local soils, which are more fertile to begin with, is doubtful. Inevitably, following the rush of interest in the topic of biochar, there are now a number of recent scientific reviews documenting potential harmful effects of the material.
62. What is known is that poultry litter biochar is extremely alkaline due to the liming effects of the calcium carbonates added to poultry feeds. In small doses this would be beneficial. The very limited information available suggests that the N in poultry litter biochar is less than in the original litter and has a low availability to plants. The biochar contains the P from the poultry litter but the availability of this to plants is un-quantified other than to note that biochar is strongly absorbent to P and so may act as a slow release fertiliser. In summary, poultry litter biochar remains completely untested as a fertiliser - largely it appears due to a chronic shortage of material to test. There is no market price for it nor any indication of it having a commercial value at present (http://www.biochar-international.org/images/Bryant_Presentation.pdf). However, if a market developed to reflect its carbon sequestration potential, this would provide a potential source of revenue. It could also be a source of carbon if it can be burned.
63. The short pyrolysis time and rapid cooling of the gases generated so as to condense organic compounds, are designed to maximise the liquid fraction which is known as bio-oil. The bio-oil produced during pyrolysis is potentially a fuel oil but is chemically very different from heating oil or diesel. It is considered unsuitable as a transportation fuel due to its adverse properties (e.g. instability, acidity) caused by its composition. Moreover the emissions resulting from its use are likely to be regulated.

64. Research is focussed on improving the stability of bio-oil and catalysing or bio refining bio-oil into more versatile fuel products such as diesel. While acknowledging this significant research effort to develop or unlock the potential of bio-oil as a fuel, this potential seems some way from commercial realisation, with the bio-oil described as “generally unstable, acidic (acetic acid), corrosive, viscous, and includes both water and ash contents”.
65. Gasification: This process represents a more advanced variant of pyrolysis that operates at much higher temperatures of up to 900°C, although the reaction times remain short. At these high temperatures the components of the bio-oil are volatilised and a portion burnt by allowing a limited oxygen injection, in order to generate more heat to drive the process, and also to produce carbon monoxide. Under the high temperatures, the volatilised organic compounds, aided in some cases by a catalyst, break down and react with water to form methane, hydrogen and carbon monoxide, which are potential fuels. Carbon monoxide also further reacts with water to form more hydrogen gas and carbon dioxide. The resulting gas produced is therefore a mixture of nitrogen, carbon dioxide, methane, carbon monoxide and hydrogen and is termed a synthetic gas or *syngas* for short. It has a calorific value, although generally only half that of natural gas, and can therefore be used to generate power though it is not regarded as easily transportable.
66. Potentially gasification systems can achieve high energy recovery rates of 50-60% but these yields depend on utilising the heat generated by the process. In the poultry sector there is one known on-farm gasification plant on a large broiler farm (800 thousand birds/year) in West Virginia, USA. A justification for the plant was that it could utilise the heat for heating the broiler houses, especially in the winter, although the plant itself was funded by a grant in region of \$1 million. The plant may be located too far south for the heating saving to justify the costs and we tend not to experience such cold winters as that part of the USA.

67. This plant has been in place for over 2 years but it remains unclear whether it has overcome the initial operational problems it experienced, as the litter was found to be too wet as a raw feed stock and required drying. (US broiler litters tend to be dryer than those produced locally). While initial reports suggested great interest in the system amongst poultry producers, it has not been replicated elsewhere in the US or Europe.
68. The most successful examples of the use of gasification at a commercial scale are some recently opened gasification plants used to treat municipal solid waste in Northern Europe. These are close to buildings and can link to district heating systems and so have a high heat recovery potential.
69. On the basis that they can be shown to be operational, gasification plants can be offered as an option for utilising broiler litter as they recover energy (as syngas), potentially useful heat and generate biochar. In volume terms the biochar is likely to be around 20% or less of the biomass of the litter so is more transportable. As with other forms of biochar its use on soils remains to be tested and quantified. At this time the economics of the municipal solid waste gasification systems are unknown. However, past experience is that the efficacy of any municipal solid waste system depends on imposing a charge or gate fee for the waste used which can be set against the avoided cost of land fill taxes. In comparison with municipal solid waste, broiler litter may have a higher fuel value and is a more uniform product so it is difficult to quantify the economics of the system.
70. Autoclaving: Autoclaving is a form of sterilisation in which material is heated under steam pressure to temperatures above 100°C, which achieves a rapid sterilisation. It's only role in the management of poultry litter would be based around the control of pathogens such as *Clostridium botulinum* in poultry litter. The sterilised waste would be more easily managed and recycled and could be spread on grazed grassland as a fertiliser. However, there are very limited areas of grassland that have a P requirement.

71. A 100 kt/yr plant for municipal solid waste (MSW) is in operation in Rotherham and this suggests that this could be a centralised option. It is worth noting that autoclaving poultry litter would not yield an energy dividend, unlike the various combustion options, gasification or AD/Dry fermentation, and indeed would be very energy intensive. Furthermore, the N:P ratio in the litter would still be inappropriate for local use and further processing would be required before it could be marketed locally or exported.
72. Quickwash: This is a process which has recently been proposed as a means of treating poultry litter by selectively removing phosphorus, which is recovered as calcium phosphate. The treated solid is selectively enriched with nitrogen, which lowers the risk of phosphate over-supply to soils described earlier. The process relies on washing the litter with an acid, which dissolves the phosphorus. The recovered acid is then neutralised with lime and a coagulant added to assist in precipitating out the phosphate.
73. Thus there are three products from the process: the P depleted poultry litter, calcium phosphate and the neutralised quick wash solution. The process remains untested at any practical scale. There are a number of issues associated with the management of the process and the products produced which would have to be resolved before it could be recommended as appropriate to the local situation. Some of these are outlined below.
- Applying the P depleted poultry litter would still require compliance with the organic nitrogen constraints set out earlier associated with the Nitrates Directive and perhaps also those associated with botulism.
 - The effluent from the process contains significant amounts of nitrogen (in the region of 25% of the nitrogen in the poultry litter is extracted by the acid quick wash compared to +80% of the phosphorus). Even after the phosphorus was recovered, this effluent would also face the constraints posed by the Nitrates Directive as it could only be applied to land within the organic N limit. It would also require the provision of

- The calcium phosphate recovered is the only tangible added value product, but the practicality of defining an outlet for this within the local bulk commodity fertiliser business has to be established. Costs given for the US estimate the value of the phosphate recovered at \$63 per ton of litter treated with chemical costs of \$44 ton of litter treated. This leaves only a small margin to cover the costs of capital, labour and energy that the process requires. There would seem to be extra land application costs associated with the liquid effluent, while the acidified poultry litter may pose unique problems in handling and application. In the US, the economics were stated to be substantially favoured by water quality credits for poultry operations in the catchment of Chesapeake Bay which were quoted as \$78 per ton of litter treated. These credits are obviously not applicable locally.

COMPARISON OF ALTERNATIVE TECHNOLOGIES

74. As noted in previous sections, the economics of poultry litter export are not favourable, either to the south or Britain. Our local poultry producers will often have to compete with other poultry producers who are much closer to these markets and who can supply these markets without having to pay the cost of transportation. As a result, the market price local poultry producers will receive for litter is likely to be only a fraction of its true fertiliser value, and in the case of export to Britain, will face costs which exceed market value.
75. Accordingly, when considering alternatives to the land spreading of poultry litter, an important consideration is whether the alternative technology has the potential to improve the economic feasibility of poultry litter disposal/utilisation, through extracting energy and/or generating a saleable product with greater market value. For successful application in practice, it is also important that any new processing option is robust, reliable, well tested elsewhere and compatible with existing bio-security protocols within the industry. It must also

be capable of treating poultry litter at a 'significant' scale, which for the purposes of this review, is considered to be at least 100 kt per annum.

76. The six alternative treatment options outlined above have been reviewed in detail with respect to these criteria, and the findings are summarised in Table 5. When assessed against the criteria highlighted above, the technology which currently satisfies all of the objectives is thermal treatment of poultry litter via pyrolysis or gasification. Anaerobic digestion, dry fermentation and autoclaving do not result in a significant volume reduction, and all of the N and P present in the litter is also present in the end product. The "Quick Wash" process does not generate energy and disposal of the end product (P stripped litter) may be difficult.
77. Considering thermal treatment in more detail, gasification offers a number of advantages over pyrolysis. Gasification is now a relatively proven technology for municipal waste treatment, and a number of plants are currently operating in Europe processing 30-50 kt waste per year, although none of these plants use poultry litter. Gasification also produces a higher energy yield than pyrolysis, avoids the production of bio oil which has very limited markets, and produces a lower volume of end product.
78. However, a number of technical challenges will need to be overcome in assessing the feasibility of gasification as a means of processing poultry litter. These include evaluating the suitability of poultry litter as a feedstock, assessing the potential power output of a gasification plant fuelled by poultry litter, and identifying and developing appropriate markets for the gas and the biochar end product.

Conclusions

79. The broiler poultry sector is a significant part of the local economy, sustaining employment for over 7,000 people on farms and in processing, and

generating around 14% of the gross output of the local agriculture sector. However, the industry also produces around 260 kt of poultry litter of which, at present, only 83 kt is managed sustainably (70 kt applied to arable land and 13 kt used for local mushroom composting). Recent reductions in the P content of poultry litter, achieved through improved diet formulation, have increased the quantity of litter which could be applied to arable land to around 100 kt per annum. Consequently, an alternative use/disposal is required immediately for 160 kt of litter/annum, potentially increasing to 300 kt/annum in future years, if poultry production continues to expand.

80. Following a comprehensive review of alternative technologies/options to utilise poultry litter it is concluded that thermal treatment, and in particular gasification, appears to offer potential as an alternative to fluidised bed combustion. Gasification is increasingly being used across Europe as a method for treating municipal waste and the process extracts significant quantities of energy during treatment. However, a number of technical challenges need to be overcome in applying the gasification approach to poultry litter. These include evaluating the suitability of poultry litter as a feedstock, assessing the potential power output of a gasification plant fuelled by poultry litter and identifying and developing appropriate markets for the gas and biochar end product.
81. Of the other options reviewed, export to Britain for land spreading on arable land also offers some potential, but this option will incur significant and ongoing costs due to high transport costs and the low financial value of poultry litter as a fertiliser. Estimated annual costs for this option are between £4 to 6 million (based on export of 200 kt poultry litter per annum). Alternatively, there is some scope for land spreading of poultry litter on local grassland (low P index soils only) by heat treating or autoclaving poultry litter prior to spreading – this sterilizes the litter and eliminates the risk of botulism. This option would also incur significant ongoing annual costs, due to the energy costs associated with heat treatment and/or autoclaving.

82. Given the need to demonstrate to the European Commission that significant progress has been made in dealing with the issue of surplus poultry litter, the Review Group recommends that industry should consider the potential of gasification, including research to develop a prototype poultry litter fuelled gasification plant. Depending on progress with a prototype plant, other options may be needed to reduce the volume of poultry litter being land spread before the end of the current Nitrates Action Programme (December, 2014). Of the alternative options reviewed, transport to Eastern Scotland for land spreading is currently the lowest cost option (approximately £30/t of litter exported). Consequently, the Review Group recommends that industry should also give consideration to options to reduce the transport costs of poultry litter for export – for example use of baling, and the logistics of shipping poultry litter need to be investigated.

Table 5 Summary of a range of alternative processes/technologies for utilisation/disposal of poultry litter

	Gasification	Pyrolysis	Anaerobic Digestion/	Dry fermentation	Autoclaving	'Quick wash'
Will this treatment process work best on-farm at regional or centralised/ national level?	Centralised/ National	Centralised/ National	On-farm or regional	On-farm or regional	Centralised/ National	On-farm or regional
Will this treatment process extract energy or require energy?	This process will extract significant quantities of energy as producer gas and potentially energy entrained in bio-char. Energy released during thermal treatment will be less than fluidised bed combustion.	This process will extract significant quantities of energy as producer gas and potentially energy entrained in bio-char and bio-oil. Energy released during thermal treatment will be less than fluidised bed combustion.	This process will extract energy in the form of methane gas but the quantity extracted will be significantly less than from thermal treatment.	This process will extract energy in the form of methane gas but the quantity extracted will be significantly less than from thermal treatment. Dry fermentation generally will extract less energy than Anaerobic Digestion.	This process will require energy. No energy is extracted from the organic matter in poultry litter.	This process does not require a significant energy input and No energy is extracted from the organic matter in poultry litter.
Will this treatment process add value to the poultry litter or produce a saleable product? (excluding energy generated during processing)	No current market exists for biochar. A market would have to be developed to utilise this product. Volume significantly reduced (by up to 80%) so export transportation costs would be much lower accordingly.	No current market exists for bio-oil or biochar. A market would have to be developed to utilise these products. Volume significantly reduced (by up to 65%) so export transportation costs would be much lower accordingly.	Small improvement in nutrient value may be obtained following digestion. Volume and nutrient content would remain the same.	Small improvement in nutrient value may be obtained following digestion. Some volume reduction could be expected but this may be offset by water volume added to facilitate process, and no change in nutrient content	No added value obtained, but by eliminating botulism risk may open additional land spreading options. Volume of litter would be largely unchanged and no change in nutrient content.	Markets exist for recovered P which is potentially a high value product. Value of P stripped litter would be reduced and may be more difficult to dispose of. Acid wash, addition of precipitant and pH correction will significantly increase the overall volume.

<p>Has this process been used elsewhere at a significant scale (100 kt/yr) in treating poultry litter?</p>	<p>Limited examples of gasification being used to process poultry litter commercially, although some recent trials in the US are investigating the technology. Gasification has been used at a significant scale for treatment of municipal solid waste</p>	<p>Limited examples of pyrolysis being used to process poultry litter commercially, although some recent trials have investigated its use in small scale farm-based operations.</p>	<p>Process not widely used for poultry litter due to cost and issues with ammonia inhibition. Due to dry solids limitation on this process, the footprint and economics of plant to process 100,000 tonnes per year would likely be unfeasible.</p>	<p>Process not widely used for poultry litter. Due to dry solids limitation on this process, the footprint and economics of plant to process 100,000 tonnes per year would likely be unfeasible.</p>	<p>No examples of autoclaving being used to process poultry litter but has been used at a significant scale for municipal solid waste</p>	<p>Process is development. Has not been utilised at full scale.</p>
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