ENERGY from WASTE (EfW):

A FEASIBILITY STUDY ON THE ECONOMIC AND ENVIRONMENTAL CO-BENEFITS OF BIOGAS PRODUCTION WITHIN RURAL COMMUNITIES.

DECLAN MORONEY

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SUPERVISOR

Dr PATRICK WALSH

DEPARTMENT OF BUILDING &CIVIL ENGINEERING
DEPARTMENT OF MECHANICAL & INDUSTRIAL ENGINEERING
GALWAY MAYO INSTITUTE OF TECHNOLOGY, IRELAND.

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DECLARATION OF ORIGINALITY

SEPTEMBER, 2010

The substance of this thesis is the original work of the author and due reference and acknowledgement has been made, when necessary, to the work of others. No part of this thesis has been accepted for any degree and is not concurrently submitted for any other award. I declare that this thesis is my original work except where otherwise stated.

(Signature of Candidate)

Name of Candidate
(Candidate)

(Signature of Supervisor)

Name of Supervisor
(Supervisor)

Date

In completing this dedication I would like to thank a number of people who have been closely involved since the start.

Dr Mark Kelly, for starting a discussion one day on Masdar, Eco towns, and Utopia. It does not exist and probably never will, and I am not sure about the other two either!

Dr Patrick Walsh, my supervisor, who needed the patience of Job. The guidance and knowledge which were available to me was immense, it was hugely appreciated, and time will see if I used it wisely.

Ms Loreto Quinn-Canning, Ms Breda Mannion, Mr Pat Fox, Mr Jerry Fallon, Mr John Lyons, Mr Tony Porter and Mr Jim Chadwick. Local knowledge, as HSBC say is worth everything. I will be always grateful for the time and assistance which each individual afforded me.

Conor, Nia, and Caitlin Moroney; for cups of tea and sanity. Keep it up this thing is only starting...

...and to my wife Elizabeth.

Previously, I commented on her timing being poor, this time it was my own entire fault. This could not be done without you!

Declan Moroney, September 2010

Amicis Semper fidelis

Abstract

Energy from waste (E/W) technologies in the form of biogas plants, CHP plants and other municipal solid waste (MSW) conversion technologies, have been gaining steady ground in the provision of energy throughout Europe and the UK. Urban Waste Water Treatment Plants (UWWTP) are utilising much of the same biochemical processes common to these E/W plants. Previous studies on Centralised Anaerobic Digestion (CAD) within Ireland found that the legislative and economic conditions were not conducive to such an operation on the grounds of low energy price for electric and heat energy, and due to the restrictive nature of the allowable feedstocks.

Recent changes to the Irish REFIT tariff on energy produced from Anaerobic digestion; alterations to the regulation of the allowable use of animal by products(ABP); the recent enactment of the Renewable Energy Directive (09/28/EC) and a subsequent review of the draft Biowaste Directive (2001) required that the issue of decentralised energy production in Ireland be reassessed. In this instance the feasibility study is based on a extant rural community, centred around the village of Woodford Co Galway.

The review found that the prevailing conditions were now such that it was technically and economically feasible for this biochemical process to provide energy and waste treatment facilities at the above location. The review also outlines the last item which is preventing this process from becoming achievable, specifically the lack of a digestate regulation on land spreading which deals specifically with biowaste. The study finds that the implementation of the draft EU biowaste regulations, with amendments for Cr and Hg levels to match the proposed Irish regulation for compost, would ensure that Ireland has some of the most restrictive regulations in Europe for this application. The delay in completing this piece of legislation is preventing national energy and waste issues from being resolved in a planned and stepwise fashion.

A proposed lay out for the new Integrated Waste from Energy Plant (IW/EP) is presented. Budget economic projections and alternative revenue streams are outlined. Finally a review of the national policies regarding the Rural Development Plan (RDP), the Rural Planning Guidelines (RPG) and the National Renewable Energy Action Plan (NREAP) are examined against the relevant EU directives.

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1. Introduction.

Society within the developed and developing regions of the world often share more similarities than that which may seem to differentiate them. A requirement for clean water, wholesome food, stable energy provision, employment and domestic security are all basic necessities. The by-products of the provision of these basic elements, within a modern societal framework, have often run counter to the greater public good. Resource depletion and exploitation, waste creation and treatment, fossil fuel-dependant energy generation technology, and centralised regional settlement and employment provision, have led to a realisation that the current economic paradigm which has existing since the early twentieth century, may not be the most equitably or sustainable means with which to secure the long term environmental and social systems which humanity requires to survive (Schumacher, 1973; Galbraith, 2004; Nuttal, 2008; United Nations, 2009)

Jacobson & Lauber (2006) outline, in a German context, how heretofore it is often non-governmental organisations (NGO) or citizens' groups which have driven the policy initiatives currently espoused within programme's such as the 'Green New Deal'. The advent of the world economic crisis in the period 2007-2008, in large part the result of unsustainable actions within the specialist financial sectors (Tett, 2009) has seen a policy shift within the major international institutions and organisations towards the 'green & clean' technology and energy sectors (United Nations, 2009). Diversification into these new sectors is seen as a means of securing economic stability whilst at the same time acting to protect the environmental and resource sectors against continued overexploitation.

Pronouncements, policy initiatives and directives from a variety of source's, i.e. United Nations (UN) International Energy Agency (IEA), Organisation for Economic Co-operation and Development (OECD) , European Commission (EC) and national governments, regarding a 'Green Economy' are now common place and form major policy goal for all the above organisations (Lean, 2008; OECD, 2009; Nuttal, 2008; United Nations, 2009). The key shift is the understanding that in the 21st century, economic development can be carried out in a sustainable and symbiotic means as opposed to the parasitic and exploitive manner of the 20th Century. (E.U., 2009)

Examples of the priority areas being targeted by these broad nation al and transnational initiatives are contained within the UN document, but crucially, reflect older initiatives and issues which have been patronised by NGO's groups since the 1970s (Schumacher, 1973; Jacobson & Lauber, 2006).

Key objectives described within the UN 'Green Deal' (Nuttal, 2008)

- Clean energy and clean technologies including recycling
- Rural energy, including renewable and sustainable biomass
- Sustainable agriculture, including organic agriculture
- Ecosystem Infrastructure
- Reduced Emissions from Deforestation and Forest Degradation (REDD)
- Sustainable cities including planning, transportation and green building.

With regard to these objectives the aim of the following work is to examine whether the deployment of a clean energy production technology, which utilises waste product, can successfully contribute to achieving the aims outlined in the Green New Deal document (United Nations, 2009); and to examine issues or conflicts which may inhibit this result.

This work will concentrate on the utilisation of waste streams from agriculture, municipal and residential to produce biogas and other marketable products via appropriate bio-refinery principles and technology. Market and non-market benefits of this process will be reviewed to understand the interconnections which exist in these processes. Finally this work will examine the viability of these activities within rural communities as a catalyst for sustainable development from an economic, social and environmental aspect.

2. Is it Waste or Resource?

The treatment of waste generated from human activities has heretofore been undertaken as an acceptable side effect of the social and economic activity associated with developing and developed nations. Economic activity via extraction, production, utilisation and disposal of materials contribute to the waste sector and all elements of society within the developing and developed world contribute to its generation. Consumerism, and the requirement to provide for this economic paradigm, has at times increased the waste portion of production, as well as increasing the impact that manufacturing activity places upon the natural and built environments.

The OECD define waste as *materials that are not prime products*[1] *for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards or intends or is required to disregard. Waste may be generated during the extraction of raw materials, during the process of raw material, to intermediate and final products, during the consumption of final products and during any other human activity.* (OECD, 1999)

Waste treatment varies according to the feedstock and final processing. Traditional processes utilised in handling waste material include thermal destruction, land fill, down cycling, recycling, and general degradation of the discarded materials (Eunomia, 2008). It has been recognised that the indiscriminate production of waste and the subsequent unproductive disposal methods cannot be allowed to carry on as the infrastructural, environmental, sociological and lost opportunity costs become too great for society to bear.

On a European scale the Sewage Sludge Directive (1986/278/EEC), Waste Packaging Directive(94/62/EC)[2], Land Fill Directive (1999/31/EC), Waste Electrical and Electronic Equipment directive (2002/96/EC) , and most recently the Renewable Energy Directive (2009/28/EC) all encourage or mandate that waste, its generation, handling and disposal are prioritized for reduction in volume; redesigned towards increased recycling or upcycling; or are utilised in the production of additional useful products such as energy, base chemical production, bio fuels, nutrient recycling, feed products and soil enhancers as either composted or humic material.

In the main, the processes outlined above are industrial scale activities which are currently being targeted for industrialised, and by inference, centralised areas (I.E.A., 2009) (Kamm, Gruber, & Kamm, 2005; van Ree & Annevelink, 2007). Strategic reasons for the planning decisions involving these industries include economics of scale with regards to raw material handling, symbiotic industrial processes and proximity of markets for resultant products.

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[1] Products produced for the market place

[2] Including the amending directives, 2004/12/EC; 2005/20/EC

Thus as an example, the Port of Rotterdam now contains industries which process primary[3] hydrocarbon materials to fuel, chemical and associated materials as well as bio-refinery industries which process waste products from these manufacturing processes, and upcycle / recycle a variety of residuals for reuse within the primary manufacturing processes (I.E.A., 2009).

In situations as exist in the Port of Rotterdam, industrial scale facilities are appropriate with the particular environment, however the object of this work is to examine if the principles of bio refinery's, which apply at the previously described industrial scale, can be transposed to a smaller, more decentralised scale with similar benefits. The principles which will be examined are summed up in the definition of a bio refinery as outlined in IEA task 42 as ' *the sustainable processing of a biomass into a spectrum of marketable products'*. (I.E.A., 2009) (van Ree & Annevelink, 2007)

It should, however, be recognised that within the proposed feasibility study location, the majority of the conceptual frameworks of a bio refinery as outlined in van Ree & Annevelink (2007:13,14) would not constitute an appropriate technological fit. Consequently it is proper to describe those technologies which can perform the required tasks, and outline how these operations may subsequently have a greater 'demonstration effect' (Schumacher, 1973:149) and encourage succeeding uptake in similar environments.

In this scenario the availability and type of waste residuals will constitute a variety of available biomass feedstock's and this will dictate the primary and secondary processes which may be developed to exploit this resource into marketable products and non marketable co-benefits (Yiridoe, Gordon, & Brown, 2009).

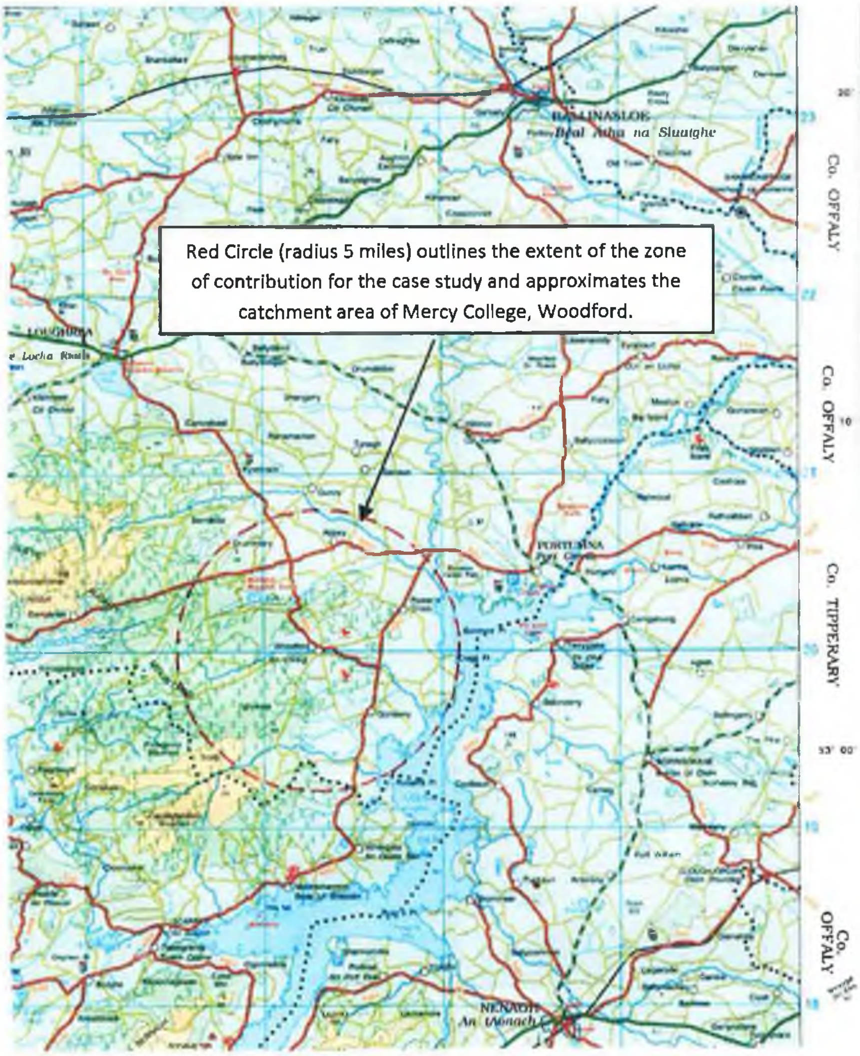
[3] Primary Hydrocarbons – Fossil fuels

3. Feasibility Study - Location, Description and Socio -Economic profile

3.1. Location

The site of this case study is centred upon Woodford[4], Co Galway, which is located in the south east of the county. Based on this location, an area, of radius 5 miles, was determined to constitute the maximum zone of contribution[5]. The choice of this study perimeter is based on the premise of economic distance as reported in the EPA discussion document (2006), and follows on from Gallagher (2007) where it is reported that the compensatory zone for the effects of locating waste management infrastructure eases substantially beyond 4 miles. This delineation also corresponds approximately to the catchment area of the local secondary school, Mercy College, Woodford.

Figure 1. - Location map Case study area – Woodford Co Galway



[4] CSO designated Census Town – a cluster of 50 or more houses, not having a legally defined boundary in which within a distance of 800 meters there is a nucleus of either 30 occupied dwelling houses on both sides of the road or twenty occupied houses on one side of the road. (CSO, 2006)

[5] Zone of Contribution - Area in which supply and demand actors or affected parties would be identified for the purposes of the case study.

This catchment area encompasses the following Distinct Electoral division[6] (DED), Woodford, Drummin, Coos,[7] Ballyglass, Ballynagar, Abbeyville, Marblehill[8] and Loughatorick.[9] Population data from the latest census for these areas is listed below.

Table 1. CSO Census data 2006 – Population and area data relating to the case study area

Electoral area	Electoral division	ED No	2002 persons	2006			% change 2002 - 06	Total household with septic tank	Hectares
				Total	M	F			
Loughrea	Ballynagar	102	183	202	104	98	10.4	66	2333
Loughrea	Loughatorick	126	34	34	19	15	-	Inc with ed. 129	3845
Loughrea	Marblehill	129	363	373	198	173	2.2%	137	3566
Loughrea	Woodford	134	479	500	246	254	4.4%	70	2325
Portumna	Drummin	163	350	369	200	169	5.4 %	130	4085
Portumna	Ballyglass	164	179	169	81	88	-5.6 %	52	1381
Portumna	Coos	165	140	136	69	67	-2.9%	48	3479
Portumna	Abbeyville	167	270	252	117	135	-6.7 %	88	1791
			1998	2035	1034	999	1.85%	591	22805

3.2 Description.

3.2.1 – Land use

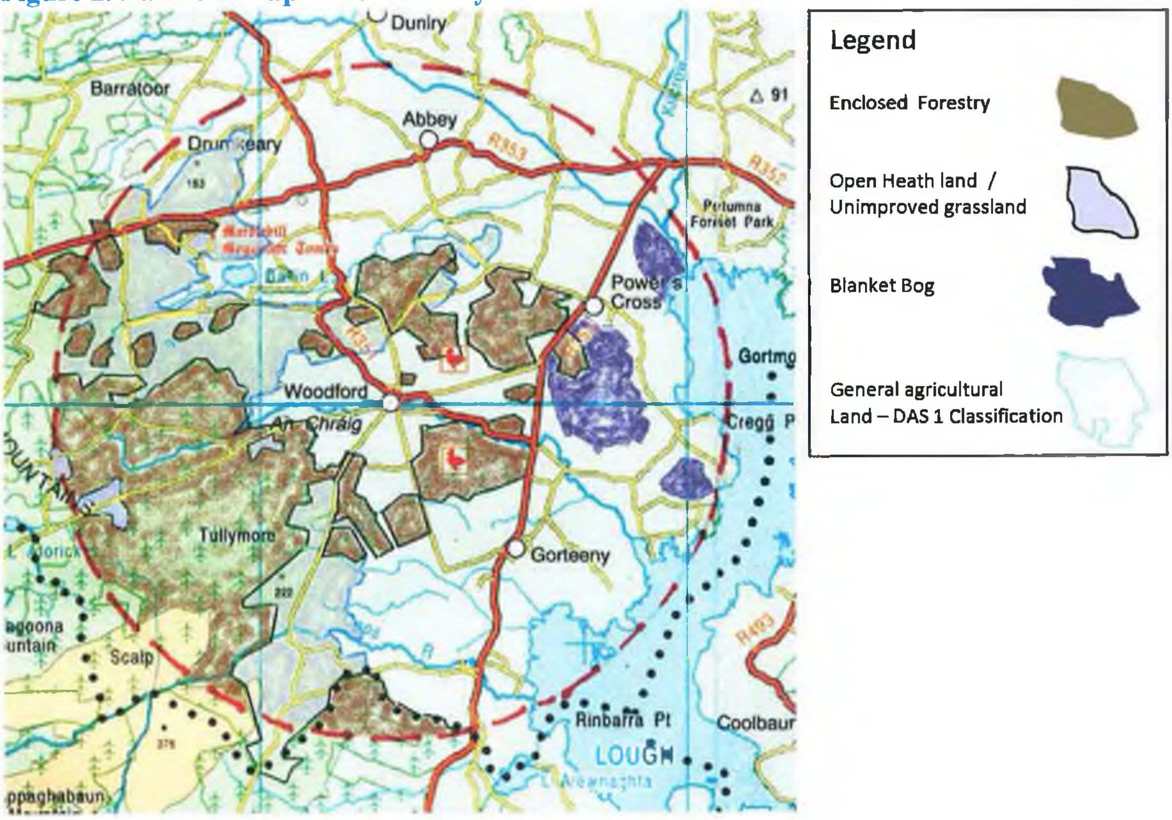
The Woodford area is described by Frawley *et al* (2005) as a rural area with high density of forest plantations, and is listed as a More Severely Handicapped (MSH) area agriculturally by the Department of Agriculture, Fisheries and Food (DAFF, 2010). The most recent available Census data in relation to agriculture practices in the area dates to 2000 and the data for the DED's within the zone of contribution are listed below in table 2.

[6] District Electoral Division – Electoral Divisions (EDs) are the smallest legally defined administrative areas in the State for which Small Area Population Statistics (SAPS) are published from the Census.
[7] Part of
[8] Part of
[9] Part of

Table 2. Break down of agricultural holding type in the case study area

District	E.D. name	ED No	Farms	DAS[10]	Dairy	Beef	Mixed	Hectares
Loughrea	Ballynagar	102	38	1	0	30	10	2333
Loughrea	Woodford	134	41	1	0	30	0	2325
Loughrea	Marblehill	129	71	1	0	60	10	3566
Loughrea	Loughatorick	126	7	1	0	10	0	3845
Portumna	Coos	165	28	1	0	30	0	3479
Portumna	Abbeyville	167	49	1	10	30	10	1791
Portumna	Drummin	163	64	1	20	40	0	4085
portumna	Ballyglass	164	29	1	10	10	10	1381

Figure 2. Land use map for Case study area.



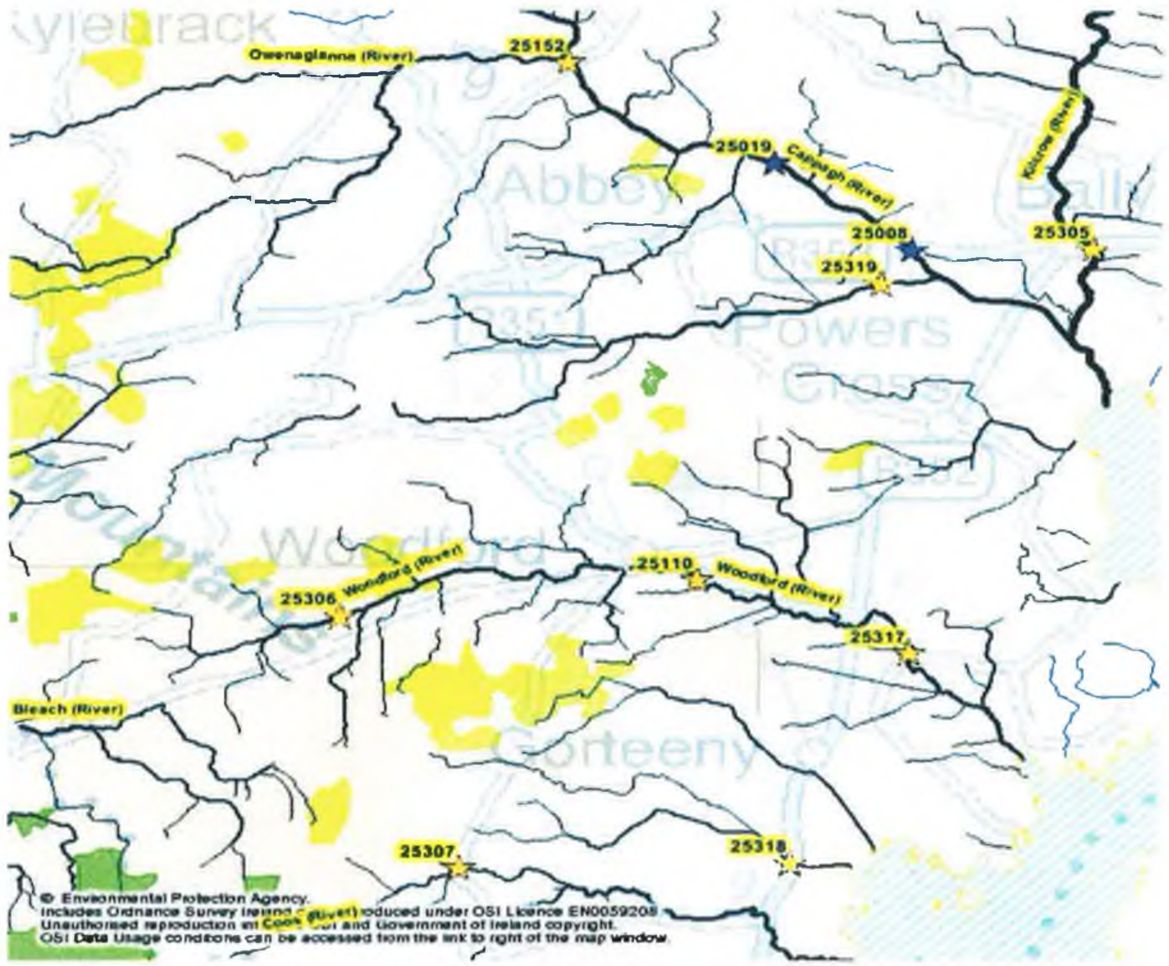
(OSI, 2001)

[10] DAS disadvantaged area status – See appendix a for data relating to this designation. Designation 1 indicates that these lands are classified Most Severely Disadvantaged , as applied under the terms of council directive 75/272/EEC (DAFF, 2010)

3.2.2 Water resources

The area is bounded by a number of rivers and lakes, namely the Cappagh River (EPA 25/C/02) and the Kilcrow River (EPA 25/K/01) to the north and north east, Lough Derg to the east and south east, and the Coos river (EPA 25/C/08) to the south. The western boundary is dominated by the Slieve Aughty Mountains. The Woodford river (EPA 25/W/01), the Ballinlough stream (EPA 25/B/15) and the Drumkeary stream (EPA 25/D/11) all drain the remainder of the study area to their outfalls at Lough Derg (Clabby, *et al.*, 2004) which is designated a Sensitive Water Body (DELG, 2001).

Figure3. Main water courses within the study area



Repoduced from GIS,(2007)

The EPA water biological quality analysis (Clabby, *et al.*, 2004; Clabby, *et al.*, 2008) of these rivers indicates, that in general, water quality is Q 4, 4-5, however each of the main watercourses have had pollution events associated with them, and these events are linked in the main, with agricultural practices and incidents related to sewage release to the receiving waters.

According to the Geological Survey of Ireland (GIS, 2007) the case study area consists of locally important (LI) bedrock aquifers coupled with extensive areas of poor aquifers (PI). The delineation of these aquifer regions follows the makeup of the underlying bedrock which is locally diverse. The predominant bedrock is Devonian Old Red Sandstone and Dinantian Lower Impure Limestone. Local variation of the bedrock occurs in the boundary regions of these bedrock strata.

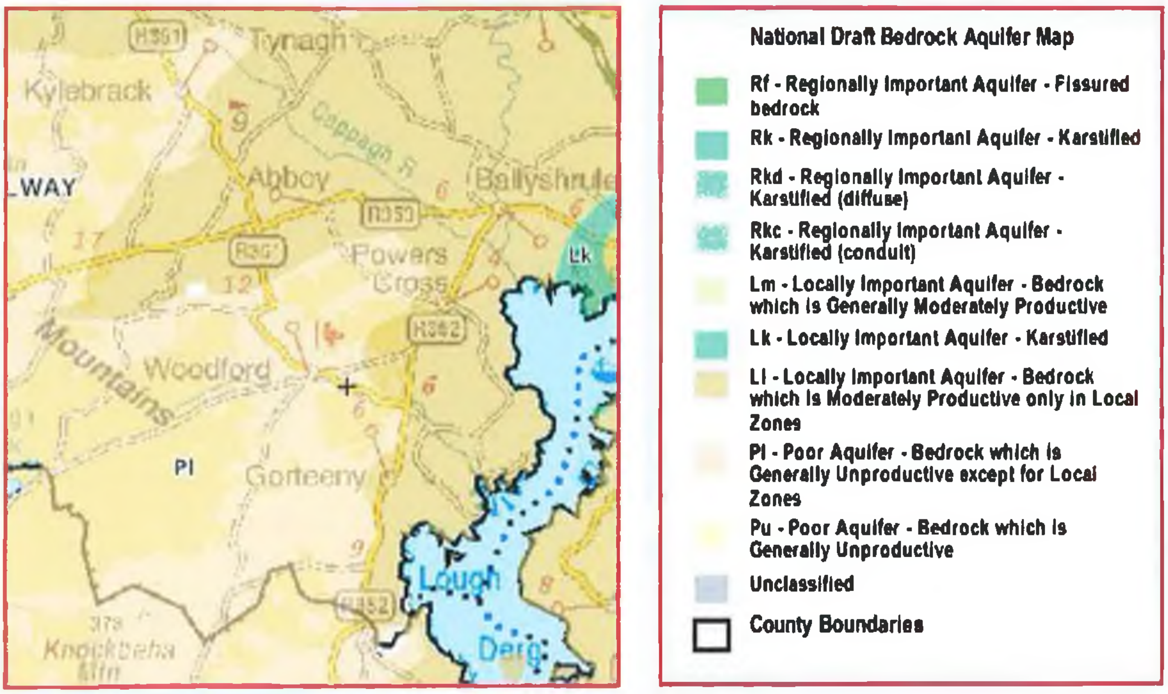
The subsequent subsoil's and their vulnerability classification reflect the parent bedrock, its properties and climatic patterns of the region (EPA, 2003). Thus the areas of greatest agricultural productivity as outlined in the CSO agricultural census, (i.e. the DEDs of Marblehill, Abbeyville Ballyglass and Drummin) are also subject to high soil vulnerability conditions. Within the balance of the DED's encompassed by the study area, soils which are described as Low to Moderate vulnerability exist, but it should be noted that locally, conditions for all vulnerability classifications exist. *See Figures 4-7 below*

As a discrete area within SE County Galway, the study area has a high concentration of protected habitat designations. These areas impose separate restrictions on the local communities and enterprises and serve to highlight the importance of this area in terms of landscape, habitats, and species protection on both a national and European scale.

Table 3. Designations present within the Study area.

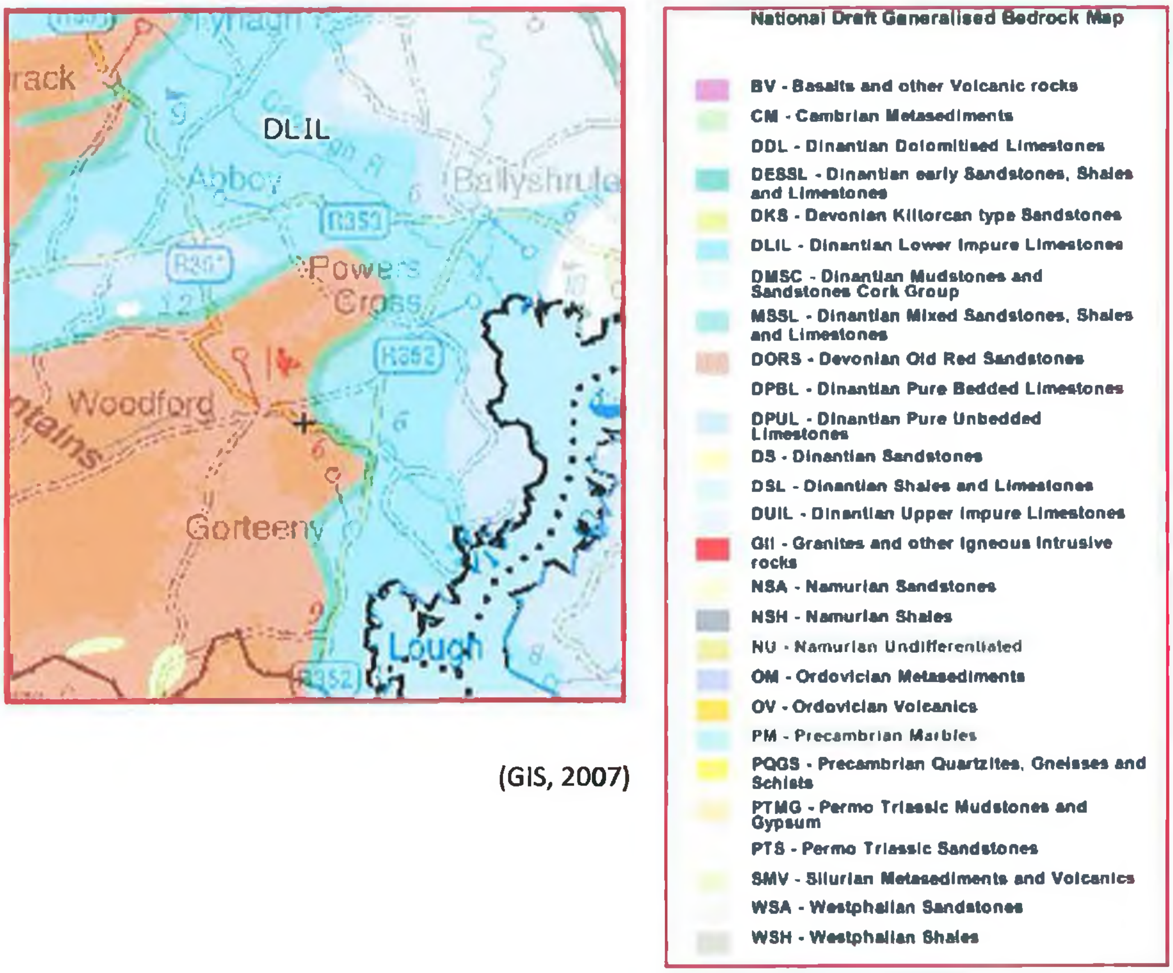
Designation	Reference	Location
SPA	004168	Slieve Aughty Mountain
SPA#	004058	Lough Derg
NHA#	001229	Slieve Aughty Bog
NHA#	002379	Derryoober Bog
SAC#	000248	Cloonmoylan Bog
SAC#	000261	Derry Crag Wood Nature Reserve
SAC#	000319	Pollnaknockaun Wood Nature Reserve
SAC#	001313	Rosturra Wood
SAC#	000231	Barroughter Bog
SAC	000308	Lough Atorick Bog
Natura 2000	IE 0002241	Lough Derg (North east shore)
# This site is also listed under as part of the European Natura 2000 Network. *Developed from* (NPWS, 2010)		

Figure 4. Draft Bedrock Aquifer Map – Study area



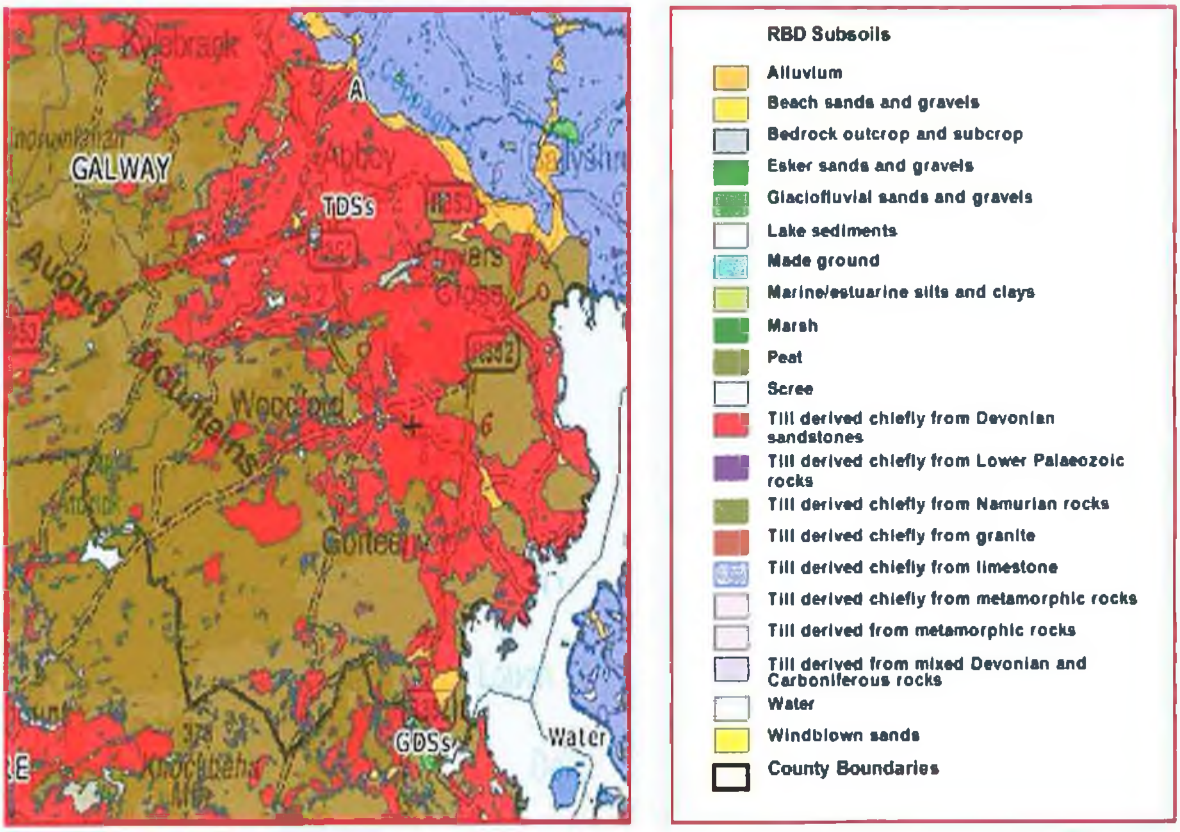
(GIS, 2007)

Figure 5. Generalised Bed rock Map – Study area



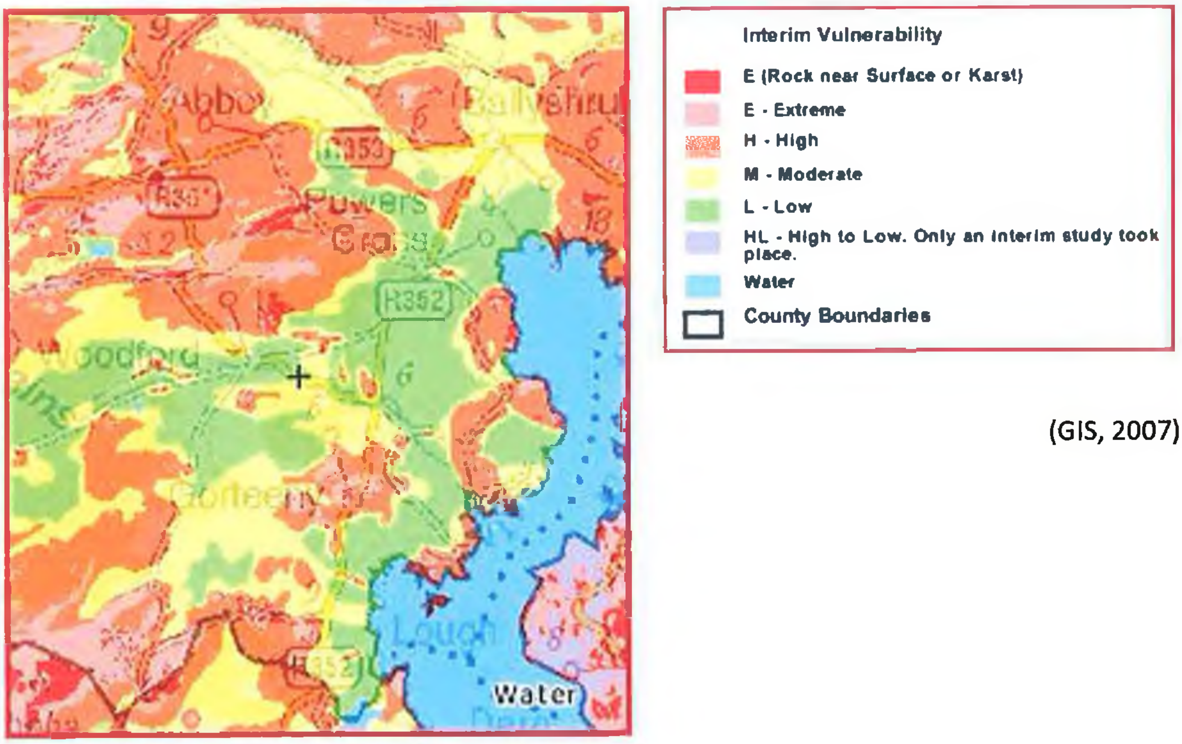
(GIS, 2007)

Figure 6. Sub soils - Study Area



(GIS, 2007)

Figure 7. Interim Soil Vulnerability Map - Study Area



(GIS, 2007)

3.3 Socio-Economic Profile

The village of Woodford and the surrounding study area is located within region 5[11] of the CLÁR[12] designated regions (DCEGA, 2010 b). This designation recognises that this region is especially disadvantaged in terms of a variety of physical, economical and social infrastructure measures. Areas which CLÁR investment may be targeted include roads(safety only), housing and schools enhancement, sewage infrastructure, potable water provision, and energy conversation schemes. A key aim of the CLÁR program is to enable rural areas to counteract the depopulation which is threatening large areas of rural Ireland.

Figure 8. CLÁR Region 5- South East Galway

Table 4. CSO Census data 2006 – Population- Woodford. Co. Galway.

Town	Electoral division	1996	2002 persons	2006			Percentage change
				Persons	Male	female	
Woodford	Woodford*[13]	298	280	301	144	157	7.5% increase

(CSO, 2007)

[11] Region 5 – Galway (part of), Specifically Slieve Aughty / Woodford area.
[12] CLÁR - The CLÁR programme (Ceantair Laga Árd-Riachtanais), launched in October 2001, is a targeted investment programme in rural areas.
[13] * indicates part of electoral division – Woodford ED includes Woodford town and outlining rural areas.

Frawley *et al* (2005) described in detail the socio-economic demographics of Woodford village and immediate surrounding area, and certain aspects of this data are instructive in summarising this village's position in its wider landscape. Of the population, 22 % of the households were involved in agriculture, but only 3% relied on agriculture as the sole means of income. Forestry constitutes a large part of the local land area but local employment in this sector, is restricted to small number of haulage contractors and processors. Over 36% of the households travelled more than 20 miles to work, and significant numbers (32%) travelled greater than 30miles. In terms of education 45% of heads of households (HoH) had primary education only and 29% had completed secondary and above. The high instance of primary only education may be a reflection of the age demographic of this group with 35% of household heads being over 65 years old.

Given the relatively isolated geographical location of Woodford, a common theme in this work by Frawley *et al* (2005) was the general feeling of safety and peacefulness which was expressed by the respondents, with 92 - 98% expressing a feeling of safety from crime and violence. It is surmised within this work that the negative aspects experienced in commuting from these rural areas is offset by the wellbeing experienced in participating in these close knit communities, however one could also argue that the lack of suitable local employment, the social responsibility inherent within extended family structures and farming units, and the availability of modern education facilities all play an equally important part in the decision to live in these type of rural areas.

2.4 Summary

From the economic and social data the situation in Woodford is one which is common within rural Ireland. Population growth is threatened by an ageing population (CSO, 2007), which is slowly losing its younger demographic to more centralised locations (Frawley, O'Meara, & Whiriskey, 2005). The traditional employment opportunities within agriculture and forestry have reduced considerably, and existing or proposed government programmes in these sectors, actively encourage consolidation actions by new farming entrants. These rural areas are described as 'Rural Restructuring' areas, (Moles *et al*, 2000:106). They are identified as areas of mixed amenities, changing economic practices, social stresses and dwindling populations, requiring infrastructural and economic stability.

Actions to shore up the existing agricultural sector in the more disadvantaged areas are attempting to displace agricultural production techniques with those of stewardship and environmental interests (DCEGA, 2010a). Increasing awareness of the fragility of the important natural resources to be found in the more isolated regions mean that protective measures such as SPA's, NHA's, and SAC's impose supplementary regulation and restriction on the extant communities and their production activities (DEHLG, 2008, 2009a, 2009b). The existing population understand and value the natural resource which exists around them, and that elements of this landscape need to be protected (Frawley, O'Meara, & Whiriskey, 2005), however unless it can be managed and promoted or ,utilised sympathetically for both economic and environmental purposes, then it may only provide a limited, alternative income for the current communities.

The recently amended Rural Development Program 2007-2011 (RPD) has stated that rural communities are an nationally important in terms of the energy security, economic stability and achieving the climate change target requirements of the country. Verstraete, (2002) postulated that the reordering of priorities in regard to ' all waste' , it's utilisation and generation, would become a key factor in future planning and development of societies, and with the evolvement of EU legislation in the field of waste (EC, 1999, 2001; E.U., 2009) this may be coming to pass.

On a local level the key issue is implementation of an integrated energy from waste (E/W) strategy in a manner which increases the 'demonstration effect[14]', and encourages the replication and improvement of the principles in a sustainable, community led 'bottom up' initiative. To this end this work will review the viability of energy generation from agricultural and municipal waste feedstock's within the study area as a means of increasing both the economic potential of local enterprises and communities, and at the same time contributing to the protection and enhancement of the environment locally.

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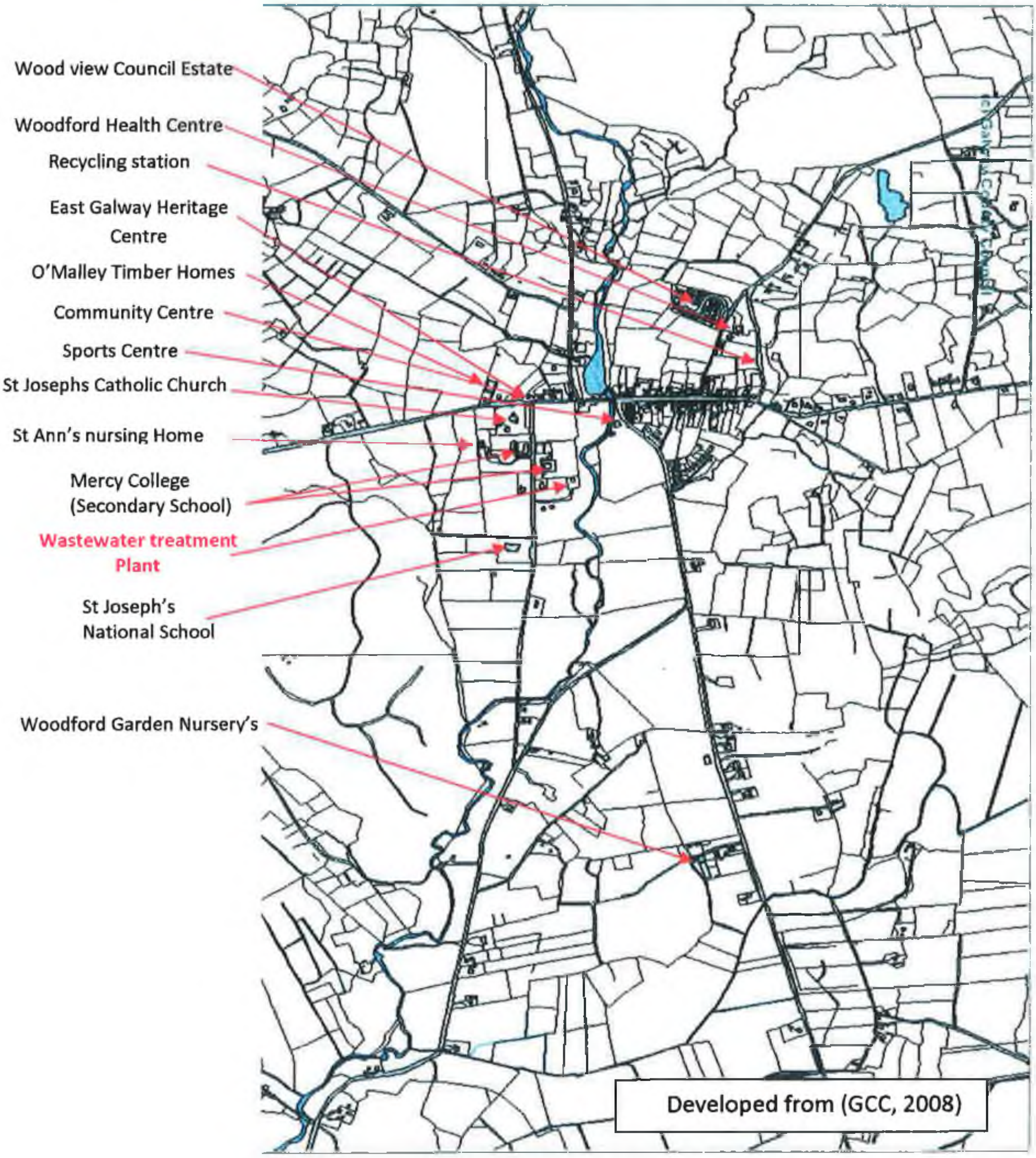
[14] 'Demonstration effect' (Schumacher, 1973) p 149 for explanation of concept

Figure 9. Woodford Village – Layout 2010



4. Available Waste Profile – Feasibility Study Area

The updated Rural Development Programme 2007 – 2013 (amended) (DCEGA, 2010a) stresses the importance which rural societies and their associated industries, agriculture and forestry, must play to allow Ireland to achieve targets in climate change, energy security and economic stability. These goals reflect the wider global aspirations relating to the 'Green Economy' and the 'Green New Deal' incentives (United Nations, 2009). In terms of energy production however it is notable that within the revised RDP the emphasis in regard to energy production is placed upon the 'low hanging fruit' option of biomass products such as short rotation coppice (SRC) and first generation[15] energy crops such as miscanthus[16], oil seed rape, etc.(*Measure code 121*:DCEGA, 2010a).

In contrast the direction outlined by Europe in relation to renewable energy generation, is to develop more methods of extracting energy and material value from waste feedstock's (E.C., 2009). It has put in place the financial incentives to develop the second generation processes and techniques with increased emphasis towards transportation fuel as a development driver.

The strategic importance of the utilisation of waste residues, from agricultural processes, for the Irish economy has been reported upon extensively. The EPA (2005) discussion document on the '*Importance of Anaerobic Digestion, Benefits for Waste Management, Agriculture, Energy and the Environment*' follows on from (Mahony, *et al*, 2002) and this has been developed further in (Healion, 2005) (Murphy & McKeogh, 2006)(Heslop, *et al*, 2007) & (Singh, *et al.*, 2010). Indeed these texts reflect a much greater and broader discussion which has been ongoing in Europe and beyond since the early seventies (Monnet, 2003) (Raven & Gregersen, 2005) (Demirbas, 2006) (Albihn & Vinneras, 2007) (Negro, *et al.*, 2007) (Han, *et al.*, 2008) (McDonald, *et al.*, 2008) (Gebrezgabher, *et al.*, 2009) (del Rio & Burguillo, An empirical analysis of the impact of renewable energy delopyment on local sustainability, 2009) (Yiridoe, *et al.*, 2009).

Within the feasibility study area the local authority, Galway County Council, (GCC) provides the basic municipal services for the village, with potable water supply for the

[15] First generation Bioenergy processes are described as those processes which utilise energy crops directly e.g sugar cane for ethanol production. Second generation processes are proposed to be those which utilise general waste materials for the production of fuels, base chemicals and other marketable products.

[16] *Miscanthus Giganteus*(Elephant grass)

village and immediate surrounding area, and a combined sewage scheme[17] for the village area only.

Municipal waste is collected via private waste contractors (EPA, 2009), and a contractor operated bottle bank/recycling station is located informally at the edge of the village area. The processing of these waste streams necessitates large infrastructural development and suitable road networks and as such is not suitable for a rural location as described here. Indeed, within GCC's jurisdiction, the council has removed itself from the management of these facilities and the whole county and city area are serviced by private waste contractors and processers (EPA, 2009). A new water supply is to be provided for the village under the EPA Remedial Action List[18] (Pender, 2010 *per com*).

4.1 Existing Waste Water Treatment Facilities

The village of Woodford is served with a waste water treatment system (WWTS) which was originally installed in c.1960 and consists of a primary and secondary ImHoff™ settlement tank , and thereafter is discharged into the nearby Woodford River (Fallon, 2010, *per com)*. This system currently equates to a primary treatment system, with minimal pretreatment of the incoming inffluent. The original design criteria for this system are unavailable, but based on latest available census data for 2006 (CSO 2007), and enrolement numbers at both the primary and secondary schools located within the village boundaries, any new or updated wastewater treatment facility would be based upon a p.e.[19] of 489 persons (EPA, 1999), excluding future village expansion s*ee table 5 below*.

Local organisations have identified this WWTP as having an adverse effect on both aquatic life and biodiversity generally on the Woodford River and the immediate vicinity (GCC, 2010). Indeed, the current treatment unit has been recognised by GCC, as being inadequate to meet the current Wastewater Directive Standards, (GCC, 2010) and subject to adequate financing is due to be upgraded at some time in the future. As per the UWWTP directive 91/271/EEC (E.C., 2010) and S.I. 245:2001 Urban Waste Water

[17] Combined sewage systems have both human waste from toilets and storm water from the road and roof drainage networks combined within a single series of connecting pipe work. From a waste water treatment point of view this can cause problems with storm events overwhelming the operation of the treatment plant. Most modern systems are separated with storm water being discharged via dedicated interceptors into suitable receiving waters

[18] Remedial Action List – This is an Environmental Protection Agency strategy to ensure that public water supplies meet the standards of the Water Framework Directive.

[19] p.e.. Population equivalent. Term of measurement utilised to estimate the total treatment capacity of a wastewater treatment facility. This measurement is based upon the static, i.e. resident, and dynamic, e.g. schools, businesses etc, populations of the area in question. 1 p.e. is the organic biodegradable load having a 5 day biochemical oxygen demand(BOD) of 60g per day (DEHLG, 2008) (EPA, 1999) (DELG, 2001)

Treatment Regulations (DELG, 2001) this situation is allowed to prevail due to the size of the village to which treatment is being provided. Within the UWWTP directive, agglomerations of less than 2000 p.e. but with a collection system require only 'appropiate treatment'.

EPA monitoring of the Woodford river system would indicate that although the nominally treated effluent is being discharged directly into these receiving waters, the water quality at the monitoring stations downstream of this discharge point is consistently good to excellent, (Clabby *et al* 2004:184 ; 2008). Thus the cyclical agrument develops that if the water quality on testing is good, irregardless of the *de facto* practice of discharging nominally treated effulent into the water course, then the imperative to upgrade the system to any acceptable international standard does not exist.

Figure 10. Treatment plant Woodford Co Galway

Figure 11. Treatment plant outfall to River

From the available data an estimation of the the daily volume to be treated at this plant can be derived and is presented below.

Table 5 . Calculation of estimated p.e. for Existing Woodford Village Requirements.

Location	Description	No of persons	Flow liters day / per person	Total Liters/day	BOD_5 g /day/ per person	BOD_5 g/d	Estimated p.e. (No Expansion)
Mercy College Woodford	Secondary School, Non Residential with canteen	236[20]	60	14160	30	7080	
St Joesphs National School	National school non residential no canteen	99[21]	40	3960	20	800	
St Ann's Nursing Home	Residential Elderly people plus nursing	30[22]	300	9000	65	1950	
Village	Local housing	301[23]	180	54180	60	18060	
Industrial / office	Local Businesses	27[24]	30	810	20	540	
Public houses (3 no)	Residential	5	200	1000	60	300	
Public Houses (2 no)	Non residential	4	60	240	30	120	
Public house (5 no)	Patrons[25]	50	10	500	10	500	
Totals		752		83850 DWF[26]		29350	489[27]

Developed from (EPA, 1999)

The energic potential of biosolid, as expressed in biogas yield, is reported as between 0.14 (Verstraete, *et al*, 2009) , 0.27 (Gomez, *et al*, 2010) and 0.32 Nm3/ kg TVS (McDonald, *et*

[20] 2010 enrolment numbers plus teaching and admin staff, personal communication with Principle Mrs L. Quinn-Canning
[21] 2010 enrolment numbers plus teaching and admin staff, personal communication with Principle Ms Breda Mannion
[22] Average occupation, includes staff, personal communication with Owner Mr Pat Cox.
[23] (CSO, 2007)
[24] Includes heritage centre (15p) timber factory(5p) shops (4p)Hairdresser(1p) beauty parlour (1p) computer repair(1p) (figures in brackets indicates employees)
[25] Authors personal experience derived from working in this commercial environment within the study area.
[26] DWF Dry Weather flow,
[27] Equal to total BOD divided by 60g/day to derive p.e. for the catchment

al , 2008). There is also some divergance on the Total Solids/Volitale Solid (TS/VS) ratio to be found in this material as repesented in the above literature sources .

International practice in energy extraction from this waste stream, which is suitable for this location, can be reduced to a limited number of applicable technologies. Direct combustion of the dried biosolid material via incineration, direct combustion of the biogas derived from conventionally activated sludge (CAS), or indirectly in the form of land spreading of the biosolid material to biomass crops for future combustion in combined heat and power (CHP) Plants. (Eunomia, 2008). Alternatively the biosolid material may be incorperated within the topsoil to enhance the biological structure and increase the fertility of the receiving soils (U.S.E.P.A., 2000).

Increasingly the later option of land spreading of biosolids directly or via incorperation within the soil matrix is encountering firm resistance among residential populations, due to the issues of odour control, heavy metals content, and issues of bioaccumulation and leaching of biological and chemical compontants. (Jones-Lepp & Stevens, 2007) (Schoof & Houkal, 2005) (O'Connor, *et al*, 2005) (Alvarez *et al*, 2002) (McBride, 2003). Incineration of this material is not a cost effective manner in utilising this resource due both to the suitability of the technology required to achieve this aim, and the yearly volumes of material to be treated i.e c.12 ton *(refer to table 5 above)*. Subsequently this leaves biogas production from the waste material as an applicable technological alternative.

Verstraete *et al* (2009) Gomez *et al* (2010) and (Atlas, 2009) outline the difficulties of utilising this resource. These range from the dilute nature of the incoming inffluent material, low dry matter (DM) content, volitile solids to total solids ratio (VS/TS) and the effects of heavy metals, organic and inorganic pollutants on the production of biogas. (Guillemet, et al., 2009) further describe the raw constitutants of the incoming material and offers analysis of the variation to be found between urban and rural treatment systems.

The up-concentration via seperation of the suspended solids (SS) of the inffluent as described in Verstraete *et al*, (2009) offers a solution for a number of these issues. Up concentrating of the influent by using appropiate pre screening, and floccation / couagulation techniques would allow for the collection of 10700kg/pa of biosolids from the existing village system. An additional biosolid resource relates to the private treatment plants (septic tanks) located within the study area.

Table 6. Municiple waste arisings (2008) data.

	Municiple waste managed (ton/pa)	Municiple waste generated[29] (ton/pa)	Household waste Managed (ton/pa)	Household waste generated (ton/pa)	Disposal of Household waste (ton/pa)	Recovery of Household waste (ton/pa)	Uncollected household waste (ton/pa)	% OF[30] house hold waste	Available Organic waste[31] Potential (ton/pa)
National figures	3,103,820	3,224,218	1,556,789	1,677,338	1,155,567	401,312	120,459	30.5 – 46.1%	
Per captia[32]	0.70	0.73	0.35	0.38	0.26	0.090	0.027	Ditto	
Galway County Ave	121284	126481	60642	65840	45048	15593	0.062[33]	Ditto	
Study area Ave[34]	1424	1485	712	773	529	183	126	Ditto	225

Developed from EPA 2009, CSO 2008

It is apparent from the NWR (EPA, 2009) that County Galway as a whole has an apparent issue in regard to the incident of uncollected waste compared to the national average. The NWR figures indicate a 200% difference between the national and regional figures. Purcell (2009) also highlights the noticeable disparity of waste generated in urban versus rural areas, and reported that greater quantities are being collected from urban regions compared to the rural counterpart. Internationally, Ireland's generation of waste is considered to be the highest in the OECD at 0.76t/capita/pa (Purcell, 2009). Currently the village and surrounding areas are serviced by a 2 bag collection system, which entails a collection of mixed residuals i.e. 'black bag' and a separate collection of mixed dry recycables i.e ' brown bag'.

Within the waste streams available above, both the 'black bag' / 'brown bag', streams require large infastrustrual facilites to handle and process these elements. However both of these elements contain large amounts of organic matter otherwise known as the organic fraction (OF).

29 Includes waste uncollected
30 OF - organic fraction = organic material, garden material, paper & cardboard, Available organics , organic and garden = 30.5%
31 Includes uncollected waste and managed household waste streams.
32 Per person figures based upon CSO 2008 Population area estimates of 4,422,100
33 Indicates that Galway county has an issue with uncollected waste.
34 Per person calculation based on CSO 2008 Small Area Population Statistics population area estimates of 1,833.

This OF whose precentage within MSW ranges from 30.5% - 46.1% (EPA, 2009) to 48.9% -73.7% (Gomez, *et al*, 2010), depends on the biodegradable profile of the material to be included, has been targeted at both European (EC,2009;1999)and national levels (EPA, 2009; Eunomia, 2008) for exclusion from land fill.

Organic matter, when enclosed within the anaerobic conditions present within land fills, undergoes partial methanogenesis and subsequently a portion of this material is released as landfill gas with a methane content of 35 – 45%. The leachete from this OF material also has the potential to pollute ground water, and subsoils depending on the prevailing geology and hydrogeology (EPA, 2000) (Eunomia, 2008).

Source seperation of the OF-MSW is undertaken in parts of the Galway region by the utilisation of a 3rd collection stream, the so called 'green bag' to eliminate this element from the final waste process (EPA, 2009). In other parts of the region mechanical biological treatment (MBT) is undertaken, where this seperation is achieved at the processing plant prior to the final disposal of the waste residuals to land fill. Under both secenarios the seperated OF is then subjected to further treatment. This can be aerobic if the end product is to reduce the organic compontant and to create a stabilised material for composting or landfilling (EC, 1999). Alternatively it may be anaerobic if the energic compontant of this material (biogas) is required in addition to the production of stabilised material for landfilling or further composting (E.U., 2009; Eunomia, 2008).

As with biosolids previously, the platform for energy production from OF of MSW is the generation of biogas via the biochemical process of anaerobic digestion (AD). The energic potential of OF, as expressed in biogas yield, has been widely reported and yields range from 0.275 (Caplea *et al*, 2008). 0.288 (Mohan & Bindhu, 2008), 0.50 (Gebrezgabher *et al*, 2009), 0.67 Nm^3 CH_4/kg total volitle solids (TSV) (McDonald *et al*, 2008).

Gebrezgabher *et al* (2009) and McDonald *et al* (2008) report increased biogas yields and reductions in chemical oxygen demand (COD) / total volitle solids (TVS) in systems where biosolids and OF-MSW are co-digested. In terms of economics a waste treatment system which has a common platform for energy production and utilises the same biochemical process raises interesting possibilities. Rather than developing multiple technologies to treat individual waste streams, the management of the waste streams can be in terms of pre-treatment, batching, and parameter control all of which can be applied to the multiple waste streams thus reducing costs and increasing the efficency of the waste treatment and energy production systems.

4.3 Existing Agricultural and Forestry Waste Streams.

In terms of quantity of waste residuals available (ton /pa) within the study area the greatest local resourse exist within the agricultural and forestry sector's. Currently in terms of forestry, two distinct commerical entreprises exist within the study area which convert bulk forestry biomass into marketable products. These saw mills are located in Woodford and Gorteeny and on annual estimations convert between 1000 – 1500 tpa each (Conry, 2010) (Mahon, 2010). These enterprises are 1-2 men operations in which the princible owner provides the majority of the labour supplemented by casual labour. Residuals, (sawdust, waste timber, etc) from these operations are utilised locally for equestrian bedding, and temporary constructions with an increasing precentage being diverted to local reprocessers such as Connaught Timber, Tynagh, Co Galway, or Fisna Forest Products, Scarriff, Co Clare.

As contained in the CSO Agricultural Census of 2000 (CSO, 2002) (CSO, 2006b) within the study area agriculture[35] makes up 36.4% of land use. The employment profile for the same areas indicates that 29% of the population within the feasibility study area are engaged in farming practices on a full time / part time basis.

Table 7. Break down of agricultural holding within study area.

DED	Farmed (Ha)	Crops (Ha)	Total DED (Ha)	Total Agri (Ha)	% Agri
Ballyangar	763	11	2333	774	33.17
Lough Atorick	249[36]	16	3845	265	6.89
Marble Hill	1704	16	3566	1720	48.23
Woodford	802	0	2325	802	34.49
AbbeyVille	1372	26	1791	1398	78.05
Ballyglass	689	N.L.[37]	1381	689	49.8
Coos	590	0	3479	590	16.95
Drummin	1961	23	4085	1984	48.56
Total	**8130**	**92**	**22805**	**8222**	**36.05**

Developed from COS 2002

[35] Total area farmed, including crops, fruit, horticulture and potatoes. (CSO, 2006b)
[36] Incomplete data set, Includes areas not listed (N.L.) due to confidentially
[37] Not listed in CSO 2000 figures due to confidentially

Table 8 . Agricultural Empolyment profile - Study Area

DED	Head of Household	Spouse	Other family	Regular Non Family	Totals
Ballynagar	38	12	13	2	65
Lough Atorick	n.l.	2	3	1	6
Marble Hill	71	27	26	5	129
Woodford	41	6	14	0	61
Abbeyville	49	27	26	5	107
Ballyglass	29	11	20	0	60
Coos	28	7	7	2	44
Drummin	64	23	38	2	127
Total	**320**	**115**	**147**	**17**	**599**

Developed from COS 2002

Increasingly and with particular reference to the nitates regulations S.I. 101:2009 (DEHLG, 2009), agricultural holdings are ensuring that the storage of farm slurry is contained within structures which allow extended periods of containment, these periods range from between 16 – 26 weeks depending on enterprise. This allows the management of land application of the residual material to be controlled to periods where the likehood of leachete / runoff is reduced. (DEHLG, 2008).

In the last 30 years increased use has been made of this feedstock for the production of energy via biogas production and utilisation in gas engine/CHP technology ((Mahony, *et al* 2002; Monnet, 2003; Raven & Gregersen, 2005; Demirbas, 2006, Rodhe *et al* 2006; Heslop, 2007; Marsh, 2008; Cantrell, *et al*, 2008; Ward *et al*, 2008; Lansing,*et al* 2008). Primarly utilised in electrical generation, utilisation of the waste heat generated from this process in CHP units has increased the efficency of this conversation technology from 25-35% for electricity alone to between 65 – 85% where a market for the heat can be utilised. (HVCA, 2008).

Anaerobic Digestion(AD) has been the primary biochemical process in the development of the biogas platform from agricultural manure waste's (*please refer to table 9 below*)., and technical advancments in low and medium temperature anaerobic environments look may offer greater efficencies in overall production (Bohn, *et al.*,2007; Ryan, *et al.*, 2005)

The common biochemical platform between the primary waste streams, to be used in this feasibility study allows for efficiencies to be achieved and operations to be simplified. Issues relating to the most appropiate AD configuration to be employed with these waste streams will be detail further in chapter 5.

Figures for the containment vessels for agricultural residues (slurry) within the study area are incomplete, however discussions with local farming repesentatives (Lyons, 2010; Porter, 2010) have indicated that potential storage of slurry within a sample of 46 farming units in the study area is in excess of 15,500 ton/pa. This figure of 46 farming units equates to a sample size of 14% of the total farms within the study area.

100% acceptance by a community on any proposal is unexpected to be achieved, so for the basis of the completion of this review the maximum annual agricultural residual to be treated will be taken as 15,500 ton/pa. The biogas potential of manure wastes are widely reported and the following table presents the range which exists within a limited review of the current literature.

Table 9. Biogas Potential of Agricultural Manures (Cattle)

	Agricultural Waste Category	**VS / TS %**	**(Biogas yield) Nm^3 /Kg VS**	**CH_4 (Content % biogas)**	**Author / work reported in**
1	Manure - Cattle	80.8	0.438	64.4	(McDonald *et al*, 2008)
2	Manure- Dairy	79.7	0.269	59.4	(McDonald *et al*, 2008)
3	Manure – Dairy	80	0.2	60.0	(Heslop, *et al* 2007)
4	Manure Dairy	89.2	0.298	49.3	(Demirbas, 2006)
5	Manure – Dairy	81.0	0.25 – 0.50	60.0	(Caplea, *et al*, 2008)
6	Slurry – Cow	75 – 85	0.20 – 0.30	55 – 85	(Monnet, 2003)
7	Slurry – Cow		0.21	60	(Heslop, 2007)
8	Slurry – Cow			61.7	(Lansing *et al* 2008)
9	Slurry – Dairy	76.6	0.13 0.179	49 @ 30d/35°C 68@ 50d/35°C	(Kaparaju & Rintala, 2008)
10	Slurry – Cattle	76 – 83	0.2 – 0.3	c.60	(Booth, *et al*, 2007)
11	Slurry – Dairy	75.7 – 78.74	0.21 – 0.23	58-60 (TPAD-55°C / 35°C)	(Harikishan & Sung, 2003)

Utilising the data above and excluding the highest and lowest readings, (i.e data set 1, 9 biogas yield only.) the average biogas yield estimate is 0.237 Nm^3/kg VS with a CH_4 % content of 61.07. These figures will be utilised in the economic analysis to be performed as part of this work. The average VS/TS ratio derived from the above figures is 80.44% and dry matter will be assumed to be $10\%/t^{-1}$.

4.4 Summary – Waste Profile

The waste available within the study area is varied and ranges from biosolids, MSW, OF-MSW, forestry and agricultural residues, however the opportunity to utilise a common biochemical process, to develop a primary energy source has meant that the waste streams to be exploited are Biosolid , OF-MSW and Agricultural Slurry.

The amounts which are applicable in the study area are

- Biosolid – *potential*
    - Primary 10700 kg/pa
    - Secondary 37900 kg/pa
- Organic fraction – Municipal Solid Waste *potential*
    - 225,000 kg/pa
- Agricultural Slurry (dairy/cattle) *potential*
    - 15,500,000 kg

Anaerobic digestion (AD) is the common biochemical process for the above waste streams which will allow for the production of Biogas. The processing of this waste material via AD will be examined in terms of its waste treatment potential, energy generation potential, soil amending potential, nutrient supplementation potential, and other non-marketing co-benefits.

5 Bio-refining, technology and principles.

Orthodox interpretation of a Bio-refinery facility include an '*integrated plant producing multiple value added products from a range of renewable feedstock's*' (I.C., 2006) as a '*facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass*' (NREL, 2009)or as integrated facilities which, '*...convert a variety of feedstock's, including residues, into a portfolio of products with improved energetic chain efficiency, economy and environmental effects..*'(IEA 2009a).

Within the International Energy Agency's (IEA) Bioenergy Group, bio-refineries and associated co-processes are under taken by the sub group; Task 42 – Bio-refineries. Within this specific remit the Task 42 group have further described this industry such that a, "*Bio-refinery is the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)*" (IEA 2009b).

Kamm, *et al.*, (2005) describe in detail the methodologies utilised within this sphere of industry, and though diverse these processes are utilised in logical sequence, cognisant of the biological nature of the feedstock and the required product or products; the environmental impacts of each step of the processes, and the economic validity of the operation as a whole.

From the above it can be demonstrated that a central paradigm in relation to such facilities or processes, is that the primary feedstock should originate from a sustainable biological source. Indeed, this underlying principle is a logical development of the IEA definition of the Bioenergy which is described as utilising '*material which is directly or indirectly produced by photosynthesis and which is utilised as a feedstock in the manufacture of fuels and substitutes for petrochemical and other energy intensive products*'(IEA 2009a).

The Renewable Energy Directive (RED) 2009/28/EC (E.C., 2009) reinforces the utilisation of waste materials and specifically incentivises the production of transport fuels from wastes. Within RED, units of transport fuel energy derived from residual or waste streams are counted as double as opposed to transport fuels derived from other renewable sources e.g. pure plant oil PPO.

The earlier landfill directive has the reduction of the biodegradable organic materials in landfill as a key objective. This is to diminish the issues relating to leachete, methane production, and volumetric quantities which have represented major issues within landfill management since the issue was first addressed in on a European Community wide basis in 1975 with the Directive on Waste 75/442/EEC.

As outlined in chapter 2, this work does not intent to recommend the implementation of industrialised solutions for the task in hand, but rather is attempting to examine if the technologies and principles at work within industrialised bio refinery complexes can be successfully implemented within more discrete and decentralised locations. The identification of available waste streams, and a common biochemical process, Anaerobic Digestion, now allows one to examine the range of possibilities which may be located in series or parallel with this process to achieve the greatest benefit in terms of economics, environment and community sustainability.

5.1 Anaerobic / aerobic digestion

Anaerobic and Aerobic Digestion are natural processes through which biological material is broken down via microbial and bacterial action in the presence or absence of oxygen. As such these processes are present in almost all environments and the speed of the conversation of the biological material (feedstock) is a function of the controlling parameters. These include micro and macro fauna, chemical and bacteriological composition, temperature, moisture content, O_2 levels, pH and time (Cavinato *et al.*, 2010). Both systems are utilised within the waste management industry for the conversion and reduction of waste volumes, and within bio refinery processes, AD is the more commonly used of the two processes for biogas, H_2 production platforms. (I.E.A., 2009) .

In waste management and biogas production AD is subject to operational variations with regard to the feedstock, product required, operational time scales, gross volumetric handling etc. Meulepas *et al*, (2005) and Ward *et al*, (2008) detail the environmental parameters which need to be addressed to ensure successful operation of AD systems. These include

- Feedstock Content
- Temperature
- Nutrients
- Toxicants
- pH and Alkalinity

- Water content.

One item which is not referred to in Meulepas *et al.,* (2005) is time. Where biogas production is an economic driver of an integrated system, then hydraulic retention time (HRT) can form a significant part of the operational management. Harikishan & Sung (2003) have reported 50% increases in biogas yield, when the HRT was extended from 30-50 days out to 250-340 day HRT. However HRT periods of this magnitude are not practicable in commercial operations as the infrastructural requirements regarding storage is would predicate against this.

Harikishan & Sung., (2003) U.S.E.P.A., (2006) and Chan *et al*., (2009) all discuss the implications of utilising in-series or integrated AD bioreactors. Issues relating to temperature regimes and anaerobic/aerobic configurations are outlined, with corresponding results in the increasing biogas yield, reduction of biological oxygen demand and reduction of volatile solids for the production of Class A Biosolids (USEPA, 2003). Chan *et al*, (2009) detail new configurations and prototype designs for high organic loading regimes of waste water treatment, applicable where space in municipal settings is a limiting factor.

Capela *et al.,* (2008), Demirbas (2006) Cavinato *et al.,* (2010) McDonald *et al.,* (2008) and Gomez *et al.,* (2010) all develop strategies for the co-digestion of agricultural wastes with other organic wastes under AD conditions. Capela *et al.,* (2008) outlines in detail the yield potential for various co-digestion strategies, with reported yields of 0.0240 – 0.290Nm^3 CH_4/Kg TVS. These results are in line with literature reported averages for manure on its own (0.237 Nm^3 CH_4/kg VS *table 9 above*), and are as a result of utilising OF-MSW, industrial sludge (IS) and cow manure (CW) in ratios of 95%/5%/5%. McDonald (2008) reports rates of biogas production equating to 0.514 Nm^3 CH_4/kg VS for 70/30 cattle manure /hog manure mix, and 0.517 Nm^3 CH_4/kg VS for 85/15 cattle manure/ offal mix. The consensus among these authors is that co-digestion, increases the productivity of biogas production, increases BOD/COD removal, stabilises C/N ratios and increases mineralisation rates of both phosphorus (P) and nitrogen (N) within the resultant digestate and liquor.

Tambone *et al.,* (2009) describe the stability of the digestate derived from co-digested feedstock's including OF-MSW, Agri-industrial waste, cow slurry and energy crops. The effect of AD was to reduce oxygen demand (OD) and increase recalcitrant fractions (i.e.

lignin and non-hydrolysable lipids) within the final digestate. The work outlined a strong correlation in results between two methods of testing the anaerobic potential biogas production of a sample. The SOUR-test[38] (OD_{20}, $mgO_2/g\ TS^{-1}20\ h^{-1}$) results are available in a 48 hr period where as the Anaerobic Potential Biogas production (ABP) technique requires periods of 60 d to complete. The SOUR-test has the potential to simplify and reduce costs associated with AD operations in the confirmation of stability of the final material. It is detailed in this study that the final digestate material studied had respiration activity (OD_{20}) figures of 30mg O_2 /g @ 50 day HRT. Nevertheless this is 3 times the required rate for stabilised digestate or compost under the draft EC regulations for this material to be utilised as class 1 material (EC, 2008).

As outlined earlier pH is a critical parameter in AD operation. Massanrt-Nicolau *et al* (2008) have investigated and reported the effect of decreasing the pH parameter during anaerobic conditions. It is reported that a pH 5.5 and a temperature of 35^0C, facilitate the generation of H_2 at a yield of 0.018 Nm^3H_2/kg VS @ 47% H_2 content. Thought the content level and the yield are both low this is a notable achievement, as the production of H_2 directly from AD increases the opportunity for the direct production of H_2 without the necessity of reforming CH_4 to H^2. Reforming CH_4 to H^2 is undertaken by means of steam reforming or alternatively utilising water electrolysis or water gas shift, each of which require large amounts of primary power in order to be accomplished. The above work has correlations with works carried out by (Pathak *et al*, 2009), which related to the effective ranges for the bioleaching of heavy metals (HM) from sewage sludge. In order to effectively remove HM, pH ranges between 1.5 – 6 have been shown to accommodate removal rates of up to 100% depending on metal speciation and pH regime (Pathak *et al* 2009: 2350). However to ensure adequate mineralisation ratios of P:N in the final digestate, it has been found that the pH range needs to be maintained 3-4 to 6 pH.

Utilisation of complementary technologies downstream or in parallel with standardised AD technology has been addressed previously. Cantrell *et al* (2008) details alternative thermo-chemical conversion (TCC) technologies to be utilised in series with standard AD technologies. Utilising both biochemical and thermo-chemical technologies, they argue increases the overall efficiency.

[38] D'Imporanzo, G.; Adani, F.; (2007). The contribution of water soluble and water insoluble organic fraction to oxygen uptake rate during high rate composting. Biodegradation. 18; 103-113.

This work examines the alternative operational requirements of bio-methanol, bio-hydrogen and algal photosynthetic H2 production, as well as the utilisation of these products under TCC technologies such as pyrolysis, wet and dry gasification etc. The applicability of some of these technologies may not complement the location or infrastructural facilities present in more decentralised locations, and as yet some of these process are unproven on a commercial basis.

5.1.3 Aerobic Digestion (Composting)

Composting of AD digestate, i.e. material that has been processed by AD, and of OF-MSW is becoming increasing popular as it is understood that the process of composting can benefit the final material prior to addition to soil or in terms of producing material with a stabilisation and sanitation profile which addresses landfill criteria (EC, 1999).

A major concern with usage of both products is the content of heavy metals (Alvarez, *et al.* 2002) (Fairbrother *et al.*, 2007) (Madrid *et al.*, 2007) (Achiba, et al., 2009) (Atlas, 2009) (Smith, 2009), levels of pathogens (Sindu & Toze, 2009), viruses, biological (Schowanek, et al., 2004) and chemical residues (Caplea *et al.*, 2008) present within these processed materials and the subsequent bioaccumulation or transmission factor to all biotic forms.

In relation to bio availability of heavy metal (HM) it is shown that the segregation procedure, i.e. source-segregated or mechanically-sorted, had a greatest influence on the final levels of the HM within the resultant compost (Lópaz *et al.*, 2010; Hargreaves *et al*, 2008; Farrell & Jones, 2009). Thus the feedstock material is crucial in any management regime to control HM levels to be addressed in land application (Smith, 2009). Subsequent applications of compost there-after decrease the bioavailability of HM by sorption and in are shown to reduce existing background levels (Farrell & Jones, 2009; Smith, 2009).

(Ruggieri *et al.*, 2008) present findings in relation to the comparision of 3 external composting systems, Turned pile (TP), Turned forced-aerated Pile (TAP), and Static Forced-Aerated Pile (SAP). With reference to the proposed Directive on Biowaste, (EC, 2001) (EC, 2008), Ruggieri *et al.*,(2008) report that both the TP and TAP experiments comply with the draft regulations for biowaste as specified with regard to minimum temperature and maintaining the period ,in days, of this temperature, (55^0C for a period of two weeks to include 5 full turnings). Once the compost was matured the respiration rate dropped to 2.4 – 1.0 mg O_2/ g $^{organic\ matter}$ /h^{-1} which are substantially below the requirement of 10mg O_2/g $^{organic\ matter}$ / h^{-1}. The limiting factor in both the TP and TAP systems was moisture content, with data showing that in all cases, levels periodically dropped below 40%, which is taken as the lower limit to ensure organic degradation.

Komilis (2006) demonstrates how the key parameters of time and material composition with regard to hydrolysable carbon fraction (HCF) affect aerobic decomposition. The distribution of readily, moderately, and slowly HCF vary within a biodegradable material. Komilis reports that OF–MSW contains the greatest % of rHCF, to total organic carbon (TOC) @ 25%; the greatest % of rHCF + mHCF to TOC @ 92% and that grass contains the largest % of mHCF @ 90%. Though reported in terms of aerobic conditions, the occurrence of HCF ratios among feedstock's, offer important considerations for finalising mixture ratios for co-digestion in AD. In turn this contributes to the analysis of the results to be found in literature concerning AD performances with regard to elevated biogas production.

(Gremer *et al.*, 2010) outline issues in maintaining adequate temperature gradients on externally composted faecal and co-substrate material. As in Ruggieri *et al.*, (2008) mixing was achieved without forced aeration for the external composting experiment and subsequently this setup resembles a Turned Piled (TP) experiential design. The in-chamber experiment described by Gremer *et al* (2010) does not have any forced aeration nor does it seem to have a mixing regime. In this regard then it more closely resembles the Static Aerated Pile (SAP) experiment described by Ruggeri *et al* (2008).

Both experiments were conducted for excess of 80 days. In-chamber temperature profiles achieve the draft Biowaste standards (EC, 2001) for temperature and duration. It should be noted however that the ambient temp for the experiment is 30^0C, and this may affect any replication within a European context. Neither Gremer *et al* (2010) or Ruggieri *et al* (2008) note the importance of HCF in contributing to the results reported in either work. In the case of Gremer *et al* (2010) the percentage of woody bush utilised as a co-composting agent would have acted contrary, i.e. maintaining high core temperature and subsequent pathogen removal, to the desired result due to the high levels of mHCF and sHCF to be found in these types of biological materials (Komilis, 2006).

The use of composted material from various feedstock's is widely controlled in a number of jurisdictions (BSI, 2005) (EC, 2001) (USEPA, 2003). Within Ireland the implementation of BSI PAS:100 (BSI, 2005), forms the basis of the voluntary regulatory framework, though an industry-led standard has been developed for consideration (Prassad & Foster, 2009). Where material is defined as originating from animal by-product (ABP) then the following regulations take precedence; S.I. no 508:2009 (DEHLG, 2009), S.I. 253: 2008 (DAFF, 2008) and conditions for operation of Biogas plants (DAFF, 2009) *See table 10 Below*

5.2 Bio refinery – Summary.

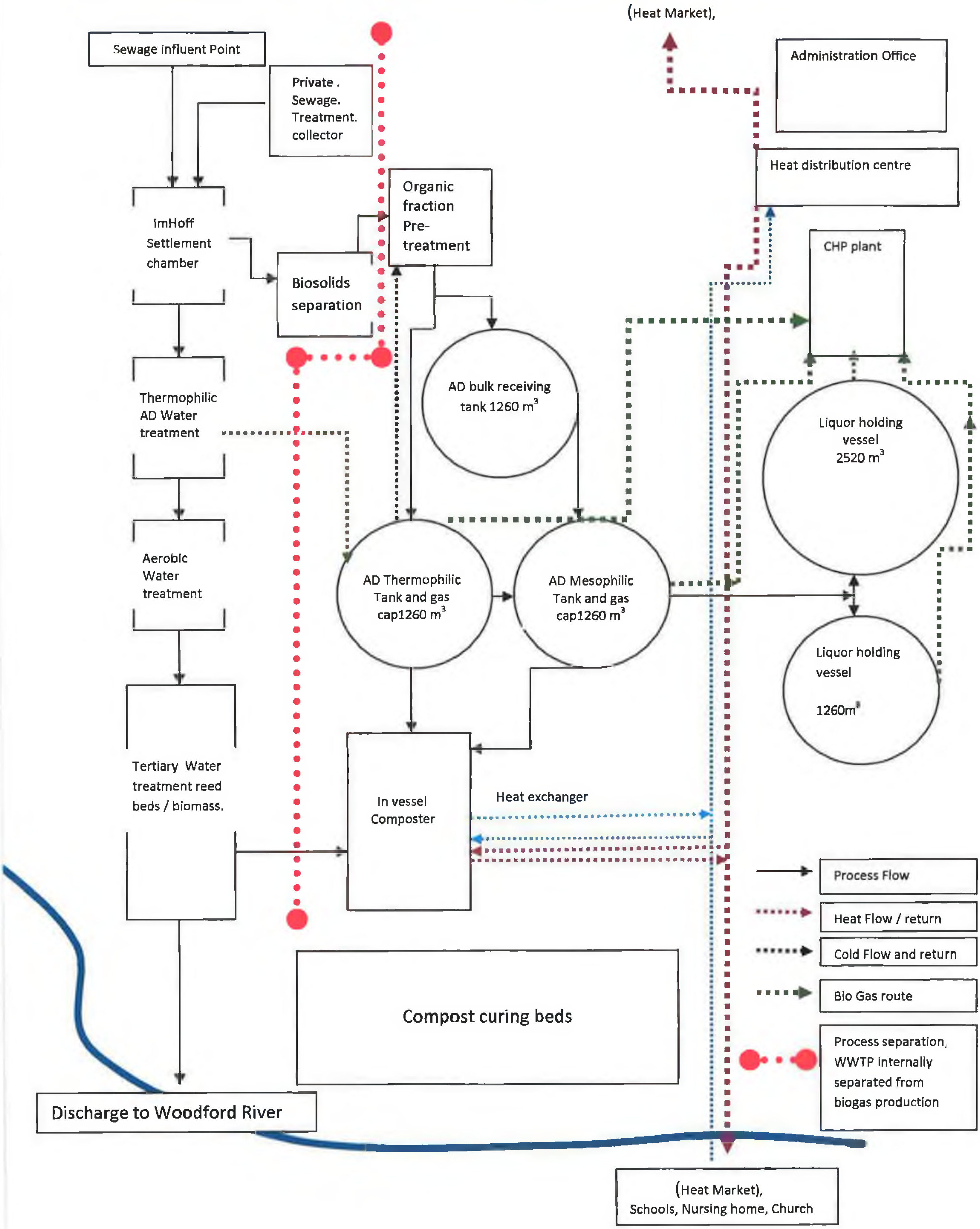
Anaerobic digestion (AD) is widely utilised in waste water treatment, biogas production and as well as being a general biochemical process within bio-refinery systems (Edelmann, 2007) (Al Seadi, et al., 2008) (I.E.A., 2009) (Chan, *et al.*, 2009). With regard to the dual objective of waste treatment and biogas production then the consensus within the reviewed literature would state that the following configuration would be the most efficient.

- Waste Water Treatment Plant (WWTP)
  - Settlement tank / biosolids separation
    - Private septic tank addition point
  - Anaerobic Digestion @ thermophilic range (CH$_4$ removed)
    - *Additional* Anoxic tank (N:P removal)
  - Aerobic treatment tank.
  - discharge treatment via reed bed /SRC system (Biomass resource)
    - Alternative - Bioleaching (Heavy metal extraction)
    - Alternative - Algal treatment (Biomass resource)

Parallel operation

- Energy from Waste (EfW)
  - Organic fraction/ biosolids pre treatment
  - Anaerobic Digestion (thermophilic) (Ch4 removed)
  - Anaerobic Digestion (mesophilic) (Ch4 removed)
  - Aerobic (Composting) treatment of digestate (Composted resource)
  - Long term AD low temp(3-6 month) storage Liquor (CH4 removed)
  - Biogas utilisation via CHP (Electrical/heat recourse)

Figure 12. Schematic of proposed Integrated Energy from Waste Plant (IW*f*ETP)



Under the Biowaste directive (EC, 2001), Class 1 compost / digestate has unrestricted agricultural application. The co-digestion of waste from source separated OF-MSW, UWWTP derived biosolid, and agricultural slurry residues to the above biowaste standard, has the potential to resolve a number of issues within rural communities.

It allows for a common platform to utilise multiple waste streams, to achieve a variety of options. It can release viable amounts of energy from agricultural residues (Heslop, *et al.*,, 2007), whilst at the same time stabilising carbon: nitrogen ratios thereby increasing the availability of total organic nitrogen. The neutral pH balance of the digestate and liquor fractions will decrease the bioavailability of heavy metals that may be present in the background soils while simultaneously reducing any additional heavy metal accumulation. (Achiba, et al., 2009; Lόpaz, *et al.*, 2010)

The integration of SS/OF-MSW increases the efficiency of biogas production by providing a buffering element within the digester system. The addition of materials with high% of rHCF and mHCF provides increased energy to the microbial activities within the digester. These new energetic sources also increase the mineralisation of the organic material thus ensuring the nitrogen & phosphorous elements remain tightly bound to the fibre material and are more resistant to leaching when compared to raw slurry. (Harikishan & Sung, 2003)

Consequently the increasingly stabilised digestate now has an increased value in terms of fertilizer and in allowing the end user to remain compliant with regard to nitrate regulations (Battistoni, *et al.*, 2007). The integration of SS/OF within this system reduces the pressure on centralised municipal waste management resources attempting to collect this fraction under normalised 'organic green bag' initiatives. Instead operational savings can be diverted to regional funding for education on waste reduction practices.

Once established, the integration of an Up-concentration waste water treatment plant (UcWWTP) within the energy process, allows for a fully modern AD treatment with secondary aerobic and tertiary treatment plant to be installed. The additional mineralisation of the digestate via bio-solid and urea addition, allows for the valuable replacement of N & P which may be lost in the acidogenesis and methanogenesis processes which are part of the AD biochemical process. (Verstraete, *et al.*, 2009)

In principle each sector, agricultural, domestic, industrial commercial and public, benefits from the synergistic possesses at play. The following sections will concentrate on the financial viability of this proposal, the socio-economic implications and the issues which currently resist this type of proactive development.

Table 10 – Comparative Composting / Digestate standards

Parameter	Compost / Digestate		Stabilised biowaste	Compost	Compost	Digestate	Biosolid
	Biowaste Directive (EC, 2001)			**Ire** (Prassad & Foster, 2009)	**UK PAS:100** (BSI, 2005)	**UK PAS:110** (BSI, 2010)	**Part 503** (USEPA, 2003)
	Class 1	**Class 2**	**Land fill**		**General use**		**Class A**
Mo (mg/kg dm)							75
As (mg/kg dm)							41
Se (mg/kg dm)							100
Cd (mg/kg dm)	0.7	1.5	5	1.3	1.5	1.5	39
Cr (mg/kg dm)	100	150	600	92	200	100	
Cu (mg/kg dm)	100	150	600	149	200	200	1500
Hg (mg/kg dm)	0.5	1	5	0.4	1	1	17
Ni (mg/kg dm)	50	75	150	56	50	50	420
Pb (mg/kg dm)	100	150	500	149	200	200	300
Zn (mg/kg dm)	200	400	1500	397	400	400	2800
PCB (mg/kg dm)			0.4				
PAH (mg/kg dm)			3				
Impurities > 2mm	< 0.5%	<0.5%	<3%	<0.5%	<0.5	<0.5	
Gravel and stones > 5mm	<5%	<5%	-	-	8	8	
Salmonella spp				0	0	0	3MPN/4g
Escherichia Coli CFU/g DM				1000	1000	1000	1000MPN /g Dm
Enteric Viruses							1 PfU / 4g DW
Helminth Ova							1 / g DW TS
VS reduction %							38>
Organic Matter %	30	30	30	20			
Stability (AT_4) mg O_2/g DM				13	16		
Residual Biogas Potential l /g VS						0.25	
Volatile Fatty Acids g COD /g VS						0.43	

6. Energy from Waste (E*f*W): Financial considerations.

It is recognised that digestate material[39] as a by-product of an AD process has a market value both in terms as a partial replacement for artificial fertilizer or as a soil improver (Marsh, 2008) (Monnet, 2003) (U.S.E.P.A., 2006). The market value of this product ranges from neutral (Murphy & McKeogh, 2006) to positive depending on the format and mechanical handling of the product (Rodhe, *et al*, 2006) (EA, 2008a) but the feedstock for this process determines the applicability of this material. Currently within the UK the PAS[40] 110:2010 for digestate material provides a voluntary code of practice which strictly regulates the feedstock sources to ensure that resultant material conforms to the prescribed standards for Quality Digestate production (BSI, 2010) (EA, 2008b) (EA, 2008a).

As with the PAS:110 Protocols for composts (BSI, 2005) a key objective of PAS:110 and the associated Quality Protocols (QP) and Waste Protocols (WP) for anaerobic digestate (BSI, 2010) is to provide industry actors with marketable products which have been developed from source segregated waste streams / feedstock and which conform to the required standards. The application of these materials within identified markets is currently restricted under PAS:110, and typically it is envisaged that digestate material derived is for use in general agriculture, forestry, land remediation etc.

On a European arena, Class 1 digestate from biowaste (EC, 2001) offers a possible solution to the issues raised in this work. Within Ireland no standards exist for the use of biowaste / biosolids as described in the European draft directive on biowaste. Comparisons outlined in *table 10 above* indicated that the compliance requirements between European and US Class 1/A bio solids/bio wastes are substantially different with a increase risk aversion present within the European limits.

This conservative approach is due to a perceived lack of detailed technical information regarding the applicable of digestate[41] or quality digestate[42] in specific agricultural and horticultural practices and in particular with regard to pathogen levels, heavy metals, organic and inorganic pollutants (Schowanek, et al., 2004) (Fairbrother, *et al.*, 2007)

[39] Digestate material refers to Whole Digestate (both Liquid and Fibre fraction), Liquor, and separated Fibre fraction.

[40] Publically Available Specification – voluntary industry practice specifications developed in association with the British Standards Institution (BSI) which are developed as guidance documents until such time as full BSI standards may be issued in relation to the particular process / issue

[41] Digestate – material produced via anaerobic digestion, (EA, 2008a)

[42] Quality Digestate – material produced via anaerobic digestion which fulfils the requirements of PAS110:2010 (EA, 2008a)

(Sindu & Toze, 2009). Background levels of HM are unknown on a ha^{-1} by ha^{-1} basis throughout the EU, so the reduced limits presented within the biowaste directive can be seen as a risk adverse policy towards unknown interactions and bioaccumulation levels in the future (McBride, 2003).as yet final implementation of this biowaste directive has not been agreed despite 10 yrs of negotiation.

It is anticipated that these restrictions may alter as the technical developments in anaerobic digestion, exposure assessments to hazardous agents and data relating to the bioaccumulation of elements within produce exposed to this material becomes available (EA, 2008a).

Anthropogenic biosolids matter via waste water treatment systems or other process are included within the draft Biowaste directive, and a full list of the acceptable biowaste categories as described under are the European waste catalogue code are listed in appendix A.

Within the Irish jurisdiction, biogas plants which utilise animal by-products (ABP) and other biological feedstock are regulated by S.I.252:2008 and S.I.253:2008 (DAFF, 2009) (DAFF, 2008) and EC 1774/2002 (EC, 2002). Restrictions on the processing type, feedstock, handling and distribution are extensive and the primary purpose of the legislation is the '*protection of the human and animal health by providing controls for the safe use and disposal of animal by products*' (DAFF, 2008). In this context it is the renewable energy potential of the ABP which is of primary concern and the digestate which is produced is still regarded as a hazardous product.

6.1 Financial Assumptions

The following assumptions will be under taken with this work. Materials Assumptions

1. All processed materials will comply with Biowaste directive (Class1 Material)
2. The waste materials to be co-digested are
    a. Source selected organic fraction of municipal solid waste including domestic kitchen waste, (excluding paper, cardboard, etc)
    b. Green garden material.(grass, weeds etc)
    c. Yard sweepings including leaves, branches, etc.
3. Biosolids via waste water treatment plant.
4. Biosolids from private septic tanks
5. Agricultural residues (slurry)

The following assumptions will be under taken with this work. Energy assumptions

1. The biogas potential of the waste materials are as follows
    a. Agricultural residues (*Averages; refer to table 9 above*)
        i. DM 10% by weight
        ii. Biogas yield 0.237 Nm^3/kg VS with a CH_4 % content of 61.07
        iii. VS/TS ratio 80.44%
    b. Organic Fraction – MSW (McDonald, *et al*, 2008; Battistoni, *et al*, 2007)
        i. DM 30.5% by weight
        ii. Biogas yield 0.676 Nm^3/kg VS with a CH_4 % content of 65.4
        iii. VS/TS ratio 78. %
    c. Biosolids – WWTP (McDonald, *et al*, 2008)
        i. DM 1% by weight
        ii. Biogas yield 0.32 Nm^3/kg VS with a CH_4 % content of 57.7
        iii. VS/TS ratio 71.1%

2. The waste materials to be co-digested are – Source selection Criteria
    a. Source selected organic fraction of municipal solid waste
        i. domestic kitchen waste, (excluding paper, cardboard, etc)
        ii. Green garden material.(grass, weeds etc)
        iii. Yard sweepings including leaves, branches, etc.
    b. Biosolids
        i. via waste water treatment plant.
        ii. from private septic tanks
    c. Agricultural residues (slurry)

3. Annual Quantities of Waste materials Waste Material Resource.
    a. Source selected Organic Fraction
        i. 225,000 kg /pa
    b. Biosolids
        i. WWTP 10,712 kg (plus 30,000,000kg blackwater)
        ii. PST 37,900kg /pa
    c. Agricultural Slurry
        i. 15,500,000 kg / pa

4. Energy Sales Costs
    i. Electricity - (DCENR, 2010a 2010b)
    ii. €150 / MWh
  b. Heat
    i. No set market price, Economic price set to €30 / MWh
    ii. In plant usage set at 50% of production (minimum)
  c. Digestate liquor
    i. Free to centralised distribution points
  d. Composted Digestate
    i. € 10 ton
  e. Gate fee
    i. None
5. Operational Costs
  a. Annualised costs €10/ton material digested
6. Waste treatments sales
  a. Processing private septic tanks @ €175 per unit
  b. WWTP costs are €1 per M^3 treated
7. Development costs /Initial capital costs paid from central exchequer
  a. Total cost € 1.4m
  b. Capital WWTP cost Galway County Council

6.2 Economic Results

Table 11a. Estimated Biogas yields – waste streams, isolated & combined.

		Biogas Production Yields individualised and combined					
		Kg /pa	Dry matter %	VS/TS % DM	Yield%	CH_4 %	M^3 CH_4
1	Agri residues	15500000	0.1	0.8044	0.237	0.6107	180459.615
2	Biosolid residues uWWTP	30295000	0.01	0.711	0.32	0.577	39770.9852
3	Biosolid residues PST[43]	3758760	0.01	0.711	0.32	0.577	4934.46404
4	Organic Fraction	225000	0.305	0.78	0.676	0.645	23339.0606
5	Co Digestion All Waste	49778760	0.0527[44]	0.75	0.3	0.6	354150

Table 11b – estimated kWh production, CHP utilising Scrubbed biogas.

	kWh production from CHP plant utilising Biogas							
	MJ /M^3 CH_4	Total MJ /CH_4	MJ/ kWh	Total kWh/pa (potential)	Electrical efficiency	Heat efficiency	Total Electrical kWh	Total heating kWh
Agri residues	37.78	6817764	3.2	2130551	0.3	0.48	639165	1022664
Biosolid residues WWTP	37.78	1502547	3.2	469546	0.3	0.48	140863	225382
Biosolid residues PST	37.78	186424.	3.2	58257	0.3	0.48	17477	27963
Organic Fraction	37.78	881749.	3.2	275546	0.3	0.48	82664	132262
Co-Digestate All Waste	37.78	1337982	3.2	4181195	0.3	0.48	1254358	2006973

[43] PST private septic tank
[44] This DM figure is a cumulative percentage total of the combined fractions, i.e. OF 0.006, Biosolid residue PST 0.0007, Biosolid residue uWWTP 0.15, Agri residue0.031. Total 0.0527 % DM

Table 11c, Economic return, REFIT price for electric .

Economic returns - Biogas					
	REFIT Cost per MWh^e 45	Cost per MWh^h 46	Potential MWh^e 47	Potential MWh^h 48	Total revenue
Agri residues	€150.00	€30.00	€95,874.81	€30,679.94	€126,554.75
Biosolid residues WWTP	€150.00	€30.00	€21,129.58	€6,761.47	€27,891.04
Biosolid residues PST	€150.00	€30.00	€2,621.59	€838.91	€3,460.50
Organic Fraction	€150.00	€30.00	€12,399.61	€3,967.87	€16,367.48
Co Digestion All Waste	€150.00	€30.00	€188,153.78	€60,209.21	€248,362.99

45 kWh^e Kilo watt Hour - Electricity
46 kWh^h Kilo watt Hour - Heat
47 CHP electrical generating efficiency 30% - (HVCA, 2008)
48 CHP Heat generating efficiency 48% - (HVCA, 2008)

Table 12. NPV 30 yr period, 50% grant aid, interest @5%pa, all figures €million.

Yrs	installation price	Grant Aid & 50%	NPV	operating costs [49]	Revenue (a) [50, 51]	Revenue (b) [45]	Revenue (c) [45]	Revenue (d) [45]	Gross debt	Debt servicing	Net deficit
0	-€2.4300	-€1.2150	€1.2150	-€0.1226	€0.1531	€0.1034	€0.0280	€0.0130	€1.0401	€0.0520	€1.0921
1			€1.1571	-€0.1196	€0.1459	€0.0985	€0.0266	€0.0124	€0.9934	€0.0497	€1.0431
2			€1.1020	-€0.1167	€0.1389	€0.0938	€0.0254	€0.0118	€0.9489	€0.0474	€0.9964
3			€1.0496	-€0.1139	€0.1323	€0.0893	€0.0241	€0.0112	€0.9064	€0.0453	€0.9518
4			€0.9996	-€0.1111	€0.1260	€0.0851	€0.0230	€0.0107	€0.8659	€0.0433	€0.9092
5			€0.9520	-€0.1084	€0.1200	€0.0810	€0.0219	€0.0102	€0.8273	€0.0414	€0.8686
6			€0.9067	-€0.1058	€0.1143	€0.0772	€0.0209	€0.0097	€0.7904	€0.0395	€0.8299
7			€0.8635	-€0.1032	€0.1088	€0.0735	€0.0199	€0.0092	€0.7552	€0.0378	€0.7930
8			€0.8224	-€0.1007	€0.1037	€0.0700	€0.0189	€0.0088	€0.7216	€0.0361	€0.7577
9			€0.7832	€0.0982	€0.0987	€0.0667	€0.0180	€0.0084	€0.6896	€0.0345	€0.7241
10			€0.7459	€0.0958	€0.0940	€0.0635	€0.0172	€0.0080	€0.6591	€0.0330	€0.6920
11			€0.7104	€0.0935	€0.0895	€0.0605	€0.0163	€0.0076	€0.6299	€0.0315	€0.6614
12			€0.6766	€0.0912	€0.0853	€0.0576	€0.0156	€0.0072	€0.6021	€0.0301	€0.6322
13			€0.6443	€0.0890	€0.0812	€0.0548	€0.0148	€0.0069	€0.5755	€0.0288	€0.6043
14			€0.6137	€0.0868	€0.0773	€0.0522	€0.0141	€0.0066	€0.5502	€0.0275	€0.5777
15			€0.5844	€0.0847	€0.0737	€0.0497	€0.0134	€0.0063	€0.5260	€0.0263	€0.5523
16			€0.5566	€0.0826	€0.0702	€0.0474	€0.0128	€0.0060	€0.5029	€0.0251	€0.5281
17			€0.5301	€0.0806	€0.0668	€0.0451	€0.0122	€0.0057	€0.4809	€0.0240	€0.5049
18			€0.5049	€0.0786	€0.0636	€0.0430	€0.0116	€0.0054	€0.4599	€0.0230	€0.4829
19			€0.4808	€0.0767	€0.0606	€0.0409	€0.0111	€0.0051	€0.4398	€0.0220	€0.4618
20			€0.4579	€0.0748	€0.0577	€0.0390	€0.0105	€0.0049	€0.4206	€0.0210	€0.4417
21			€0.4361	€0.0730	€0.0550	€0.0371	€0.0100	€0.0047	€0.4023	€0.0201	€0.4225
22			€0.4153	€0.0712	€0.0524	€0.0354	€0.0096	€0.0044	€0.3849	€0.0192	€0.4041

[49] Operating costs @€8 per ton agricultural slurry treated.

[50] Revenue (a) MWh electric, MWh heat, 50% heat production reuse in process, Revenue (b), Sewage treatment -Private septic tanks €175 ea, Revenue (c) GHG reduction /ton CO2 equivalent @€20/ton. Revenue (d) odour / N-eutrophication reduction. (Heslop, 2007; Heslop et al 2007).

[51] Revenue A costs are cumulative totals of items 1; 2; 3; 4; tables 11(a),11(b),11(c) ,individual CH_4 yields for separate fractions (conservative figures). The relationship of waste fractions and any beneficial CH^4 additional yield for co-digestion is known to exist, but is dependent upon % mix of materials, seasonality and other parameters. (Caplea, et al., , 2008; McDonald, et al., 2008)

23			€0.3956	€0.0695	€0.0499	€0.0337	€0.0091	€0.0042	€0.3682	€0.0184	€0.3866
24			€0.3767	€0.0678	€0.0475	€0.0321	€0.0087	€0.0040	€0.3523	€0.0176	€0.3699
25			€0.3588	€0.0662	€0.0452	€0.0305	€0.0083	€0.0038	€0.3371	€0.0169	€0.3539
26			€0.3417	€0.0645	€0.0431	€0.0291	€0.0079	€0.0037	€0.3226	€0.0161	€0.3387
27			€0.3254	€0.0630	€0.0410	€0.0277	€0.0075	€0.0035	€0.3087	€0.0154	€0.3241
28			€0.3099	€0.0614	€0.0391	€0.0264	€0.0071	€0.0033	€0.2955	€0.0148	€0.3102
29			€0.2952	€0.0599	€0.0372	€0.0251	€0.0068	€0.0032	€0.2828	€0.0141	€0.2970
30			€0.2811	€0.0585	€0.0354	€0.0239	€0.0065	€0.0030	€0.2708	€0.0135	€0.2843

Table 13 NPV, 30 year period, 100% grant aid, Interest at 5% pa, All figures in € million

Yrs	installation price	Grant Aid & 100%	NPV	operating costs [52]	Revenue (a) [53, 54]	Revenue (b) [47]	Revenue (c) [47]	Revenue (d) [47]	Gross Profit	Debt interest	Net deficit
0	€0.0000	€0.0000	€0.0000	-€0.1226	€0.1531	€0.1034	€0.0280	€0.0130	€0.1749		
1				-€0.1196	€0.1459	€0.0985	€0.0266	€0.0124	€0.1637		
2				-€0.1167	€0.1389	€0.0938	€0.0254	€0.0118	€0.1531		
3				-€0.1139	€0.1323	€0.0893	€0.0241	€0.0112	€0.1431		
4				-€0.1111	€0.1260	€0.0851	€0.0230	€0.0107	€0.1337		
5				-€0.1084	€0.1200	€0.0810	€0.0219	€0.0102	€0.1247		
6				-€0.1058	€0.1143	€0.0772	€0.0209	€0.0097	€0.1163		
7				-€0.1032	€0.1088	€0.0735	€0.0199	€0.0092	€0.1083		
8				-€0.1007	€0.1037	€0.0700	€0.0189	€0.0088	€0.1007		
9				-€0.0982	€0.0987	€0.0667	€0.0180	€0.0084	€0.0936		
10				-€0.0958	€0.0940	€0.0635	€0.0172	€0.0080	€0.0868		
11				-€0.0935	€0.0895	€0.0605	€0.0163	€0.0076	€0.0805		
12				-€0.0912	€0.0853	€0.0576	€0.0156	€0.0072	€0.0745		
13				-€0.0890	€0.0812	€0.0548	€0.0148	€0.0069	€0.0688		
14				-€0.0868	€0.0773	€0.0522	€0.0141	€0.0066	€0.0635		
15				-€0.0847	€0.0737	€0.0497	€0.0134	€0.0063	€0.0584		
16				-€0.0826	€0.0702	€0.0474	€0.0128	€0.0060	€0.0537		
17				-€0.0806	€0.0668	€0.0451	€0.0122	€0.0057	€0.0492		
18				-€0.0786	€0.0636	€0.0430	€0.0116	€0.0054	€0.0450		
19				-€0.0767	€0.0606	€0.0409	€0.0111	€0.0051	€0.0410		
20				-€0.0748	€0.0577	€0.0390	€0.0105	€0.0049	€0.0373		

[52] Operating costs @€8 per ton agricultural slurry treated.

[53] Revenue (a) MWh electric, MWh heat, 50% heat production reuse in process, Revenue (b), Sewage treatment -Private septic tanks €175 ea, Revenue (c) GHG reduction /ton CO2 equivalent @€20/ton. Revenue (d) odour / N-eutrophication reduction. Heslop 2007;, Heslop et al (2007)

[54] Revenue A costs are cumulative totals of items 1; 2; 3; 4; tables 11(a),11(b),11(c) ,individual CH_4 yields for separate fractions (conservative figures). The relationship of waste fractions and any beneficial CH4 additional yield for co-digestion is known to exist, but is dependent upon % mix of materials, seasonality and other parameters. (Caplea, et al., , 2008; McDonald, et al., 2008)I

21				-€0.0730	€0.0550	€0.0371	€0.0100	€0.0047	€0.0338		
22				-€0.0712	€0.0524	€0.0354	€0.0096	€0.0044	€0.0305		
23				-€0.0695	€0.0499	€0.0337	€0.0091	€0.0042	€0.0274		
24				-€0.0678	€0.0475	€0.0321	€0.0087	€0.0040	€0.0244		
25				-€0.0662	€0.0452	€0.0305	€0.0083	€0.0038	€0.0217		
26				-€0.0645	€0.0431	€0.0291	€0.0079	€0.0037	€0.0191		
27				-€0.0630	€0.0410	€0.0277	€0.0075	€0.0035	€0.0167		
28				-€0.0614	€0.0391	€0.0264	€0.0071	€0.0033	€0.0145		
29				-€0.0599	€0.0372	€0.0251	€0.0068	€0.0032	€0.0124		
30				-€0.0585	€0.0354	€0.0239	€0.0065	€0.0030	€0.0104		

From the figures available in tables 11a, b, c, the Integrated Waste from energy treatment plant has a 0.14 MW generating capacity at 30% electrical efficiency. This level of production ensures that the plant can avail of the full quota of REFIT tariffs available at the moment. As part of the National renewable energy action plan (NDERP) these tariffs will be available for 15 years up till 2025, and are linked to Consumer Price index (CPI) for inflationary or as currently experienced deflationary purposes. In addition the CHP unit has the ability to generate 0.16MW of district heating. With the NPV calculations presented above (Tables 12,13,) the plant has been allocated 50% of this heat for production processes.

In contrast with Heslop et al (2007) EPA (2005) and Mahony et al (2002) gate fees have not be allowed for in this operation. The object of this feasibility is to determine if the local resource is sufficient to ensure its viability. As outlined in both Purcell (2009) and Gallagher (2007) and Fahy, (2006) communities who have waste management facilities presented to them raise stern opposition on the basis of L.U.L.U (locally unwanted land use) or N.I.M.B.Y. (not in my back yard) arguments. The justification for this type of an integrated waste from energy (W/E) biological treatment plant is to empower the local communities in the management and development of their own waste streams, not as processers of external waste sources.

With regard to digestate it is proposed to compost this material to ensure that the final material meets requirement of the Biowaste directive for Class 1 material. A review of the technology (Chan, Chong, Law, & Hassell, 2009) (U.S.E.P.A., 2000) (USEPA, 2002) indicates that in vessel technology would be more appropriate in this location. In vessel composting requires less isolation time to achieve sanitation requirements, offers better leaching control, presents solutions towards heat recovery, odour control and vermin control. The ability of the vessel to operate under adverse weather conditions ensures that operationally the composting process is less affected by weather events and from a management aspect will present a greater degree of compliance. It will also ensure that traffic movements in and around the curing areas are reduced as this methodology does not require either force aeration pads or additional machinery to facilitate the pile-turning regime which would otherwise be necessary. Removal rates of 38 -40% have been recorded for thermophilic / mesophilic systems, (Harikishan & Sung, 2003) and based on the biosolids and agricultural residuals incoming to the system this will leave a marketable product of 900 – 930 tons of composted digestate of class 1 quality /pa.

The market value of this material is assumed to be €10/ton, with application in the horticultural and nurseries commercial sector. This then contributes €9000 – €9300/ pa to the final estimates.

Digestate liquor, which has valuable amounts of macronutrients and micro nutrient components has been attributed and zero sum cost, as the return of this product to the agricultural land area is a key component of the business plan for the above project. The availability of the land resource ensures that an alternative technology for the removal and processing of the nutrient load of the liquor does not have to be applied.

Harikishan & Sung(2003) demonstrated the increase in ammonia nitrogen (NH_3-N) in relation to the thermophilic and mesophilic stages with NH_3-N percentage increasing for 14% - 18% of the initial g VS/l/day all OLR rates and final fixed levels of 1.09g/l NH_3-N. Similar results are reported by Kaparaju & Rintala (2008) however the digestion was only carried out a mesophilic temperature ranges. Utilising these ranges for TKN and NH3_N values and appling them to the above proccess the estimated savings of direct application of chemical fertilizer TNK + NH-$_3$N to for the above unit will be 31ton TNK, 16.5t NH-$_3$N per annum.

Indicitave costs per ton are available of the teagasc website (Teagasc, 2010) Rates for Nitrogen (N) = € 750-800 p/ton, Phosphrous (P) = 1200 p/ ton, Potassium (K) €380 p/ton.

McDonald et al., (2008) determined the N.P.K. rates for a number of waste feed stocks and when extrapolated towards this work give the following potential savings. Similar results for N.P.K. are reported in EPA(2005)

- N. 16.5t@ €775 ton = €12,787
- P. 8.3t @ €1200 ton = €10,025
- K. 43.3t@ €380 ton = €16,433

Total fertilizer savings per annum are €39,245, which will accure to the farming businesses who supply the raw slurry material to the W/E treatment plant. (Horst & Kamh, 2004) describe the methodologies under which P uptake is completed by plants and report that P applied via organic matter (digesate / compost) allows slow release to the surrounding soil and plant uptake responds significantly to this effect. Artifical chemical phosphate additions react considerable quicker within the soil matrix and subsequently may be lost to the plant. Alternatively as outlined in Klapwijk & Temmink, (2004) a number of techniques for the extraction of P either before or after treatment of the waste material in a thermophilic / mesophilic system. It is suggested that in both instances the P removal rate may be as high as 65 – 70% with the remainder still present in the digestate liqour. With reported rates of 0.4 – 0.5kg P/t (liquid digestate) there exists a potential for the enterprise to derive c. €7000 euros of extractable bio-phosphorus. *e.g.(((15500*.4)/1000)*€1200.*

As part of the operational efficency of the digesate distribution, reserviours will need to be located through out the surround area. The proposed layout of the EfW treatment plant has storage in gas tight vessels for 6mths so as to allow sufficent reservoirs od material to build prior to utilisation under the Nitrate regulations (DEHLG, 2008)and to extract the post digestion methane portion from the digestate liquor material(Kaparaju & Rintala 2007). Additional storage equal to 6 no reserviours of 1200m3 containment will be requireed to ensure that full storage is avaialble both on farm, at the EfW treatment plant and within the distributed reservoirs.

The spreading of the digestate material will be undertaken in the same manner as previously landspreading operations so no special machinery is required to avail of the benefit.

Waste water treatment costs vary (FORAS, 2008) but figures for Galway indicate a combined price (potable water supply & waste water treatment) of €1.50 M^3. Utilising this figure and attributing €0.50 to Potable water supply, €1.00 will be applied to the waste water treatment element.

The daily M^3 treated at the integrated plant is 84m3 which is equal to a pa total of €30,295.

Table 14 Summary of revenue / costs relating to integrated EfW treatment plant

Revenue/Cost stream Description	M^3 /pa	Value €	kWh @30%	kWh @48%	Sub Total	Total	Profit/ loss (€20/ton/ Co_2)	Profit /Loss (€50/ton/ Co_2)
Biogas	248502							
Digestate Liquid	15500	2.50			38750			
Digestate Solid Composted	930	10			**9300**			
Fertilizer								
Nitrogen		775 / t			12,787			
Phosphorus		1200/t			10,025			
Potassium		380/t			16,433			
Water treatment	30,295	1.00			**30,295**			
Water treatment Private Septic	591	175			**103425**			
Electricity		0.15	880139		**132,023**			
Heat		0.03		1408271	42,245	**????**		
CO2 Abatement Per t Biomass	15500@ é20/t eq'	1.8			**27900**			
CO2 Abatement Per t Biomass	15500@ é50/t eq'	4.5			69750			
N-Eutrophication reduction	15500 t processed	0.39			**6045**			
Reduction in Noxious smells	15500 t processed	0.50			**7750**	**316738**		
Operating Costs	15500	7.4			114700			
CH_4 Scrubbing cost	248503	0.03			7455			
Transportation Costs	15500	2.30			35650	157805	**158933**	**200783**
Transportation capital cost	15500	4.8			**74400**			
Development cost	15500	74			**1147000**			
Distribution Storage Costs	7000	25			**175000**	1396400		

6.3 Discussion of results.

A key assumption for the following discussion is that the development Costs and capital investment is sourced from central Government Funding. All other costs and revenues are from the operation of the plant. The other major assumption utilised is that the processed material, digestate, in liquid and solid form meets the requirement of the Biowaste directive (EC, 2001) for class 1 material, with no restrictions in use.

Referring to table 11 a, b, c, above, it is clear that the utilisation of agricultural slurries in the volumes used in this feasibility study do not make this operation viable. The total revenues for electricity, composted digestate and abatement sales are €154,018 leaving a deficit of €3,800/pa.

The integration of the other waste streams however increases both efficiency of production (Booth, Bell, McGovern, & Hodsman, 2007), (Caplea, Rodriques, Silva, Nadais, & Arroja, 2008) (Cavinato, Fatone, Bolzonella, & Pavan, 2010) (EA, 2008a) (McDonald, Achari, & Abiola, 2008) widen the revenue stream, and allows for greater treatment of all wastes (Verstraete, Van de Caveye, & Diamantis, 2009) (Meulepas, Nordberg, Mata-Alvarez, & Lens, 2005).

The utilisation of these resources means that the annual revenues of treatment and energy production € 316,738 pa, exceed the operational costs of € 157,805 pa, by € 158,933. These figures disregard any heat market which may exist. At 100% sale there is an additional potential revenue stream of

Within the location of Woodford the largest consumers of heat and power consist of

• St Ann's Nursing Home[55]	937918 kWh heat pa
• Mercy College Woodford[55]	314507kWh heat pa
• St Josephs National School[55]	77542 kWh heat pa

Total heat produced by the proposed plant is 1.4 M kWh of which 50% will be allocated to plant operational needs. This leaves a surplus of 704,135 kWh potential. The total required by the above facilities is 1.32 M kWh based upon oil purchases.

[55] Personal communication Mr Pat Cox, MS Loreto Quinn-Canning, Ms Breda Mannion

With boilers operating at various efficiency, the total produced kWh heat may be between 85-95% (i.e. 1.13 – 1.26 M kWh) Thus the potential market exists for 100% of the heat produced. Infrastructural costs to exploit this market have not been developed as part of this work.

The potential tons of oil equivalent (T_{oeq}) savings per year are as follows

- Commercial heat market (based upon examples only) 56 T_{oeq}
- Total Heat Utilised (commercial and industrial) 59 T_{oeq}
- Total energy Electrical /heat produced 97 T_{oeq}
- Fertilizer equivalent
    - Nitrogen at 2.7T_{oeq} / ton 45 T_{oeq}
    - Phosphorus at .7 T_{oeq} / ton 5.8 T_{oeq}
    - Potassium at .48 T_{oeq}/ton 21 T_{oeq}

Oil equivalent figures derived from Gellings & Parmenter, (2004)

Thus it can be seen that the utilisation of the waste streams outlined above contribute to the overall plant efficiency, and as will be described in the next section, to the community. The lack of the necessary infrastructure to best utilise these products now becomes a limiting factor. For example the heat market which exists in Woodford, in association with this plant, cannot derive benefit due to the lack of suitable connection and the lack of future economic support to enable development of a heat network.

The revised RDP (DCEGA, 2010a) and the regional planning guidelines (RPG) (WRA, 2010), highlight the discrepancies which are faced by organisations which are attempting revitalise these rural areas. In relation to renewable energy the RPG highlights the requirement that the existing distribution infrastructure is maintained and reinforced. While it espouses the value of 'renewable energy' or 'community based renewable energy', it also determines that regarding its development in rural areas it should be in line with 'appropriate locations', and with 'existing infrastructure'. These oblique statements show an increasing reliance towards centralised generation and distribution.

Any development will be measured against the habitat directive assessments (HDA 1-25) which form the criteria by which all actions are judged. As such no one item is judged in isolation as the phrase 'cumulative action' reoccurs throughout the HDA ensuring that, developments which increase an efficiency in a process may not be allowed planning on its individual merit simply because an existing less efficient activity predates it. In effect it incentivises early adoption of inefficient techniques at the expense of improvements in processes. In terms of energy production, no mention is made of combining with waste industries, save for a brief note on the promotion of biological treatment of source separated organic matter.

With regard to the RDP 2007 – 2012 the only indication to bio-energy is under the Target Agricultural Modernisation Scheme (TAMS) , (measure 121), where all funding is targeted at dairy and arable farming converting hectarage to energy crops. The issue of energy from farm waste as indicated by the EPA (2005) document seems to have been ignored.

These instances provide the basis for the follow section. It will analysis the issues which may act against this potential contribution, and attempt to describe the structures both local and national which may provide a path towards the development of this integrated waste from energy plant (IW/EP).

7. IE/WP; National Policies, Community Structures &Economic considerations

'Sustainable development' as a concept is thought to be easily understood, however the practicalities are such that the successful implementation of this theory can be difficult.

Some commentators note, that from the viewpoint of potential small scale service providers, certain policy aims coupled with inadequate levels of economic assistance; lack of coordinated energy policy; insufficient funding and research and a deficiency of long term energy planning illustrate that national government policy could be construed as a form of political 'green washing[56] (Raven & Gregersen, 2005), (Walker, 2008), (Han, Moi, Lu, & Zhang, 2008) (Wolfe, 2008) (Negro, Hekkert, & Smits, 2007)

The supply of energy to communities via centralised anaerobic digestion (CAD) is not a new concept either in Ireland or abroad. Camphill community in Ballytobin, Co Kilkenny, has been doing just this since 1999, (Healion, 2005) and on a more substantial scale the village of Jühnde Germany (I.E.A., 2009) where the participants to the scheme are 100% self sufficient in heat and power. In both in situations the feedstock is agricultural residues supplemented by; food waste for Camphill, (Chadwick, 2010) and energy crops for the Jühnde plant (I.E.A., 2009).

7.1 National Policies

CAD plants within have also been investigated (Mahony, *et al.*, 2002; Heslop, *et al.*, 2007) and feasibility studies completed. Conclusions within both reports' can be summarised as follows,

(Mahony, O'Flaherty, Colleran, Killilea, Scott, & Curtis, 2002)

1. Recommend that a pilot plant be developed, located away from EU designations, in location with available heat and energy market, such as outlined in the case study.
2. Develop a digestate management plan for land application, considering the impending EU legislation
3. Look at other sites where alternative resources are in place e.g. sewage
4. Consider nutrient removal possibilities e.g. phosphorus

[56] 'Green whitewashing', 'Green Sheen'. The term is generally used when significantly more money or time has been spent advertising being green (that is, operating with consideration for the environment), rather than spending significant resources on environmentally sound practices.

(Heslop, Hjort- Gregerson, Moller, Sommer, Birkmose, & Nielsen, 2007)

5. Excessive regulation on use of animal by products for land spreading application.
6. Low heat value.
7. Low electricity price.
8. Small CAD plant with limited feedstock types.
9. Local Feedstock of dairy sludge was committed to existing uses.

As stated earlier the Camphill community has had a CAD plant in operation since 1999, and it has operated successfully in that time. In discussions with the plant manager Jim Chadwick, he confirmed that the plant was currently operating with 4 staff, two full time, 2 part time, and that the plant was offsetting c.€ 50,000 pa in oil costs for the community. The primary residue utilised was agricultural slurry supplied from 3 local farmers and catering waste, i.e. catering grease, which was sourced from the Dublin city region. Gate fees which previously had been €100/ per ton were now (July 2010) approximately €50 and that this was affecting the financial effectiveness of the operation. The biogas produced was exclusively for heating with excess being flared off. As of July 2010 there was no electrical connection to the main grid from the CHP unit which was not yet connected.

It was stated that the biogas potential of the agricultural slurry was greatly enhanced by the addition of the catering waste. The issue of security of supply was of great concern to the plant, as increasingly it was difficult to source this material due to completion from other markets.

Each of the farmers who supplied the slurry reapplied it to their lands and in all instances nutrient management plans were in place and adhered to. Each farmer had fully replaced their chemical fertilizer requirements by application of the digestate liquor and anecdotally it was report that there was no perceived drop in production. In the case of one farmer, it was expected that land spreading was to cease for a season or two due to fact that the nutrient management plan indicated that the mineral content of the land was complete. Though the Camphill biogas plant may be small is none the less a fully functioning CAD plant with importantly 10ys experience of operation. In this regard I would believe that this situation fulfils the item 1 raised by Mahony *et al* (2002).

With reference to Item 2, 3 and item 5, the PAS:100 (BSI, 2005), PAS:110 (BSI, 2010) (EA, 2008a, 2008b) and more appropriately the proposed Biowaste directive (EC, 2001) currently offers a strategic plan and criteria for the implementation of digestate and biowaste spreading in Ireland. The specifications listed in the biowaste document for class 1 material are considerable more restrictive that that for PAS:110, and substantially more restrictive than those in place for Class A biosolids (USEPA, 2003). In 3 regards the proposed document for compost for Ireland (Prassad & Foster, 2009) offers tighter control in both Cr and Hg and Organic matter. Thought the RED directive (E.U., 2009) clearly states that as a policy, where it applies to renewable energy (para.42), member states should not impose stricter conditions than the community standard, the inclusion of these limits in association with the draft biowaste document within a single national policy would ensure that Ireland would have a regulation which was one of the strictest in Europe.

The RDP 2007-2012 (DCEGA, 2010a) does outline that in, particular with the dairy sector and generally in agriculture that in anticipation of quota removal in 2015, the agricultural sector should 'play to its strengths' and maintain a ' green image based upon its grass production' . The inference is clear in the language employed, which is to ensure that the public image is a 'green clean' product, and it is to be expected that any application of digestate or biowaste material irrespective of regulation of standards will be resisted.

Nutrient extraction (item 4) as highlighted by Mahony et al (2002) as an area of further development. The preservation of nutrient content within the solid digestate and liquid digestate in equal measure (Kaparaju & Rintala, 2008) would suggest that this issue may not be as important as previously outlined. Work completed in relation to phosphorus uptake by plant systems with digestate indicates that it is a more 'natural' process, i.e. slower and better distributed, than that of applied chemical fertilizer (Horst & Kamh, 2004) and general nutrient availability of digestate post composting (Komilis, 2006; Lópaz, *et al.*, 2010) offers no adverse affects to plant growth or yields.

Item 6 relates directly to infasturctural deficencies which is unlikly to be ammended in the short to medium term. The provision of district heating and cooling is outlined consistantly in the RED Directive (para 46), as a priority, yet the recent National renewable Energy Action Plan DNEAP (DCNER, 2010a) fails to instigate any policy for the retrofitting of district heating with the current building stock. Further it fails to outline any possible actions which could be undertaken by communities acting in partnership to achieve this aim. The primary points in regard to district heating within the NREAP outline that it should be encouraged within new housing stock. By this inaction it is apparent that any developments will be aimed at industrailised activities where CHP provision will allow the beneficial use of heat and power, but this will in effect remove or entail to be removed large amounts of energy potential from the source location , i.e. rural areas, and transport it to centerilised production areas where non market benefits will be lost.

Item 7 has been deal with under the new REFIT (DCENR, 2010b) provisions which outlined that AD generated Electricity under 500kw production will be eligable for a selling price of €0.15 /kWh produced. This figure is fixed until 2025 and is linked to the CPI in terms of inflation.

The provision of limited feedstock may be dealt with under the Biowaste directive (EC, 2001) which was discussed above previously as this increases the amount of acceptable resources as well as outlining the minimum standards to be achieved in the production of digestate, both liquid, soild and compost. In relation to size, the Camphill biogas plant utilises 21tons of mixed material per day, and the proposed IWfEP described in this work operates at 43ton mixed material per day. In both in cases the theoretical and extant facilities are making profits. As outlined in the RED directive, the justification of renewable technological energy provision is multifold. Therein it is recognised that imbeded or distributed energy offers more that energy security. Primarely it

- Fosters local development through employment, security of income, alternative diversity of employment.
- It enables security of local energy supply.
- Reduces transmission losses over centeralised distribution.
- Decreases the requirement for wide spread reinforcment and upgradeing of networks.
- and can shorten transport distances in relation to waste processing, employment and service provision.

Many of the above provisions are also aspraitions of the RDP (WRA, 2010), and CLAR (DCEGA, 2010 b) however as discussed earlier phrases such as 'appropiate location' 'cumulative actions' and 'existing infastructure' would cause one to be temperate in one's expectation of progressive and lateral thinking with regard service provision and development.

7.2 Community structures

Raven & Gregersen (2005) described how the majority of the energy developments in the Danish system were and are in fact cooperatives. Other works involving community development often involve the empowerment of local structures to ensure the projects are successful often with mixed results (Han, Mol, Lu, & Zhang, 2008) (del Rio & Burguillo, 2009) (Walker, 2008).

Walker,(2008) &Wolfe (2008) outline the major benefits incentives of this level of community ownership with the key points as

- Local income and regeneration
- Local approval and planning permission
- Local control
- Lower energy costs and reliable supply
- Load management
- Ethical and environmental commitment

The barriers to successful community energy initiatives are also listed therein but in the main these are issues relating to planning, central administration, grid connection, control both at a local and regional level, and beneficial ownership (del Rio & Burguillo, 2009; Walker, 2008; SW Ltd, 2009).

Within Gallagher (2007) it is clear that with regard to waste infrastructures the key is 'comprehension before compensation' and that although compensation policies for communities hosting waste facilities have a positive impact, 'it is only <u>once</u> the community is thoroughly engaged in the process for mitigating their concerns'

The issue of compensation is often highly divisive but the community structure allows for constructive learning and criticism, peer networking and influence to generate positive results. Gallagher (2008) also points out that the community involved will discriminate towards a waste stream which has a local origin, thus developing a local responsibility towards local waste generation and ultimately, treatment.

The key assessments within Gallagher (2008) for future waste infrastructures as they relate to the IW/EP are,

- Environmental effectiveness
- Economic (static)efficiency
- Economic (Dynamic) efficiency
- Administrative Feasibility
- Political Viability
- Equity.

Purcell (2009) in reviewing strategies for MSW management remarks that generation and attitudes about management are spatially variable, that national or regional plans may not be appropriate or successful, but that locally targeted plans accomplish greater results.

As with Gallagher (2008) previously, Purcell (2009) discusses the issue of 'participatory government' or 'tokenism' v 'command and control' with the ultimate observation that where a cooperative scheme is utilised to control a waste infrastructure then this exploit of citizen action will mean that each individual has a duty to his fellow citizen and this can then benefit or contribute to the community as a whole. In this it reflects the 'citizen groups' described in Jacobson & Lauber, (2006).

(Hodgson, 2006) in contrast highlights the issues which act against renewable energy developments. In both cases examained the failures can be attributed to the following

- Early movers (in terms if technology type or implementation within a region)
- Framing the debate. (Consulting with the local population either to early in the process or too late)
- Trust in the developing entity(private or public)
- Scale (tiers of government disregarding policy initiatives)

By deciding from the outset to involve the whole community in a cooperative system, then issues relating to the 'debate' and 'trust' can be avoided. However, this in turn may bring different issues, financing and expertise into focus.

7.3 Economic Considerations

Community groups may not have the full remit of expertise to hand to institute a waste from energy development. This subsequently will impact on the organisations ability to raise funds on the markets. In relation to the point regarding expertise, cooperatives may employ directly the required management to instigate and 'bed in' the development. Ultimately thought the control for the system remains with the organisation and its members who are also the community in which this operation is located.

With regard to finance as in the German and Danish renewable energy field, the imperative would have to be placed on the regional or national government to act as the capital provider either on a zero interest or low interest basis (Raven & Gregersen, 2005). This will involve issues of completion bias from private industry; however without this 'no strings' seed investment the enterprise will always struggle to convenience traditional lenders to come on board, due to perceived lack of expertise and caution in relation to the 'early mover' syndrome.

Negro, *et al.*,(2007) in attempting to understand the disjointed development within the digestion field in the Netherlands surmised that the lack of coheasion between the entrepreneurial mind-set and the national government institutions with regard to policy and regulation and long term goals (greater than one political cycle) ensured that the critical mass required to overcome technological problems, and allay the risk averse fears of institutional lending never unfolded. It was also noted that the indigenous actors in the field of AD did not act in a cohesive manner as an association dissipating the sectors voice at central government.

With all elements of business the hardest items to value are the intangibles, such as 'good will' 'image' etc. With the proposed IW/EP there is a potential for the organisation to generate profits in the region of €158,000 p/a (*all things being equal and all assumptions being meet*). Gallagher (2008) has outlined the effectiveness of compensation towards a community but how does one distribute this largesse without alienating the very individuals and communities which are so vital to its success.

Community actions in terms of

- Community transport schemes
- Service provision,

- Energy cost contributions to elderly / infirm members of the community
- Sponsorship of community groups, sports clubs, organisations
- Training and awareness schemes
- Advise and education
- Educational scholarships and bursaries

All these items allow for the benefits of waste from energy to be allocated. However the more economical aspects of the development can also act as a hub for future development. As mentioned previously the village of Woodford has two educational facilities within its boundaries. The development of such a facility would allow for interest in chemistry, agronomics, geology, hydrogeology, energy, energy efficiency, biology, physics, and ecology to be demonstrated at a more fundamental, practical and intimate level.

As well as the management positions within the plant, there will be the requirement for mechanical fitters, electrical engineers, and SCADA control expertise to develop and monitor the control systems. HGV Drivers will be required for the collection and delivery of the raw and processed material. In line with the land spreading of the digestate, there would be an opportunity for a small laboratory to develop to service the needs of the plant, the agricultural nutrient management plans and monitoring of the associated water courses.

The provision of the heat resource will allow enable other industries to bring added value to their product, e.g. Timber drying in association with forestry products, frost tender horticulture under glass, etc. The by-products of the AD process, digestate both liquid and solid, allow for biomass crops, general market gardening, and nurseries to develop or expand with a lower cost base than previously.

Nutrient and heavy metal harvesting technology via bio leaching, algal biomass and bio-sorbents (Alvarez, *et al.*, 2002; (Wanj & Chen, 2009) (Ahluwalia & Goyal, 2007)can all now be investigated as water treatment and tertiary polishing techniques due to the installation of a process which is utilising the generated waste from a community.

The number of direct jobs may be small, and based upon the Camphill experience between 4-8 individuals (Chadwick, 2010). Many of the smaller enterprises developing around the plant may only generate a small portion of their revenue stream from the immediate area. Instead the plant will act as a centre of experience around which these entities can coalesce. These type of hubs are a central plank of the regional planning guide 2010 – 2022 (WRA, 2010) so why should they not be allowed to flourish in the more decentralised regions.

8. Conclusion

Stability in a region or area ensures that the wider dispersed community can stabilise and ultimately regenerate (Moles, *et al.*, 2000). Education has long been a key to Woodfords success, but the market for this talent is becoming more and more centralised away from these rural areas (WRA, 2010). Initiatives such as the IW/EP will always be risky due to the 'early mover' principle discussed earlier (Hodgson, 2006). However it has the potential for the community to exploit the resources which previously was being left underutilised and in many cases wasted.

At the outset this feasibility study attempted to examine whether the goals contained within the 'green new deal' document (United Nations, 2009) could be achieved by applying the principles of bio refinery techniques and processes. These were, .

1. Clean energy and clean technologies including recycling
2. Rural energy, including renewable and sustainable biomass
3. Sustainable agriculture, including organic agriculture
4. Ecosystem Infrastructure
5. Reduced Emissions from Deforestation and Forest Degradation (REDD)
6. Sustainable cities including planning, transportation and green building.

With regards to item 1 the feasibility study indicates that it is possible for this to be achieved, and with this, items 2 and item 3 may follow. Item 4 will be a direct beneficiary of reduced nutrient inputs along watercourses, and will also be an indirect beneficiary due to CO_2 and CH_4 abatement, material and resource protection, habitat protection and increased recycling. Items 5 and 6 cannot be dealt in this work, thought one could surmised that these items too would have positive aspects. Raven *et al.*, (2005) and; Negro, *et al.,* (2007) show that the initiatives and policies of government, need to be long term, i.e. 15-20yr, in order for the critical mass to accrue within renewable energy sectors and to allow technologies to develop independently. All pertinent issues raised by the previous reviewers, Heslop *et al.*, (2007) and Mahony *et al.*,(2002) have been addressed, but it is crucial that the government policy on Biowaste, and its general land application, is dealt with as this is crucial in allowing these types of integrated waste and energy developments to succeed.

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Appendix A

Types of waste (from EWC categories) suitable for production of Quality Digestate (PAS110:2010) via anaerobic digestion	
Type	EWC Code[57]
Wastes from agriculture, horticulture, hunting, fishing and aquaculture primary production, food preparation and processing	**02 01** 02 01 01 02 01 02 02 01 03 02 01 06 02 01 07 02 01 99
Wastes from preparation and processing of meat, fish and other foods of animal origin	**02 02** 02 02 01 02 02 02 02 02 03 02 02 09
Wastes from fruit, vegetables, cereals, edible oils. Cocoa, tea and tobacco preparation and processing; conserve production	**02 03** 02 03 01 02 03 02 02 03 04 02 03 05
Wastes from sugar processing	**02 04** 02 04 03 02 04 99
Wastes from dairy products industry	**02 05** 02 05 01 02 05 02
Wastes from baking and confectionary	**02 06** 02 06 01 02 06 03

[57] European waste catalogue code

Types of waste (from EWC categories) suitable for production of Quality Digestate (PAS110:2010) via anaerobic digestion	
Type	EWC Code
Wastes from the production of alcoholic and non-alcoholic beverages (except tea and coffee)	**02 07** 02 07 01 02 07 02 02 07 04 02 07 99
Wastes from wood processing and the production of paper, cardboard, pulp, panels and furniture	**03** 03 03 03 03 08 03 03 10
Wastes from leather, fur and textile industry	**04** 04 01 04 01 01 04 01 05 04 01 07
Wastes from the textiles industry	**04 02** 04 02 10 04 02 13
Wastes packaging; absorbents, wiping cloths, filler materials and protective clothing not otherwise specified	**15** 15 01 15 01 02 15 01 03 15 01 04
Wastes from waste management facilities, off-site waste management plants and the preparation of water intended for human consumption and water for industrial use *Waste from physiochemical treatments of waste(other than that outlined in 19 02 08; 19 02 09* *Wastes from aerobic treatments of wastes (source separated)* *Wastes from anaerobic treatment of wastes(source separated)*	**19** 19 02 19 05 19 06
Wastes from waste water treatment plants not otherwise specified	**19 08** 19 08 09 19 08 12
Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions	**20** 20 01 20 01 01 02 01 08 20 01 25 20 01 38
Garden and park waste (including cemetery waste)	**20 02** 20 02 01
Other municipal wastes	**20 03** 20 03 01 20 03 02

From (EA, 2008b)

Appendix B River classification @ Q values

River and Code	: CAPPAGH (GALWAY)		25/C/03
Tributary of	: Kilcrow	OS Catchment No:	155
OS Grid Ref	: M 795 042	Date(s) Surveyed :	04/11/2003

Sampling Stations		Biological Quality Ratings (Q Values)							
No.	Location	1975	1979	1983	1987	1993	1996	1999	2003
0100	Metal Bridge	-	-	-	4-5	4	3-4	3-4	3-4
0200	Bridge W. of Duniry Village	4	4	4	3-4	4	3	4	4
0300	1.5 km N.E. of Abbey	-	-	4	4	4	4	4-5	-
0400	Cappagh Bridge	-	-	4	4	4	-	-	4-5
0500	Cloonmoylan Bridge	4-5	5	4	4	4	4	4	-

Assessment: The farm pollution recorded at Metal Bridge (0100) in 1999 is still apparent. Water quality improves over the course of the river and was quite good at Cappagh Bridge (0400) when sampled in November 2003.

Sampling Stations		National Grid Ref.		Discovery	County
No.	Location	X	Y	Series No.	Code
0100	Metal Bridge	168182	211277	52	GY
0200	Bridge W. of Duniry Village	172362	209351	53	GY
0300	1.5 km N.E. of Abbey	175240	207147	53	GY
0400	Cappagh Bridge	177220	205615	53	GY
0500	Cloonmoylan Bridge	178780	204688	53	GY

River and Code	: COOS		25/C/08
Tributary of	: Lough Derg	OS Catchment No:	155
OS Grid Ref	: R 763 946	Date(s) Surveyed :	02/07/2003

Sampling Stations		Biological Quality Ratings (Q Values)								
No.	Location	1975	1979	1984	1987	1989	1993	1996	1999	2003
0010	Br N of Boleynabrone	-	-	-	-	-	-	5	4-5	4
0180	Br N of Tooreeny	-	-	-	4	-	4-5	3	-	-
0200	Tooreeny Br	3-4	5	4	1	3	2-3	-	1	3

Assessment: Moss growth had increased considerably in the upper river (0010) since the previous survey but water quality continued to be of a satisfactory standard there. Although still significantly polluted by suspected agriculture there had been a significant improvement in the lower reaches (0200) where serious pollution was no longer evident in 2003.

Sampling Stations		National Grid Ref.		Discovery	County
No.	Location	X	Y	Series No.	Code
0010	Br N of Boleynabrone	170700	194698	52	GY
0180	Br N of Tooreeny	174793	193936	53	GY
0200	Tooreeny Br	175169	193760	53	GY

River and Code	: **KILCROW**		**25/K/01**
Tributary of	: Lough Derg	OS Catchment No:	155
OS Grid Ref	: M 801 031	Date(s) Surveyed :	02/10/2003

Sampling Stations		Biological Quality Ratings (Q Values)							
No.	Location	**1975**	**1979**	**1983**	**1988**	**1993**	**1996**	**1999**	**2003**
Carrowreagh Branch									
0005	3rd Br u/s Main Channel	-	-	-	-	-	-	-	-
0009	Br u/s Main Channel (at 209' mark)	-	-	-	-	4	2-3	4	2-3
Main Channel									
0020	Killoran Br	-	-	-	4	-	4	4	4
0100	Ahanageleery Bridge	-	-	4	4	3	3	3	3-4
0200	Oxgrove Bridge	2	4	3-4	4	4	3	4	-
0300	Hearnesbrook Bridge	-	-	3	4	4	3	3-4	3-4
0350	East Br 2 km d/s Samp St 0300	-	-	3	-	-	-	-	-
0360	West Br 2 km d/s Samp St 0300	-	-	-	4	3-4	2-3	4	4
0400	Killeen Bridge	-	-	3-4	3-4	4	-	3-4	3
0500	Moat Bridge	4	4	4	4	3	2-3	3	-
0600	Newbridge	-	-	4-5	4	3-4	3	4	3-4
0700	Ballyshrule Bridge	4	4	4-5	4	3	3-4	4	4

Assessment: The Kilcrow is a very hard water river (conductivities >500µS/cm) that shows signs of eutrophication over its length. The 2003 survey showed some improvement and some deterioration in comparison with 1999. The overall impression is one of a eutrophic river.

Sampling Stations		**National Grid Ref.**		**Discovery**	**County**
No.	**Location**	**X**	**Y**	**Series No.**	**Code**
0005	3rd Br u/s Main Channel	0	0	53	GY
0009	Br u/s Main Channel (at 209' mark)	180627	218695	53	GY
0020	Killoran Br	176312	221925	47	GY
0100	Ahanageleery Bridge	180635	217254	53	GY
0200	Oxgrove Bridge	180049	214999	53	GY
0300	Hearnesbrook Bridge	179740	213025	53	GY
0350	East Br 2 km d/s Samp St 0300	180000	211900	53	GY
0360	West Br 2 km d/s Samp St 0300	179720	211753	53	GY
0400	Killeen Bridge	179768	211016	53	GY
0500	Moat Bridge	180011	210096	53	GY
0600	Newbridge	179395	207298	53	GY
0700	Ballyshrule Bridge	179792	205702	53	GY

River and Code	: **BALLINLOUGH STREAM**		**25/B/15**
Tributary of	: Cappagh	OS Catchment No:	155
OS Grid Ref	: M 775 051	Date(s) Surveyed : 04/11/2003	

Sampling Stations No.	Location	Biological Quality Ratings (Q Values) 1987	1989	1993	1996	1999	2003
0050	Br S Acres	-	5	4-5	4-5	4	4-5
0100	First Br d/s Ballin Lough	-	4	4	-	-	-
0200	Br E of Silverstream House	-	-	-	4-5	4	-
0300	Br at Ballygowan	-	5	-	-	-	4-5
0400	Br N of Brookville	-	-	4-5	-	-	-
0500	Bridge u/s Cappagh River	4	4-5	4	3	4-5	4-5

Assessment: The Ballinlough River was in satisfactory condition when surveyed in November 2003.

Sampling Stations		**National Grid Ref.**		**Discovery**	**County**
No.	**Location**	**X**	**Y**	**Series No.**	**Code**
0050	Br S Acres	167848	202290	52	GY
0100	First Br d/s Ballin Lough	168879	202651	52	GY
0200	Br E of Silverstream House	171875	202970	52	GY
0300	Br at Ballygowan	173200	204075	53	GY
0400	Br N of Brookville	0	0	53	GY
0500	Bridge u/s Cappagh River	176786	205015	53	GY

Appendix C

Disadvantaged Area Status for agricultural lands within study area.

TOWNLAND NUMBER	*DED*	*TOWNLAND NAME*	*DAS*	*AREA ACRES*	*AREA Ha*	*REVIEW MSH*	*DESIGNATED LSH*
G29301	ABBEYVILLE	ABBEYVILLE ISLAND	1	1	0.4	5	0
G29303	ABBEYVILLE	CLOONMOYLAN	1	1110	449.2	4	0
G29304	ABBEYVILLE	COOLFIN	1	449	181.7	5	0
G29305	ABBEYVILLE	DERRYVUNLAM	1	1182	478.3	3	0
G29306	ABBEYVILLE	EASTERFIELD	1	255	103.2	3	0
G29307	ABBEYVILLE	FRIARS ISLAND	1	1	0.4	5	0
G29308	ABBEYVILLE	KYLEMORE	1	511	206.8	5	0
G29309	ABBEYVILLE	LACKAN	1	378	153.0	3	0
G29310	ABBEYVILLE	WELLPARK	1	59	23.9	3	0
G25801	BALLYGLASS	BALLYGLASS	1	212	85.8	5	0
G25802	BALLYGLASS	CAPPAGH	1	413	167.1	5	0
G25803	BALLYGLASS	CLOONMOYLAN	1	439	177.7	5	0
G25804	BALLYGLASS	CRANNAGH	1	253	102.4	5	0
G25805	BALLYGLASS	DRIMNA EAST	1	77	31.2	5	0
G25806	BALLYGLASS	DRIMNA WEST	1	77	31.2	5	0
G25807	BALLYGLASS	KILLEEN NORTH	1	255	103.2	5	0
G25808	BALLYGLASS	KILLEEN SOUTH	1	179	72.4	5	0
G25809	BALLYGLASS	KNOCKBRACK	1	81	32.8	5	0
G25810	BALLYGLASS	LISDUFF SOUTH	1	92	37.2	5	0
G25811	BALLYGLASS	LOUGHAUNROE EAST	1	248	100.4	5	0
G25812	BALLYGLASS	LOUGHAUNROE WEST	1	80	32.4	5	0
G25813	BALLYGLASS	MOANNAKEEBA EAST	1	461	186.6	3	0
G25814	BALLYGLASS	MOANNAKEEBA WEST	1	478	193.4	3	0
G29501	COOS	COOS NORTH	1	1214	491.3	0	
G29502	COOS	COOS SOUTH	1	984	398.2	0	
G29503	COOS	DERRYGOOLIN Nth	1	2214	896.0	0	
G29504	COOS	DERRYGOOLIN Sth	1	2079	841.3	0	
G29505	COOS	DERRYOOBER WEST	1	1193	482.8	0	
G29506	COOS	REYNCLAMPER	1	396	160.3	0	
G29401	DRUMMIN	BAUNTIA	1	196	79.3	4	0
G29402	DRUMMIN	BOLEYNANOLLAG	1	135	54.6	3	0

G29403	DRUMMIN	CLOONDADAUV	1	163	66.0	4	0
G29404	DRUMMIN	CLOONOON	1	376	152.2	4	0
G29405	DRUMMIN	DERRYGILL	1	541	218.9	3	0
G29406	DRUMMIN	DERRYOOBER EAST	1	491	198.7	3	0
G29407	DRUMMIN	DOOROS	1	1066	431.4	3	0
G29408	DRUMMIN	DRUMMIN	1	210	85.0	3	0
G29409	DRUMMIN	GORTEENY	1	1115	451.2	3	0
G29410	DRUMMIN	GUT ISLAND	1	2	0.8	4	0
G29411	DRUMMIN	INISHDALA ISLANDS	1	26	10.5	4	0
G29412	DRUMMIN	ISLANDAGU	1	4	1.6	4	0
G29413	DRUMMIN	KYLENAMELLY	1	419	169.6	3	0
G29414	DRUMMIN	LOOSCAUN	1	365	147.7	4	0
G29415	DRUMMIN	OGHILLY	1	326	131.9	3	0
G29416	DRUMMIN	PRIESTS ISLANDS	1	2	0.8	4	0
G29417	DRUMMIN	RABBIT ISLAND	1	1	0.4	4	0
G29418	DRUMMIN	ROSMORE	1	1010	408.7	4	0
G29419	DRUMMIN	ROSTOLLUS	1	194	78.5	3	0
G29420	DRUMMIN	SLOE ISLAND	1	1	0.4	4	0
G29421	DRUMMIN	SRAH	1	442	178.9	4	0
TOWNLAND NUMBER	*DED*	*TOWNLAND NAME*	*DAS*	*AREA ACRES*	*AREA*	*REVIEW*	*DESIGNATED*
					Ha	*MSH*	*LSH*
G29001	LOUGHATORICK	LOUGHATORICK NORTH	1	3473	1405.5	0	
G29002	LOUGHATORICK	LOUGHATORICK SOUTH	1	2672	1081.3	0	
G29003	LOUGHATORICK	TOORLEITRA	1	3356	1358.1	0	
G28801	MARBLEHILL	ACRES	1	24	9.7	0	
G28802	MARBLEHILL	ALLYKEOLAUN	1	318	128.7	0	
G28803	MARBLEHILL	BALLYCORBAN	1	119	48.2	0	
G28804	MARBLEHILL	CARROWROE	1	187	75.7	0	
G28805	MARBLEHILL	CARTRON SOUTH	1	71	28.7	0	
G28806	MARBLEHILL	CLOGHVOLEY	1	905	366.2	0	
G28807	MARBLEHILL	CULLENAGH	1	664	268.7	0	
G28808	MARBLEHILL	DERREENNAMUCKA	1	770	311.6	0	
G28809	MARBLEHILL	DRUM	1	685	277.2	0	
G28810	MARBLEHILL	GORTEENAYANK	1	21	87.0	0	

		A		5		
G28811	MARBLEHILL	KNOCKADRUM	1	140	56.7	0
G28812	MARBLEHILL	KNOCKAUNDARRAGH	1	327	132.3	0
G28813	MARBLEHILL	KNOCKDRUMMORE	1	55	22.3	0
G28814	MARBLEHILL	KNOCKMOYLE EAST	1	628	254.1	0
G28815	MARBLEHILL	KNOCKMOYLE WEST	1	384	155.4	0
G28816	MARBLEHILL	KYLENAGAPPA	1	160	64.7	0
G28817	MARBLEHILL	LAGGOO	1	914	369.9	0
G28818	MARBLEHILL	LECARROW NORTH	1	120	48.6	0
G28819	MARBLEHILL	LOUGHPARK	1	116	46.9	0
G28820	MARBLEHILL	MARBLEHILL	1	506	204.8	0
G28821	MARBLEHILL	MOYGLASS	1	872	352.9	0
G28822	MARBLEHILL	REYNABRONE	1	395	159.9	0
G28823	MARBLEHILL	ROSSEESHAL	1	50	20.2	0
G28824	MARBLEHILL	SLATEFIELD	1	186	75.3	0
G29101	WOODFORD	ALLEENDARRA EAST	1	851	344.4	0
G29102	WOODFORD	ALLEENDARRA WEST	1	1691	684.3	0
G29103	WOODFORD	BOLAG	1	434	175.6	0
G29104	WOODFORD	CLONCO	1	683	276.4	0
G29105	WOODFORD	DERRYCRAG	1	283	114.5	0
G29106	WOODFORD	KNOCKAUNCARRAGH	1	731	295.8	0
G29107	WOODFORD	LAUGHIL	1	100	40.5	0
G29108	WOODFORD	ULICKSMOUNTAIN	1	385	155.8	0
G29109	WOODFORD	WOODFORD	1	653	264.3	0