Sustainable Waste Management System for Abertay University.

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***Abstract*— Waste management is a combination of several in house activities such as collection, transport, processing or disposal, managing and monitoring of waste materials with resource management. This waste management is a very important parameter to reach the sustainably accountable world in novel way and it's gives necessary help to reduce landfill tax by minimising the disposal of waste into the landfill. The waste materials produced by human activity can either be solid, liquid, gaseous or radioactive.**

In today's world the trend is to place an ever increasing importance on energy security and sustainable development. Abertay University continually strives to prevent, reuse and recycle all waste produced, however there is residual waste which could be converted into renewable energy. According to the definition of sustainable waste management system to meet the environmental, business and social challenges facing the world today and tomorrow, the sustainable project process must ensure profitability whilst creating a lasting and clean energy system in its operations by using appropriate renewable energy technologies.

***Keywords* — Sustainable, Waste Management, Renewable energy, Composting and Anaerobic Digestion**

I. Introduction

Abertay University's sustainable waste management system must consider the existence of our planet for future generations with efficient and effective environmental practices recognised by all staff, students and visitors on campus. The operation of the university as a public body, business and provider of environmental education must hold clear accountability and ethical awareness of environmental activities with the additional provision of opportunity for all staff, students and visitors to make a valid contribution to the environmental causes which have direct recognition to the student experience.

Abertay is a modern university with a global outlook, rooted in its local and national communities. Sir David Baxter, 1st Baronet of Kilmaron as far back as 1872 left a bequest to establish an institute for the mechanics of Dundee and in 1902 the institution was recognised as a provider of education by the Scottish Education Department, one of the first to be designated as a central institution, similar to an 'industrial university'. Last year marking the 125th anniversary of the foundation as an institution dedicated to supporting science, industry and the professions with an association to Dundee's rise as a centre for computer games.

Encompassing five schools; Arts, Media and Computer Games (AMG), The Business School (DBS), Social and Health Sciences (SHS), Science, Engineering and Technology (SET) and The Graduate School. With specialist centres: Food Innovation and Urban Water Technology which provides knowledge exchange, education, training and research into anaerobic digestion and also the Sustainable Urban Drainage Systems (SUDS) providing wastewater treatment, resource recovery, environmental evaluation and decision support tools. Waste management options are placed in order within the Waste Management Hierarchy reflecting the sustainability of each, the key principle being the higher up the hierarchy structure the waste is dealt with the most advantageous.

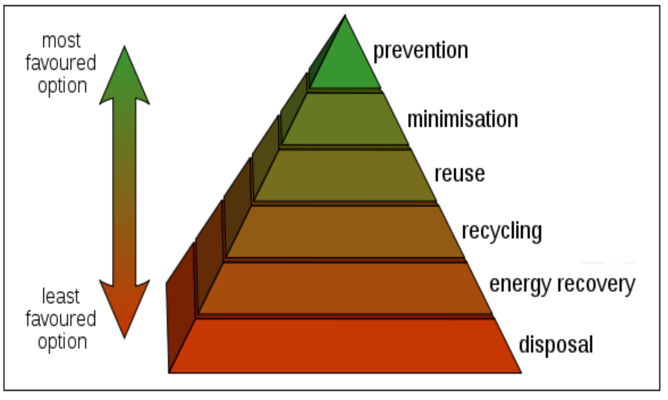


Figure 1. The Waste Management Hierarchy

There are different waste management activities which can be introduced within the industry and this is known as the Waste Management Hierarchy as shown in Figure1

By considering the above Waste Management Hierarchy there is impact on the environment from all disposal options and to avoid or minimise this impact, the only way is waste prevention and minimisation as mentioned on top of hierarchy. After the re-use, there are recovery techniques such as recycling and generating energy from waste and finally waste disposal goes to landfill or incinerator which is an undesirable options at the bottom of the hierarchy.

All options within the hierarchy have a significant impact on the environment and Abertay University must consider waste options from top down, however although the top of the model is prevention, not producing any waste in the first place would be an impractical solution for a Higher Education establishment, it is however necessary to ensure we consider minimisation of materials, reuse, recycle and as a last resort costly disposal options at landfill.

Figure 2: University floor plans identifying recycling receptacle locations

This paper investigates the opportunities for our residual waste (food & water) to be converted into renewable energy with feasibility of a lasting and clean energy system in the form of an offsite aerobic, anaerobic digester and combined heat & power plant. Both options can also provide a profit which could be considered to develop further technologies in the waste management discipline.

Within the university there are several waste streams and this includes construction waste, unused furniture, cardboard and paper, plastics, aluminium cans, household batteries, food waste and special wastes; Waste Electrical and Electronic Equipment (WEEE), fluorescent light tubes, healthcare and chemical wastes. Staff and students within the university can easily identify where recycling bins are situated by reference to floor plans which have been plotted with type of waste stream and location as shown in figure 2.

II. BACKGROUND

The background for implementation of the project relates to several strands; government legislation, Scotland's rising landfill taxes, the reputation of the campus and the resolution to operate a sustainable waste management system within Abertay University, departmentalised within the areas of the basic sustainability concept model; Environmental, Social and Economic.

The Landfill Tax (Scotland) Act 2014 was one of the first taxes devolved to the Scottish Government on 1 April 2015 through parliament and is a charge for the disposal of the universities waste to landfill. (GOV.Uk, 2016)All landfill site operators are liable for the tax which is split into two rates. Rate one is the standard rate for "active" materials and is currently set at £82.60 per tonne with rate two for all "inert" materials and is £2.60 per tonne and administered through Revenue Scotland with support from the Scottish Environment Protection Agency. (SEPA, 2016)

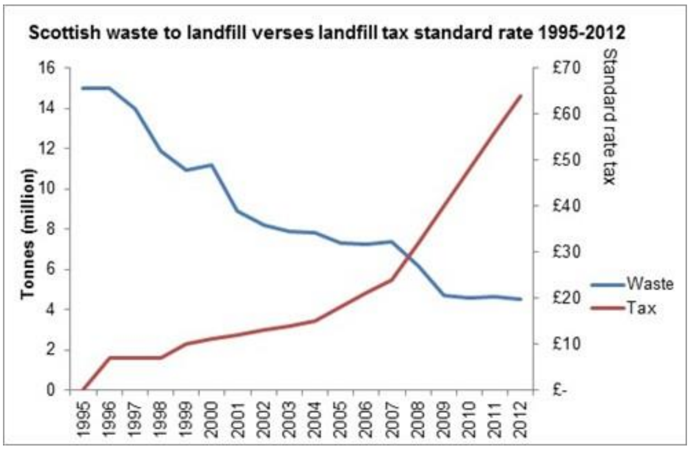


Figure 3: Display of the historic fall of waste land filled in Scotland against the rising landfill tax.

Source: (SEPA, 2016)

Abertay University complies with several areas of environmental legislation which promotes the efficient use of waste resources, these efficiencies are also directly related to the staff and student experiences with our league table environmental position.

Relative Regulations

The Waste (Scotland) Regulations 2012 - as of 1 Jan 2014 the regulations introduced a number of amendments which affected Abertay University. All paper, card, glass, plastics and metals must all be segregated for collection. As the university is sited within an urban area and producing more than 5kg of food waste from the student centre outlet there is a requirement to present food waste for collection, a practice which had been operating several months in advance of this regulation change.

The Environmental Protection (Duty of Care) (Scotland) Regulations 2014 - provides the structure and compliance for waste management practices and the control of emissions within our environment.

The Waste Electrical and Electronic Equipment (Amendment) Regulations 2015 - electrical items generally consist of hazardous content and with the rapid growth of electronic and electrical equipment in society, the regulations ensure that spent items have a reduced impact on the environment through a treatment, recovery, reuse and recycling procedure.

The Special Waste Amendment (Scotland) Regulations 2004 - identifies special waste, labelling, packaging and separation requirements. Uplift of special waste requires a consignment note when transferred which must be kept for a period of 3 years. (Legislation.Gov.UK, 2016)

The social advantages achieved through the universities current sustainability practices are far reaching as they allow staff, students and visitors to feel an increased motivation as the campus surroundings are clean and safe. An educated estates and campus services team has been achieved through training and education of our staff, which also a knock on effect into our local community with the creation of jobs and importantly the enhancement of the university's reputation allowing for improved recruitment levels and retention of students.

Research has identified that the university can improve on their current sustainable practices economically if profitable appropriate renewable energy technologies are established and these design challenges are discussed in more detail in this paper.

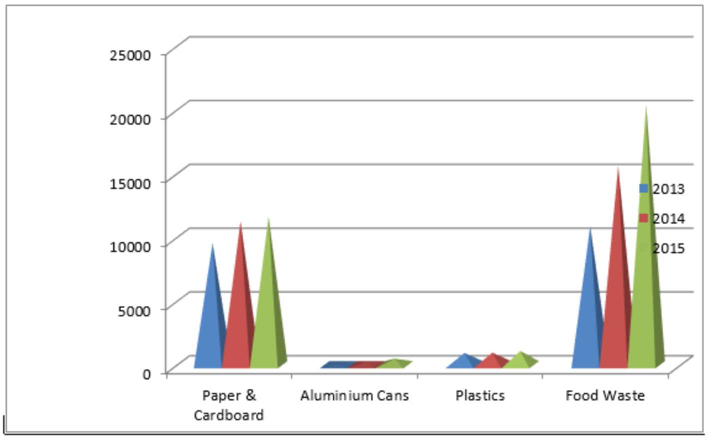
III. Current Management Practices

Abertay University's current sustainable waste management systems in place in terms of recycling practices are in partnership with the following contractors; The Saica Group, DJLaing, Kennan Recycling Ltd, Transform Community Development and the Electrical Waste Recycling Group.

The graph 1 below explains the total recycled waste in Abertay University during the period of 2013-2015 by using above partnerships and contractors.

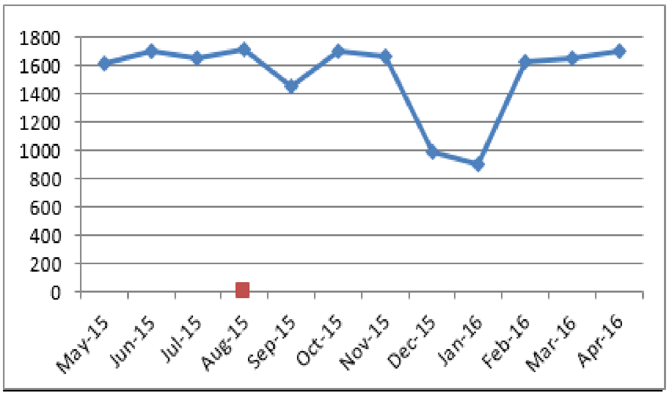
Recycling within Abertay University has slowly increased year on year since initiatives commenced. Comparing the last three years Food Waste has the highest levels, followed by Paper & Cardboard, thirdly Plastics and Aluminium being the least amount collected for recycling. As the university has been successful in increasing the Food Waste collections on an annual basis there is clear potential for this waste to be used in a more sustainable way in the production of gas or electricity.

The table 1 below itemises the waste uplifted from the university campus, designated recycler and destination.



Graph 1: Waste Recycled 2013, 2014, 2015 in KG

The table below confirms Abertay University's compliance with legislation and environmental standards. All waste on site is firstly minimised where practical then either reused or recycled. The minimum amount of waste is disposed off to keep landfill costs to a minimum. However it is clear that with a rising quantity of Food Waste energy recovery is now a solution, considering our current waste recycling there are two different processes; In Vessel Composting and Anaerobic Digestion



Graph 2: Monthly Food Waste Collections May 2015 to April 2016 (Kg/Month)

The Graph 2 indicates the Food Waste Collection graph waste indicates a steady rise month on month although over January and February there is a slight dip due to reduced student numbers attending campus due to the festive break. This prompts management to consider the option of partnerships

Waste Type	Carrier & Destination
Paper & Cardboard Waste: Quality White Paper Coloured Paper Magazines Directories Books Newspapers Cardboard - varying grades	Saica Group: A closed loop integrated cycle business model delivering sustainable solutions, maximising recovery and limiting environmental impact. With investments of over £600M since 2006 in its UK manufacturing facilities which includes a new £290M paper machine which manufactures 100% recycled paper making a significant sustainable contribution.
Plastic Waste: PET - (Polyethylene Terephthalate) e.g. fizzy drink bottles, cooking oil bottles. HDPE - (High Density Polyethylene) e.g. milk and washing up liquid bottles, fabric conditioner bottles. PVC - Polyvinyl Chloride) bottles for toiletries	Paper and cardboard waste are turned into a variety of innovative solutions within the closed loop business model which includes; retail ready packaging, fresh pack packaging for produce low gram, high performance paper. Plastic Waste is bulked and taken to a local recovery centre and recycled for re-use into plastic
WEEE Waste: Aluminium Batteries Fluorescent Strip Lighting Tubes Microwaves Fridges Freezers Washing Machines	Electrical Waste Recycling Group: An in house FPD automated mechanical processing facility; government agency approved, in house mercury distillation, copper recycling, 20 tonnes of WEEE waste processing per hour, the largest lamp recycling facility in the UK and also a battery recycling company.
Glass Waste: Laboratory Items Jars Bottles	DJ Laing: DJLaing has two sites, one just north of Dundee specialising in the recycling of all types of timber, soil and stone materials with an annual capacity of handling up to 100,000 tonnes. The second state of the art recycling site which was invested in June, 2010 is based at an industrial estate in Dundee and has a capacity of receiving 100,000 tonnes of waste materials for recycling and is the base for the Skip Hire fleet.
General Municipal Waste: Furniture / carpet waste Principal and secondary grade wood Ferrous metals e.g. iron, steel Non-ferrous metals e.g. aluminium, brass, bronze Miscellaneous	DJLaing :(cont)
Surplus Furniture: Chairs Desks Filing Cabinets Bookcases	Transform Community Development: The project distributes furniture to the public for re-use to homeless individuals securing their first tenancy or within the projects shop to generate valuable funding.
Food Waste:	Keenan Recycling Ltd:

General Food Waste Coffee Granules Paper Towels	Scotland's largest food waste recycler uplifts Abertay's food waste and there are two routes it may take; to be converted into compost within a vertical composting unit (VCU) under an aerobic process or transferred to an offsite anaerobic digestion plant where the food waste is converted into energy.
Special Waste: Chemicals Solvents e.g. paint thinners First Aid Waste	PHS Group:

Table 1: Waste Carrier & Destination

with local schools and universities as an achievable energy recovery solution would require waste to remain at consistent levels. Currently Abertay's Food Waste is being treated in two different ways and explained below;

A. Composting

Composting is a valuable strategy to consider as it is not only beneficial in avoiding the depositing of waste to landfill but also in the form of nutrient recycling as we are effectively returning nutrients back into our soil through the organic matter of food, fish processing & gardening wastes with the creation of a closed loop system.

Composting is a process that can be undertaken on a small scale (allotments and urban gardens) right up to large scale plants (institutions and factories) allowing for a reduction in our landfill costs with the additional benefit of providing nutrients back to our countries farmlands.

However, drawbacks can be significant and the main one being that large scale plants must be sited in rural areas due to the high odours and they are susceptible breeding ground of pests due to the nature of the processes taking place in this particular environment. There is also the challenge of keeping transportation costs to a minimum, consideration to our carbon footprint and energy costs minimised. There is the expense of the plant which includes sorting machinery for removal of un-compostable materials and programmable processing equipment to allow the compost to be turned on a regular basis in order to accelerate the decay process.

In a small scale environment, composting can be a simple process as in our own gardens and allotments we can produce garden clippings, vegetable waste and leaves. When mixed with soil containing the bacteria to break down the elements and water is added to keep the mix moist, the environment has been created for the production of home grown compost eliminating the need for artificial fertilisers.

As composting is the decomposition of waste with oxygen and being the opposite of anaerobic where oxygen is absent, interestingly aerobic digestion in the form of composting is actually a far quicker process and this is attributed to the release of heat energy in the form of Polpraset which is a good choice for stabilising vast amounts of waste. Biological reactions turn the Putrescible organics into an organic form which are pollution free if to be dispersed onto our land or sea which are credentials for our green environment of today's world.

During the composting process temperatures are as high as 60 c and due to the temperature being at a consistent level over 24 hours, pathogenic bacteria, viruses and helminthic ova properties are all successfully removed. A change to nutrients in their organic form; NO3 and PO4 also takes place which promotes the suitability of the compost to encourage improved root growth and also the development of poor quality soil on farmland. Part of the food waste generated at Abertay University is placed in an In Vessel Composting (IVU) unit which is an accelerated composting process where biodegradable waste; food, garden and fish processing waste is mixed with garden waste as this produces the pockets of air. The mix is placed in the (IVU) which is a plastic tank with enclosed heat chambers with an controlled PH, air flow and suitable microbes which can produce a compost in as little as a few days. The principle being a “bioreactor" with air circulation through tubes allowing for fresh air to be injected under pressure and a bio filter used as an exhaust. The In vessel composting process allows for an even temperature distribution throughout the chambers inactivating all pathogens present.

The compost produced is a BSI Pass100 accredited compost with research confirming no issues relating to crop quality, the compost can be used by farmers at any time of the year with 95% of quantities purchased by farmers and 5% by landscapers

Advantages of using the BSI Pass 100 accredited compost:

- Reduced need for bagged fertiliser
- Reduced nutrient leaching
- Increased yield potential

- Potential to improve drainage in heavier soils
- Improved water holding in light soils
- Reduced soil erosion risk
- Beneficial soil micro-organism aid - soil aggregation, nutrient recycling & plan disease suppression
- Better soil structure - greater workability of soil & increased traffic tolerance

According to Table 2 data Nutrients are highly important in the production of compost to ensure its effectiveness and for every typical 28 tonnes, Keenan Recycling Ltd confirm the following nutrients are present.

Aerobic Digestion - Biochemical Breakdown Waste

Latent Phase	Length of time required for micro-organisms to acclimatise.
Growth Phase	Biologically produced temperature rises to allow micro-organisms to thrive between 25 c and 40 c.
Thermophilic Stage	The temperature rises to its highest level with destruction of pathogens most effective and the waste stabilisation phase taking place.
Maturation Stage	Secondary fermentation takes place with temperatures decreasing from 40 c down to an ambient level. Nitrification reactions occur with ammonia being biologically oxidised to change to nitrite (NO2) and then nitrate (NO3).

Source: Polpraset. C. (1996) Organic Waste Recycling: Technology and Waste Management

Nutrients	**Total Amount (kg/ha)**	**Total Amount (units/acre)**
Nitrogen as N	244	195
Phosphate as P2Qs	87	69
Potassium as K2O	168	134
Magnesium as Mg	48	38
Sulphur as S	25	20

Table 2 Nutrients Total Amount

B. Anaerobic Mechanism

Within this Anaerobic methods there are two mechanisms will be consider

1. Combined heat and Power plant
2. Anaerobic Digester.

1. Combined heat and power

As the second method of long term power generation using renewable energy technology for Michelin Tyre PLC, we propose CHP.

What is combined heat and power (CHP)?

Combined heat and power (CHP) is an efficient and clean approach to both generating electric power and thermal energy from a single fuel source. CHP is used either to replace or supplement conventional separate heat and power (SHP). Instead of purchasing electricity from the local utility and burning fuel in an on-site furnace or boiler to produce thermal energy, an industrial or commercial facility can use CHP to provide both energy services in one energy-efficient step. (Marshall, 2014)

Figure 4 Internal combustion engine CHP plant Source- Carbon Trust

Why use CHP?

According to the heat and power association "CHP generates electricity whilst also capturing usable heat that is produced in this process. This contrasts with conventional ways of generating electricity where vast amounts of heat are simply wasted. In today's coal and gas fired power stations, up to two thirds of the overall energy consumed is lost in this way, often seen as a cloud of steam rising from cooling towers".

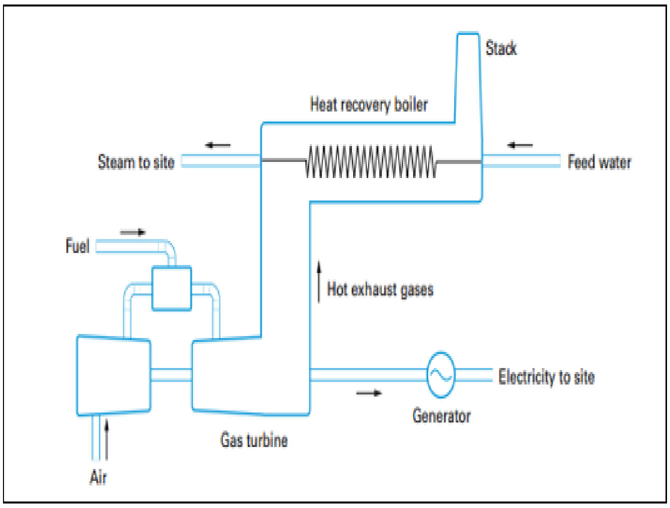


Figure 5 Custom built CHP plant

Source – Carbon trust

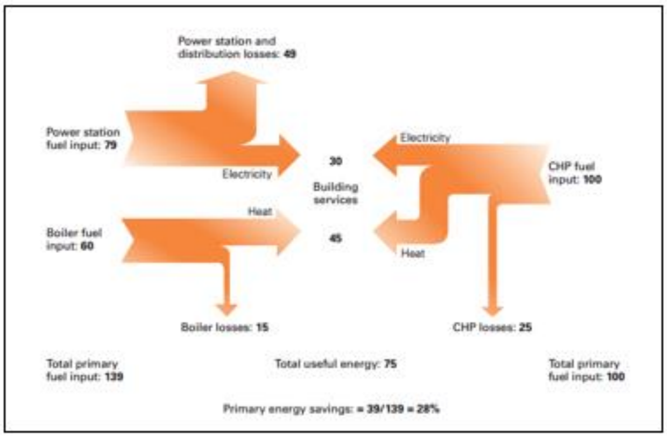


Figure 6 Energy savings through typical CHP compared to conventional sources

Source- Carbon Trust

CHP is a form of distributed generation, which is situated at or near the energy-consuming facility, whereas conventional generation takes place in large centrally-located power plants.

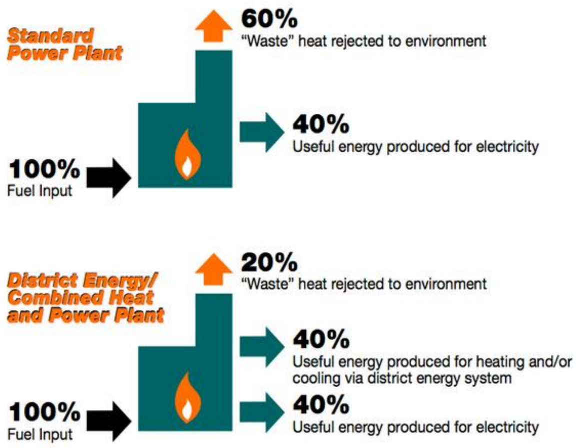


Figure 7 Energy efficiency comparison

Source- International district energy associate

CHP's higher efficiency comes from recovering the heat normally lost in power generation or industrial processes to provide heating or cooling on site, or to generate additional electricity. CHP's inherent higher efficiency and elimination of transmission and distribution losses from the central power plant results in reduced primary energy use and lower greenhouse gas (GHG) emissions. (Marshall, 2014)

The above figure 5 & 6 describe the efficiency of a CHP plant over conventional methods and energy efficiency comparison.

Advantages of CHP

- CHP reduces the cost of energy for the user
- CHP reduces the risk of electric grid disruptions and enhances energy reliability for the user
- CHP gives the better environmental performance
- CHP provides a more reliable and secure energy supply
- CHP provides electricity, heat and heat recovery in same unit

CHP Mechanism

According to the heat and power association "As an energy generation process, CHP is fuel neutral. This means that a CHP process can be applied to both renewable and fossil fuels. The specific technologies employed, and the efficiencies they achieve will vary, but in every situation CHP offers the capability to make more efficient and effective use of valuable primary energy resources". In this case, we propose using gas as a primary energy source for CHP. This gas is produced by an anaerobic digester within the company premises.

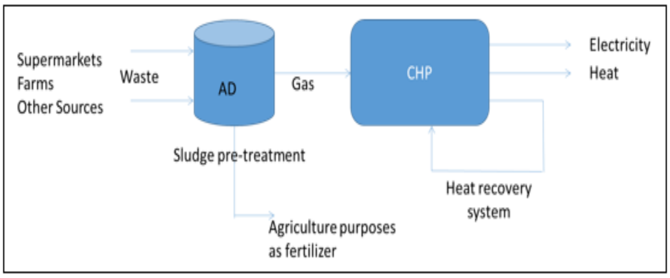


Figure 8 CHP mechanism

2. *Anaerobic Digester Plant*

Sources of waste

Anaerobic digestion is a waste management solution that has the potential to provide a source of renewable energy. Anaerobic digestion technology converts animal waste to methane biogas, which can be utilized as a renewable source of energy. The end product is a low odour, high nutrient, stabilized waste which is suitable for land application. (S. Sharvelle and L. Loetscher - 2014) In this digester, in addition to the animal waste from farms, we propose other waste sources as mentioned below.

- ✓ Waste vegetables, fruits and other type of biodegradable foods from large and small scale supermarkets
- ✓ Energy crops (ryegrass, sunflower, maize, sorghum), post-harvest residues (wheat, barley) and organic by products (animal husbandry, residual from industrial processing of agriculture products) from small and large scale farms
- ✓ Organic waste (human and industrial waste, bio waste) from breweries and distilleries
- ✓ Organic waste (residual from food and agriculture process) from abattoirs

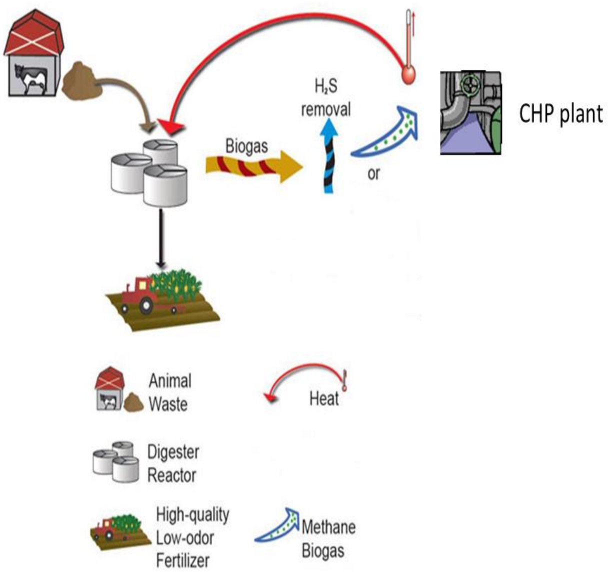


Figure 9 Typical anaerobic digester configurations.

Final disposal

After producing gas as the primary energy source for CHP the by-products from the anaerobic digester undergo pre-treatment methods such as dewatering and solid separation. Then this treated by-product goes to composting and to the fertilizer plant to produce fertilizer. Finally both the compost and fertilizer are sent back to the farms.

Gas production rate

In this case we assume that the monthly biogas production from the anaerobic digester uses a mixture of all the above sources:

The manure production rate =500 tonnes/month
Moisture content = 90%
Organic solid content = 80% of total dry solid
Minimum biogas yield = 500 m^3/tonnes
Biogas production = Amount of raw feedstock in tonnes/month

X Dry matter content %
X Organic matter content %
X Specific biogas production in m^3/tonnes

The manure production rate = 500 tonnes/month
Dry matter content 500x10% = 50 tonnes/month
Dry organic solid content 50x 80% = 40 tonnes/month
Therefore gas production = 40 tonnes/month x 500 m3/tonnes
= 20000 m^3/month
Gas production Rate = 0.46 m^3/minute

IV. Future Proposals

What are the options to improve and develop on our current sustainable initiative progress with renewable energy sources? The key drivers of good practice in recycling and waste management must all be considered. It is evident Abertay University from current practice that further work is required in the areas of financial, reputation, environmental and technological drivers and the solutions provided in this paper addresses these results through an efficient and effective sustainable waste management system through the recommendation of sustainable projects. Wasted resources have a major impact on the basic sustainable concept which must be mitigated with the delivery of suitable outcomes.

The development of a multifunctional waste management system integrated with local energy systems could link with a district heating & electricity system and with the treatment of wastewater preventing waste to landfill and considering recovery as an alternative.

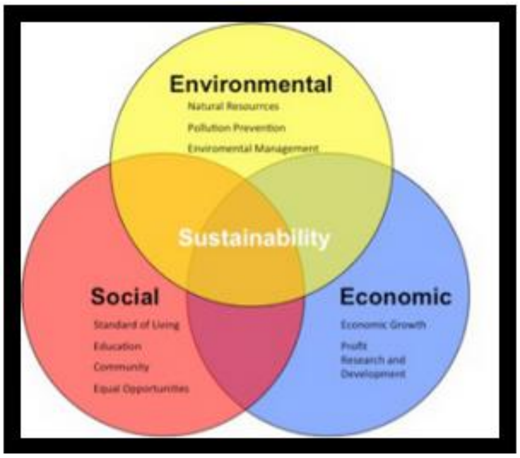


Figure 10 The Basic Sustainable Concept

These projects would increase both the economic and environmental values of current operations by diverting food waste resources, resulting in reduced waste uplift costs as the waste will have a reduced carbon footprint, which in turn environmentally reduces carbon emissions from transport overall reducing the carbon impact.

V. CONCLUSIONS

Research has identified that Abertay University's sustainable waste management and recycling practices are limited and may be seen as "quick wins". Compliance with legislation and best practice is evident however there is vast scope and abundant benefits to be achieved from developing and moving forward with our sustainable initiatives for the university. Research concludes that waste levels being recycled are increasing annually and it is important that waste data recorded is accurate to continually evaluate the universities achievements in waste management practices.

The adoption of new technologies are feasible solutions with the introduction of a small scale anaerobic digester, ensuring we are recycling our food waste economically and secondly the introduction of a combined heat and power plant will allow for the conversion of the university's residual waste into renewable energy which benefits the university by also producing a profit which can be assigned to future initiatives. There are no doubt design challenges with the proposed initiatives but with senior management support and encouragement from staff, there really are no barriers as to the success that Abertay University could achieve in this field.

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