4.0 TASK 3: REVIEW OF NEW AND EMERGING TECHNOLOGIES

4.1 Advances in Current Technologies

4.1.1 Material Recycling Facilities

MRF technology is based mostly on electro-mechanical systems and technology upgrading opportunities are modest and are limited primarily to continuing improvements in the speed and accuracy of near infra-red (NIR) detectors and the air-knives used to segregate different types of recyclable plastics.

4.1.2 Combustion based Energy from Waste

For combustion-based thermal treatment, there have been no significant recent changes in the operation of combustion equipment. A notable improvement in environmental performance has however been in respect of the options for management of air pollution control residues (APCr) also known as fly ash. This material has previously been required to be processed as a hazardous waste, prior to final disposal. Techniques developed in the UK have now enabled APCr to be processed so it can create an aggregate material which stabilizes and locks-up heavy metals and other contaminants. The UK environmental regulator, the Environment Agency, has accepted testing programs that have demonstrated the long-term suitability of this technique, although use in construction projects has been limited thus far.

4.1.3 Anaerobic Digestion (AD)

For biological based AD plants, improvements in the digestion process are modest, based primarily on pre-treatment of ‘less digestible’ feedstocks to render them usable (i.e. straw) using techniques such as thermal hydrolysis or ultrasound, to breakdown the lignin content etc. For food-only AD plants, use of a nutrient supplement has been found to be useful in helping to maintain the health of the microflora involved in the digestion process.

One recent technology development has been the upgrading of biogas, at 50-60% methane, to produce +97% methane or a natural gas quality ‘biomethane’, with the ‘bio’ reflecting the non-fossil fuel origin of the methane. The biomethane can then be either injected into the natural gas grid (i.e. gas to grid), or compressed/liquefied and used as a vehicle fuel. The upgrading technologies used (i.e. typically porous membranes and water/solvent based scrubbing), are well established and commercially proven. In addition the carbon dioxide (CO_2) removed from the biogas during upgrading can be captured and sold for commercial use.

A second development is the use of processes to convert biogas/biomethane (and landfill gas, which is similar in composition to biogas) into a liquid fuel, one based on liquefying biomethane and the other using a thermochemical conversion route for ‘gas to liquid’ (GtL). A brief overview of the technologies involved is presented below.

4.1.3.1 *Liquefication*

Liquefying biogas/biomethane and landfill gas has been undertaken successfully in the UK and US. In 2008 a consortium of Gasrec, BOC (part of the global gases and engineering Linde Group) and SITA UK (now Suez), a leading UK recycling and waste management company, announced the successful production of liquid biomethane (LBM) fuel from the Gasrec plant at SITA UK’s Albury landfill site in Surrey, UK. The process is applicable equally to biogas, as it works by upgrading landfill gas/biogas to biomethane and then using conventional liquefication technology based on compression and cooling the gas to -162°C in a heat exchanger to produce liquid biomethane (LBM). The LBM is used as fuel in the Councils' waste collection vehicles.

In the US, Waste Management Inc. and Linde Group, a leading supplier of industrial, process and speciality gases has been converting waste to LBM at the Waste Management Inc. Livermore, San Francisco facility since September 2009.

4.1.3.2 *Gas to Liquids*

In 2014 Waste Management Inc., Ventech Engineers International LLC, NRG Energy Inc. and Velocys plc announced a joint venture to use small-scale GtL plants to create fuels and chemicals from biogas and natural gas. GtL technology utilizes the Fischer Tropsch (FT) thermochemical conversion process to produce synfuels from gasified biomass. The technology dates back to the 1920s and was utilized by Germany in World War II and by South Africa during its isolated apartheid era.

In the FT process the carbonaceous material is first gasified and the gas processed to make a purified syngas (mixture of carbon monoxide and hydrogen), which is then polymerized into diesel-range hydrocarbons. While it has been around for nearly a century, GtL has generally been associated with large facilities owned by major oil and petrochemical companies. However the cost of these 'small-scale' GtL plants is still in the 'tens to hundreds of millions', rather than 'tens of billions', so will not apply to most municipally-sized AD plants.

Similar technological developments have taken place with using the gasification of biomass, where GtL has long been an option but few biomass-based BtL plants are operating. The one advantage of BtL plants is that while biodiesel and bio-ethanol production only use parts of a plant (i.e. oil, sugar, starch or cellulose), BtL production can gasify and utilize the entire biomass feedstock.

4.1.4 Advanced Thermal Treatment (ATT)

Development of the technologies used for pyrolysis/gasification has continued to evolve over the last 15-20 years, with many variations now available from a wide range of equipment providers. While most of the developments are relatively minor in nature, an exception is the use of plasma arc/torch technology to either gasify the feedstock, or to 'crack' the as-produced syngas to provide a cleaner, higher CV syngas, suitable for direct use in a gas engine, or further conversion to a liquid fuel i.e. GtL, as described above in **Section 4.1.3.2**

Plasma arc gasification technology creates high temperatures by an electrical arc/plasma that breaks down waste primarily into gas and a solid waste (slag), in a device called a plasma torch or converter. The process is intended to be a net generator of electricity, depending on the composition of the input waste and to reduce the volumes of waste sent to landfill sites.

In contrast to the other plasma systems, one technology (APP system) uses thermal gasification prior to the plasma stage. A single stage plasma gasification process for treatment of waste is not normally regarded as economic, due to the large amount of electricity required to convert waste into syngas. The syngas produced by thermal gasifiers contains condensable organic compounds that form tars on cooling and apart from direct use for combustion, makes the gas unsuitable without additional cleaning processes. By applying plasma technology to the gasification products the APP system is able to achieve efficient cracking of the complex organics in the primary syngas constituents, while limiting the electrical energy demand of the process. The resulting gas can be treated and cooled without precipitating large quantities of liquid condensate and solid tars, as occurs with conventional thermal gasification and is usually the common cause of most operational problems.

Comparison of the economic benefits of thermal gasification, plasma gasification and the combined thermal/plasma system suggests that the outcome is dependent on a multiplicity of factors, including type of waste, quantity, outputs, end use requirements and electricity and landfill costs etc. At a small scale e.g. c. <30k-50ktpa, none of the above options is likely to be considered viable.

4.1.5 Summary

Some developments have been made within the main technology classes, such as improving the efficiency of the AD digestion process and upgrading biogas to biomethane. However, apart from liquefication of biogas/biomethane/landfill gas to produce LBM, those associated with thermal conversion, such as GtL, are of a scale and costs considered unlikely to be applicable to Oxford County.

4.2 Upgrading and Use of Existing WWTP Infrastructure

Local Authorities in the UK and New Zealand have pursued the use of existing waste water treatment plant (WWTP) facilities to treat the organic fraction of their MSW. Two examples are provided, one of which SLR was involved with.

4.2.1 Case Study 1 – Avonmouth (Bristol), UK

Avonmouth is a suburb east of Bristol, in the South West of the UK and is both a port and industrial hub, comprising several large industrial plants and light industrial warehouses. Among the industrial plants are a range of solid waste treatment facilities, in addition to the WWTP operated by Wessex Water. Historically the Avonmouth WWTP has provided the treatment of sewage for the population equivalent of one million people across parts of the region and part of the infrastructure included an AD plant to treat the sewage sludge.

In 2012 a 30ktpa AD plant was commissioned at the site solely for the treatment of food waste and was the first AD plant in the UK to be co-located at a WWTP as a separate company, GENeco. The designated plant was designed and built in under a year to benefit from funding under a Government renewable energy subsidy, without which the scheme would have almost certainly been uneconomic financially. The AD plant was designed to supply biomethane and initially was used as a fuel in the ‘Biobus’ the first bus in the UK to be powered by gas derived from food, sewage and commercial liquid wastes.

A class exemption to the standard for the oxygen content in biomethane (from 0.3% to < 1% in May 2013) opened the door for ‘gas to grid’ injection of biomethane. When the operational costs of the potential biomethane upgrading options were compared, Wessex Water determined that the water scrubbing technology option provided the least whole-life cost solution. The biomethane plant was subsequently built using the water scrubbing upgrading technology and achieved grid injection on 17 November 2014.

GENeco initiated the ‘Biobus’, a pilot study to showcase the possibilities of biomethane powered public transport to reduce health risks arising from vehicle emissions. Initially the bus operated between Bristol Airport and the centre of Bath but subsequently the bus operates a new route and the bus has since been linked by Bristol City Council with Bristol City’s 2016 Green Capital initiative. The media success of the reporting of the Biobus lead to 110 news websites worldwide covering the story, with interviews held with American, Russian, Chinese and Arab news stations , plus all of the UK news stations. In March 2015, Bill Gates drew attention to the work of GENeco by acting as an ambassador for the use of biomethane and indirectly as an ambassador for the technology.

4.2.2 Case Study 2 – Fielding WWTP, Manawatu District Council, New Zealand

The Fielding WWTP operates a combination of anaerobic and aerobic biological treatment for the incoming sewage and receives a load comparable to 50,000PE. The sewage is characterised by changing concentrations within a short period of time, due to the discharge of commercial effluents that form part of the general sewage collection system. The composition of the short term, high loads indicated that the effluent is discharged by slaughterhouses and other companies treating animal products. It is understood that the operator is also considering treating additional commercial effluents from a number trades in the area and the concentrations of the potential effluents were provided for consideration to see if they were suitable for direct AD treatment.

While the initial work was based around refurbishment/replacement of the existing digester the current sewage treatment process also required changes to provide the optimum feedstock for digestion and subsequent production/use of biogas.

SLR was asked to review the proposed refurbishment/replacement of the current digester, based on the general requirements for digestion processes, integration of the additional digestion tank and a discussion about the possibility to integrate the digestion of food wastes or separated flotation sludge, including fats from slaughterhouses. The output of the review identified four options for consideration in respect of changes to the existing facility, including:

- Option 1: use of existing facilities at the WWTP and refurbishment of the current anaerobic digester.
- Option 2: use of existing facilities at the WWTP, refurbishment of the anaerobic digestion plant, and importing sludges from industrial customers.
- Option 3: changed operation of the plant, with addition of a new digester (possibly a second in due course) and separate solids deliveries from industrial customers.
- Option 4: new digestion tank, digestion of current secondary sludge plus paunch grass.

Budget costs were also provided to allow Manawatu DC to compare the financial return of each option. The Council will evaluate the options to determine the optimum solution in respect of the wastes to be treated, overall financial return of each option and associated environmental and community benefits.

4.2.3 Considerations for Utilization of Digestate

An important aspect for any AD plant is where and how the digestate will be utilised. As a rule of thumb, for every 100te input about 75-80e digestate is produced.

Key to the successful utilisation of digestate is the regulations surrounding its application to land. In the EU, digestate derived from source separated organics – household and post production – if processed appropriately by being pasteurised at 70^0C for one hour, can be applied to land as a fertiliser and soil conditioner. This applies to both whole digestate as produced, or as digestate separated into its solid and liquid components.

If organics sources from residual MSW are digested the digestate cannot be applied to agricultural land and is termed 'compost like output' (CLO) that can be only used for landfill restoration or the remediation of contaminated land, or otherwise sent to a landfill for disposal.

In the EU if non-source segregated organics are mixed with agricultural wastes and/or biosolids in an AD plant the digestate is deemed a CLO. If OC proposes to develop an AD facility that involves mixing the organic fraction of residual MSW with agricultural wastes and/or biosolids in an AD plant, then the regulations applicable to applying such a material to land will need to be consulted and adhered to.

The situation in Canada and Ontario differs from that in the UK/EU. Under the *Guideline for the Production of Compost in Ontario*[12] the regulations generally follow similar lines to UK/EU regulations but with the important distinction that the pasteurisation of certain food wastes is not required.

The *Guidelines* enable composting of a broad range of materials and provide guidance for compost facility operators, while protecting the environment and human health. The Compost Quality Standards provide three categories of compost (AA, A and B), each with their own quality standards for metals, pathogens, foreign matter and maturity. Compost meeting the AA and A standards is exempt from ministry approvals for transport and use.

Compost is graded as Category AA, A and B, with AA the highest and B the lowest, based on the maximum allowable concentration for metals in the feedstock that must be adhered to. Organic materials can be applied to land through an Environmental Compliance Approval or, specifically for a farm, as a Non-Source Agricultural Material (NSAM) for which a plan may be required.

The *Ontario Compost Quality Standards – Part III – Use of Compost*[13] describes the permitted uses for all compost types, and relevant compost quality factors. Compost types include:

- Category AA compost must not contain regulated metals in a concentration that exceeds any of the limits set out in Column 2 of **Table 4-1**;
- Category A compost must not contain regulated metals in a concentration that exceeds any of the limits set out in Column 3 of **Table 4-1**; and
- Category B compost must not contain regulated metals in a concentration that exceeds any of the limits set out in Column 4 of **Table 4-1**.

[12] http://www.ewswa.org/wp-content/uploads/2011/06/Guideline-For-The-Production-of-Compost-in-Ontario.pdf
[13] https://www.ontario.ca/page/ontario-compost-quality-standards#section-2

Table 4-1:
Maximum Concentration for Metals in Compost

Table 3.1 - Maximum Concentration for Metals in Compost

Item	Column 1: Metal	Column 2: Category AA Compost (mg/kg dry weight)	Column 3: Category A Compost (mg/kg dry weight)	Column 4: Category B Compost (mg/kg dry weight)
1.	Arsenic	13	13	75
2.	Cadmium	3	3	20
3.	Chromium	210	210	1060
4.	Cobalt	34	34	150
5.	Copper	100	400	760
6.	Lead	150	150	500
7.	Mercury	0.8	0.8	5
8.	Molybdenum	5	5	20
9.	Nickel	62	62	180
10.	Selenium	2	2	14
11.	Zinc	500	700	1850

In Ontario, digestate produced by AD is applied to agricultural fields to improve the soil organic matter content and is registered as a fertilizer under the *Fertilizer Act (Canada)*, administered by the Canadian Food Inspection Agency. Although Cat AA and A compost is exempt from transport and use approvals, all compost is considered a nutrient under the Nutrient Management Act (NMA). When applied as a nutrient on agricultural land that is required to have a Nutrient Management Plan (NMP) and/or NASM Plan, the compost must be applied in accordance with the NMP or Non-Agricultural Source Materials (NASM) Plan and O. Reg. 267/03.

Unlike Categories AA and A compost, Category B compost is not an exempt waste and is subject to Part V, EPA and Regulation 347, including approvals for transportation and management. Where Category B compost is applied to agricultural land as a nutrient and satisfies the requirements of O. Reg. 267/03 under the NMA, it is exempt from Part V of the EPA and Regulation 347 for use (it still requires approval for transportation).

Use of Category B compost would typically not be permitted in areas with regular human contact e.g. parks or residential areas but it may be put to beneficial use through the following applications:

- Organic soil conditioning: Cat B compost may be used as an organic soil conditioner in a variety of non-agricultural applications (e.g. land reclamation, mining rehabilitation, reforestation, etc.), subject to an ECA for an organic soil conditioning site that permits the spreading or application of Category B compost;

- Agricultural land use: Cat B compost may be used on agricultural land as a nutrient subject to the requirements of O. Reg. 267/03, made under the NMA;
- Landfill cover: Cat B compost may be used as daily, intermediate cover at a landfill that has an ECA (waste disposal site) that permits the use of Category B compost as cover.

Category B compost applied on agricultural land as a non-agricultural source materials under the Nutrient Management Act is restricted to a maximum annual sodium loading limit to maintain soil health.

Based on the above regulations it would appear that biosolids and residual MSW food waste can be mixed and used as Cat B compost, subject to meeting the maximum metals content in **Table 4-1**.

The *Nutrient Management Act, 2002 – O.Reg. 267/03*[14] sets out criteria in 98.0.6(1) requiring that at least one of the following conditions is satisfied before applying NASM to land:

I. In the case of solid or liquid NASM, the amount of total organic matter is more than 15 per cent of the total weight of the NASM;

II. In the case of solid or liquid NASM, the NASM is used to increase the soil pH value;

III. In the case of solid NASM, the total concentration of plant available nitrogen, plant available phosphate and plant available potassium, determined in accordance with the Sampling and Analysis Protocol, is more than 13,000 milligrams per kilogram of NASM, calculated on a dry weight basis;

IV. In the case of liquid NASM, the total concentration of plant available nitrogen, plant available phosphate and plant available potassium is more than 140 milligrams per litre of NASM;

V. In the case of liquid NASM, the condition set out in paragraph 4 is not satisfied but the liquid NASM is an aqueous solution or suspension containing more than 99 per cent water by weight and is used to irrigate crops during the period that begins on June 15 and ends on September 30 of the same year. O. Reg. 338/09, s. 70; O. Reg. 284/12, s. 7 (2).

Under the requirements above, whole/liquid digestate will fail the +15% total organic matter criteria and thus need to pass one of the remaining four requirements, which could provide difficult, subject to the wastes and testing results. While the regulations provide guidance, they are not expressly explicit with regard to compost created from AD digestate or in respect of the acceptability of biological contaminants. To assist Oxford County in ascertaining the precise situation applicable in Ontario, posing the following question to the MOECC may be of assistance:

"*Oxford County is proposing to develop a waste processing facility which may involve the mixing of the organic fraction of residual MSW with agricultural wastes and/or biosolids in an AD plant. Please confirm that subject to achieving required processing parameters in respect of pathogen kill, the digestate from such a facility would be acceptable for application to agricultural land*".

[14] https://www.ontario.ca/laws/regulation/030267