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Memorandum

To:	Jay Heaman Manager, Strategic Initiatives	**From:**	Mark Sungaila, Ben Arnold SLR Consulting
Company:	Oxford County		
cc:		**Date:**	Aug 4, 2017
Subject:	**ASSESSMENT OF WASTE REDUCTION AND RECOVERY TECHNOLOGIES TECHNICAL MEMORANDUM 1C: STAGE 3 - RESULTS OF MULTI-CRITERIA ASSESSMENT**		

1.0 INTRODUCTION

Oxford County operates a very successful municipal solid waste management program having achieved a ranking of 6th out of 230 Ontario municipalities for diverting residential waste from landfill, as well as a ranking of 1st in diversion for municipalities within its grouping[1]. The County has also embarked on an ambitious program to achieve two significant long term Sustainability goals, being 1) achievement of 100% renewable energy by 2050[2], in accordance with the County's June 2015 resolution; and, 2) achievement of Zero Waste, as articulated in the September 2016 draft Zero Waste Plan[3]. Oxford County's renewable energy commitment provides a mechanism for linking the two goals outlined above and recognizes that residual waste can form a useful feedstock for generating energy from waste. As part of its program toward achieving Zero Waste and other related goals, OC has undertaken this ***Assessment of Waste Recovery and Reduction Technologies*** (the Project). The Project is being undertaken amidst the development of recent climate change and waste management legislation (and related policies, strategies, and emerging programs), intended to dramatically reduce waste generation and disposal, and intended to drive the 'Circular Economy'.

[1] Full Report County of Oxford Waste Management Strategy, Oxford County, August 2014.

[2] Draft 100% Renewable Energy Plan, Oxford County, June 22 2016.

[3] Draft Zero Waste Plan, Oxford County, September 22, 2016.

The County has retained the consulting team of SLR Consulting (Canada) Ltd., in association with Love Environment to assist them in carrying out the Project, which will consist of five main tasks described in following **Sections 1.1** through **1.5.**

1.1 Task 1: Assessment of Existing Waste Recovery Technologies

Task 1 is a comprehensive review of existing approaches to the reduction of residual waste, leading to identification of technologies that are relevant to Oxford County. This will be undertaken in three stages:

- *Stage 1: Setting the Scene*: This is an analysis of the current waste management situation in Oxford County aimed at characterising the County's waste management situation in terms of scale, current approach, types of waste, barriers and opportunities.

- *Stage 2: Technology Options (Inclusive List).* Stage 2 is identification of a long list of technology suppliers under each material type and technology class. This long list would subsequently be screened against a set of criteria which would be agreed with the County.

- *Stage 3: In-depth Evaluation.* Stage 3 is a more in-depth analysis of the individual technologies using the County's Multi Criteria Analysis Tool (MCA).

1.2 Task 2: Case Studies of Implemented Technologies

Task 2 will result in the documentation of case studies of technologies implemented in other jurisdictions, as well as highlighting of those technologies which have been successfully implemented and which have highest likelihood of successful implementation in Oxford County.

1.3 Task 3: Review of New and Emerging Technologies

This task will be the documentation of new and emerging technologies as identified in Task 1, as supplemented by gathering of additional data as required and prepare meaningful commentary.

1.4 Task 4: Relationship of EPR and Resource Recovery with Current Waste Stream

Task 4 will examine and assess the impacts of recent climate change and waste management legislation, namely:

- Bill 151 – the *Waste Free Ontario Act* which includes both *Resource Recovery and Circular Economy Act* and the *Waste Diversion Transition Act;*
- The *Strategy for a Waste Free Ontario* (through which topics like the future of organics, disposal bans, new material designations and ICI diversion are prominent); and,
- The *Ontario Climate Change Action Plan* (and its potential impact on municipal waste operations).

This legislation will be examined in the context of several key questions, including the County's role in the delivery of waste management services in areas where producer responsibility is significantly changing, and the County's role in ensuring that expanded EPR programs that are implemented are well integrated with the overall waste management system.

1.5 Task 5: Economic Potential of Full Resource Recovery

This task will seek to identify the net economic benefits of implementing the preferred technology solutions identified in Task 1, considering the outline CAPEX and OPEX costs of technologies, and accounting for the value within recovered materials, the potential sale of power and/or heat from certain categories of technology, and avoided costs of landfilling and long-term management of impacts.

1.6 Study Documentation

Documentation generated during this study will be presented in technical memoranda covering each task. Following review and agreement by the County, the technical memos will be combined into a final report with an overarching introduction and conclusion section.

2.0 DOCUMENT OBJECTIVES AND ORGANIZATION

2.1 Document Objectives

To assist with the review of technologies as outlined in the proposed scope of works, Oxford County (OC) has provided SLR with a template for the *Multi-Criteria Assessment* (MCA) tool so that it may be applied to each of the waste processing scenarios being considered.

This memo, **Technical Memo 1C (TM1C)**, presents the underlying assumptions and methodology used in completing the MCA as well as the preliminary findings.

2.2 Glossary

As an aid to the reader the following glossary is provided for terminology used in this memorandum:

%	Percent
AD	Anaerobic Digestion
APCr	Air pollution control residues
Biomethane	Methane derived from non-fossil fuel origins.
BtL	Biomass to liquid
CAPEX	Capital expense
CHP	Combined Heat and Power
CLO	Compost-like output
CO_2	Carbon dioxide

CV	Calorific Value
DS	Dry solids
ECA	Environmental compliance approval
EFW	Energy from Waste, also known as Waste to Energy WtE), is the conversion of waste into a useable form of energy, e.g., heat or electricity. A common conversion process is waste combustion.
EPC	Engineering, procurement, and construction
EPR	Extended Producer Responsibility
EU	European Union
GtL	Gas to liquids. A refinery process to convert natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons
h	hour
HAZOP	Hazard and operations study
IC&I	Industrial, Commercial and Institutional
IVC	In-vessel Composting
kg/m^3	Kilograms per cubic meter
kpta	Kilo tonnes per annum
LBM	Liquid biomethane
MBT	Mechanical-biological treatment
MC	Moisture content
MCA	Oxford County's Multi Criteria Assessment tool, a framework for making decisions on the basis of criteria categorized as Community, Economic, Environmental, and Implementation
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
MW	Megawatts (10^6 W) is a unit of power equal to one million watts
NASM	Non-agricultural source material

NIR	Near infra red
NMA	Nutrient Management Act
NMP	Nutrient management plan
NOx	Mono-nitrogen oxides (NO and NO2)
OC	Oxford County
OPEX	Operating expense
PE	Population equivalents
Pre Feed	Refers to the development of a pre-defined design package for a facility to evaluate technical and economic feasibility
PFI	Private finance initiative
RDF	Refuse-derived fuel
SOx	Sulfur oxides
SRF	High grade solid-recovered fuel
tCO_2e	Tonnes carbon dioxide equivalent
tph	Tonnes per hour
US	United States
UK	United Kingdom
WWTP	Waste water treatment plant

3.0 OXFORD COUNTY'S MULTI-CRITERIA ASSESSMENT TOOL

The purpose of the MCA tool developed by OC is to provide a transparent methodology for assessing the sustainability of alternative options or actions in consideration of the goals and objectives of the Future Oxford Community Sustainability Plan. For a given scenario, each of the criteria is assessed relative to that of the other potential scenarios with respect to how positive an impact it has on community sustainability. Each criterion is given a score of between 0 and 5, with zero being the worst and five being the best.

The criteria scores are also weighted to ensure a balanced assessment of the scenarios between the criteria groupings, while ensuring that the criteria of most importance to OC have a greater bearing on the final outcome.

Seven scenarios were developed, demonstrating the different types and combinations of technology that are available to OC for the treatment of garbage generated and collected within the county. The scenarios considered are as follows:

- **Scenario 1**: Materials Recycling Facility (MRF) recovering recyclables and organics, with the recovered organics to be bulked and transferred outside of OC for further processing at a wet anaerobic digestion (AD) plant, and the non-recyclable material to be disposed to landfill;
- **Scenario 2**: MRF recovering recyclables and producing refuse derived fuel (RDF) for thermal treatment outside of OC;
- **Scenario 3**: Mechanical Biological Treatment (MBT), i.e. Scenario 1 above plus a wet AD processing stage in OC;
- **Scenario 4**: MBT, i.e. Scenario 1 above plus a dry AD processing stage in OC;
- **Scenario 5**: MBT, i.e. Scenario 1 above plus an organics composting stage in OC;
- **Scenario 6**: Basic MRF to recovering inert construction and demolition material, and producing RDF for thermal treatment outside of OC; and
- **Scenario 7**: MRF recovering recyclables and producing RDF for gasification at a new facility in OC.

All scenarios involve at least some initial sorting of materials at a facility to be developed within the County. Scenarios 1, 2 and 6 involve second stage processing of remaining residual waste at a facility outside the County and assume that such facilities are already available with sufficient capacity to receive such materials. The remaining scenarios are based upon the development of new secondary processing capacity within the County and with any rejects from the secondary processing being landfilled at the Oxford Waste Management Facility (landfill).

4.0 DEVELOPING THE MCA TOOL

The detailed evaluation of the seven scenarios included the consideration of their relative advantages and disadvantages as well as the ease with which the technologies could be rolled out in OC to meet the needs of the County. The detailed evaluation consisted of the application of criteria that fell into four broad categories – Community, Economy, Environment and Implementation. Each of these criteria is considered further in **Section 4.1**.

4.1 Defining the Criteria

SLR carefully considered the range of criteria defined in the MCA tool and their appropriateness to this study. It was determined that the standard MCA provided on the Future Oxford website, referred to here on as the baseline MCA, would be of limited benefit in differentiating the various waste processing systems under consideration. As such, the criteria were adapted/interpreted in a manner to better serve the technology evaluation.

4.1.1 Community

The Community-related questions do not lend themselves to differentiation of the relative merits of the identified waste processing system scenarios. All scenarios have therefore been given an equal score of zero, across the 3 Community questions, for the purpose of this exercise.

4.1.2 Economy

Q1. Improving Vibrancy of Green Economy

The extent to which each scenario results in recyclable materials remaining in OC for subsequent re-use, recovery or recycling, is used as a proxy for the improvement in the vibrancy of the OC economy. The logic for this is that export of recyclable or fuel-generating materials out of OC reduces the scope for a diverse economy and related employment opportunities.

Q2. Enhancing Entrepreneurship Opportunities

Increasing the nature and extent of material segregation within OC increases the availability of opportunities to create new products & services relating to those materials. This approach will tend to favour MRF & MBT technologies, but may also have benefits for scenarios involving compost creation.

Q3. Advancing Local Food Production

This question is focussed on the relative merits of each scenario in respect of benefits to food production. Existing composting of leaf and yard waste is already supporting crop production in the County. Waste management systems which involve source-segregation (SSO) and composting of food wastes can also provide beneficial material for crop growing. However, given that OC has no current intention of implementing an SSO system, there does not appear to be any easily applicable way of differentiating the waste processing technologies under consideration. All scenarios have therefore been given an equal score of zero, for the purpose of this exercise.

Q4. Advancement of Green Economy

It was agreed with OC that we would seek to include consideration of the relative carbon impacts of the selected technology scenarios. While it would be possible to consider this issue under a number of the broadly defined criteria in the baseline MCA, we concluded that the green economy would be an appropriate criterion within which to examine carbon outcomes. In order to do this we considered a) the direct carbon impacts of each scenario and b) the relative quantity of material recycled resulting from each scenario. The next sections explain more detail about the basis of these assessments.

<u>Q4 Carbon element</u>

In discussion with OC, carbon performance of the scenarios was selected as a proxy for advancement of the local green economy. A greenhouse gas assessment was completed for each of the scenarios to assess the carbon performance of each solution being considered. The greenhouse gas assessment provides a measure of the emissions of gases that contribute to global warming and hence, climate change. The primary gases of concern are carbon dioxide, methane and nitrous oxide; the measurement of greenhouse gas emissions, also referred to more generally as carbon emissions is units of carbon dioxide equivalents (CO_2e).

Climate change has become a major issue in contemporary society, and as a consequence governments and other organisations are making commitments to reduce their carbon emissions and the impacts on climate change. Waste management systems give rise to carbon emissions through a range of mechanisms, but equally sustainable management solutions offer the ability to reduce carbon emissions through utilisation of process outputs and generation of energy.

To aid with this assessment, the Greenhouse Gas Calculator for Municipal Waste[4] (GHG Calculator) has been used. The GHG Calculator was developed by SLR for use by the Greater London Authority, and facilitates the high level modelling of a range of municipal solid waste (MSW) treatment solutions while allowing the user to modify certain parameters such as waste composition and mass balances where required to reflect specific scenarios. The draft results of the detailed waste composition survey undertaken by AET, on behalf of OC, have been assumed to apply for modelling purposes (see **Appendix A-1**). While UK specific, SLR believes that the GHG Calculator will provide a valid indication of the relative carbon performance of the seven scenarios in the context of OC.

The GHG Calculator has been developed using Life Cycle Assessment (LCA) methodology. LCA considers the environmental aspects of an entire system (as defined by the system boundary) including activities that occur outside of the traditional framework of activities from the point of waste delivery through to final disposal.

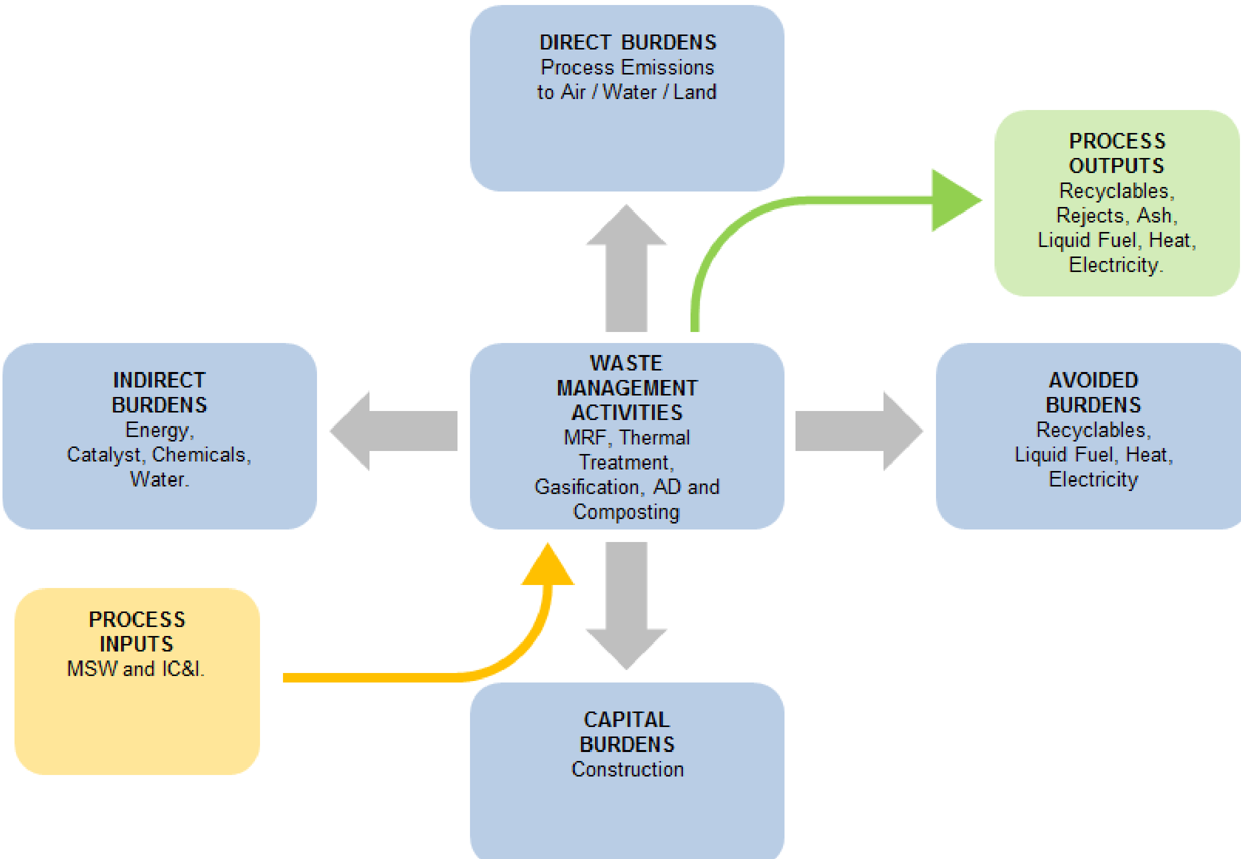
An LCA considers not only the direct impacts of a given waste management process on the environment, but also takes account of:

- Capital burdens associated with the construction of infrastructure;
- Direct burdens associated with waste management processes (e.g. direct process emissions to air);
- Indirect burdens associated with supplying raw materials and energy to the system; and
- Avoided burdens (also referred to as environmental benefits) associated with the recovery of materials and energy and subsequent diversion of waste flows from conventional sources.

The concept of direct, indirect and avoided burdens is illustrated in **Figure 4-1**.

[4] https://www.london.gov.uk/sites/default/files/glaghgcalcfinal.xls

Figure 4-1 Life Cycle Assessment Concept



The greenhouse gas assessment takes into consideration the various stages in the management of municipal waste – namely pre-treatment (MRF), AD or composting of organics, thermal treatment or gasification of RDF to produce electricity and disposal of process residues in landfill.

It should however be noted that the GHG Calculator is in practice relatively basic. For example, while the user is able to model the treatment of organics by AD, the model is unable to differentiate between wet and dry AD. Likewise with composting, the model is unable to differentiate between open windrow and in-vessel composting. From a carbon performance perspective, while there are some apparent limitations with the use of the GHG Calculator, SLR believes that its use is appropriate because:

a) Other criteria in the MCA will help to expose some differences between the scenarios where they exist, and

b) The GHG Calculator is a recognized tool, which has been used in decision making for a number of years.

Another point worthy of consideration is that the majority of scenarios (i.e. those with AD, gasification or thermal treatment) generate electricity which in turn offsets electricity from the grid. The actual benefit achieved will ultimately be dependent on a number of factors including:

Mass flows and material recovery through the MRF (i.e. mass balance);

- The electrical efficiency of the AD, gasification or thermal treatment plant; and
- Energy mix assumptions (see **Appendix A-2**).

The summary results of the greenhouse gas assessment for each of the scenarios considered are presented in **Table 4-1.**

Table 4-1 Greenhouse Gas Assessment Summary

Scenario No.	Details	Carbon Impacts (tCO_2e per tonne of waste managed)
1	MRF producing recyclables, and organics for processing outside OC	0.044
2	MRF producing recyclables, and RDF for thermal treatment outside OC	0.045
3	MBT, i.e. Scenario 1 above plus a wet AD organic processing stage in OC	0.057
4	MBT, i.e. 1 above plus a dry AD organic processing stage in OC	0.057
5	MBT, i.e. 1 above plus a composting organic processing stage in OC	0.160
6	MRF extracting inert material, and combustion of RDF at a thermal treatment facility outside OC	0.180
7	MRF producing recyclables and RDF for gasification at a new facility in OC	0.045

Q4. Recycling Element

Further interrogation of the GHG Calculator, in particular the mass balances, enables the user to quantify the process outputs for a given technology scenario or combination of treatment technologies. For a given treatment process, the mass balance is able to present approximations for the following output streams where relevant:

- Recycling;
- Compost-like output (CLO) and/or digestate;
- RDF or solid recovered fuel (SRF);
- Bottom ash and air pollution control residues (APCr);
- Biogas output; and
- General process losses such as moisture loss, vaporisation of material, etc.

Recycling performance is important in helping to score this criterion. In this context recycling is assumed to comprise dry recyclates recovered from the MRF or MBT process, as well as compost-like output (CLO) and digestate as all these materials are solid outputs that can be put to beneficial use. The results of the assessment of the recycling performance of each of the scenarios considered are presented in **Table 4-2**.

Table 4-2 Summary of Recycling Performance

Scenario No.	Scenario description	Material Recycled (tonnes of recyclates per tonne of waste managed)[5]
1	MRF producing recyclables, and organics for processing outside OC	0.149
2	MRF producing recyclables, and RDF for thermal treatment outside OC	0.303
3	MBT, i.e. Scenario 1 above plus a wet AD organic processing stage in OC	0.110
4	MBT, i.e. 1 above plus a dry AD organic processing stage in OC	0.110
5	MBT, i.e. 1 above plus a composting organic processing stage in OC	0.119
6	MRF extracting inert material, and combustion of RDF at a thermal treatment facility outside OC	0.244
7	MRF producing recyclables and RDF for gasification at a new facility in OC	0.303

The scores from the carbon performance and the recycling performance were then combined to give an overall score for this criterion.

4.1.3 Environment

Q1. Improve Oxford's Ecological Systems

The introduction of improved waste diversion will have an overall benefit on the environment. However, each of the seven waste management technology scenarios may have some moderate impact on the environment in terms of emissions to air, water and land, with the potential extent of the impact(s) increasing with the complexity of the technology option. The effect of any emissions on the ecological system will depend on both the proximity and sensitivity of the adjacent ecosystem.

[5] Inclusive of dry recyclates, compost-like output and/or digestate

Q2. Reduce Fossil Fuel Use

Each scenario uses electricity to process the feedstock but scenarios that subsequently generate electricity on site will displace electricity generated from fossil fuels. Thus in terms of the Oxford County environment, Scenarios 1, 2, 5 and 6 will be net users of fossil fuel generated electricity and scenarios 3, 4 and 7 will be net producers of electricity generated using a non-fossil or renewable fuel source.

In addition, scenarios 3, 4 and 7 produce (surplus) heat as hot water or low pressure steam that is suitable for use on/off-site for heating buildings, thereby displacing fossil fuel-derived sources of heat. Options that are net producers of electricity and heat will therefore reduce overall fossil fuel use in Oxford County.

While all the technology scenarios will produce varying levels of CO_2, the CO_2 emissions per tonne of feedstock processed will be a combination of biogenic and non-biogenic in origin, depending on whether the scenario is a net user or producer of electricity. Biogenic derived CO_2 is considered overall less damaging than non-biogenic derived CO_2, as the subsequent production of the biogenic source of CO_2 involves the uptake of CO_2, providing overall a ‘zero CO_2’ balance, albeit with a time delay.

Options that generate electricity using gas engines or combustion based technologies i.e. scenarios 3, 4 and 7, will also produce emissions to air of other gases, including NO_X and SO_X and small amounts of other gases, with the quantities depending on the specific technology used. Depending on the location of the electricity generated from fossil fuel the impact of the emissions to air on the local Oxford County environment will vary accordingly.

Q3. Reduction of Solid Waste Disposal

To varying degrees, each technology scenario will reduce the demand for solid waste disposal in Oxford County as the primary purpose of introducing waste processing is to increase diversion of solid waste from landfill. For the purpose of this assignment, this criterion is based upon a subjective assessment of the relative diversion of waste from landfill, for each technology scenario.

Q4. Protection of Water

Potential emissions to water for all scenarios are limited, as the process technologies are essentially ‘contained’ units, with any liquids produced either collected for re-use or treated for subsequent discharge to water under the appropriate regulatory regime. Operations involving treatment of organic waste have greater risk of creating pollution of surface waters and of these, composting would typically present slightly more risk than AD, as the latter has liquids contained within purpose built tanks and pipework.

4.1.4 Implementation

In order to provide good differentiation of the merits/disbenefits of each waste processing technology mix, SLR has divided Q1 in the baseline MCA into two parts and added a further three new directly relevant questions. Q1 regarding costs has now been split to address CAPEX costs in Q1 and OPEX costs in Q2. This refinement is needed because there is no direct relationship between the two parameters, i.e. a costly mix of technical solutions may have relatively modest operation and maintenance costs and vice versa.

Assessment of the six criteria, in terms of their implementation, is based on a combination of published data and SLR's experience of evaluating and implementing each technology option.

Q1. Capital Costs

While a substantial amount of data is available on the capital cost of plants, both the quantity and quality of the data varies significantly with the technology. Thus a significant amount of cost data for MRFs and wet AD plants are available, while for dry AD and gasification plants there are significantly less cost data available. In addition, the plant location and site specific aspects such as proximity to utility connections, ground conditions for construction works and local planning requirements that could lead to constraints on building heights and plant layout etc., will impact on the final capital cost of a specific facility.

Q2. Operating Costs

Data on operating costs is generally available but not always in a form that shows the cost breakdown i.e. operation and maintenance (O&M), professional fees, rates/utilities, financial costs etc. Many stated operating costs exclude financial costs and essentially are only O&M costs, which while useful create uncertainties when seeking to assess different projects on a 'like for like' comparison basis.

Q3. Timeframe to Plan & Implement

The overall time taken to implement a facility, post-achieving financial close, is dependent primarily on aspects such as regulatory matters, determining the contractual details, site investigation results, detailed design, delivery of long lead time items and the weather. The time required for undertaking the engineering elements is generally similar worldwide, as are the site investigation and detailed design phases. Specific aspects that can cause delays are regulatory matters and the weather, especially the latter if the planned start date is delayed due to contractual or regulatory issues.

For the purpose of this assignment, SLR has used its practical experience of developing each technology system to develop a relative score from each of the following time-influencing factors:

- Typical average time to carry out feasibility and develop a conceptual design;
- Typical average time to achieve the necessary regulatory approvals; and
- Typical average time to construct and commission the facility.

Q4. Technology readiness

An understanding of the level of readiness of each technology for commercial operation in North America is an important element in determining its suitability for implementation by OC. Our assessment was based on a combination of published information in trade magazines, information available on a selection of the technology provider's websites and our professional judgement.

Q5. Capability of Modular Implementation

The capability of a technology to be implemented in modular form was a particular concern of OC and our assessment was based on technical information available from the equipment providers. Facilities such as MRFs are most easily scalable as modular units, including small-scale modules. Similarly the front-end preparation equipment for most other technology options is available as modular units to varying degrees.

While all technology options are 'modular' it is the scale of the module that varies. Thus wet/dry AD plants are modular by nature but the size of the 'module' i.e. digesters, tends traditionally to be relatively large, in the order of say 30-50% of the total plant capacity. There is no technical reason for not having a smaller digester but the cost effectiveness becomes the issue.

Gasification and combustion facilities can similarly be considered 'modular' but the modules are usually of the order +25-30ktpa for plants using RDF, due to the cost effectiveness of installing an additional 'module' and the associated cost of upgrading the pollution control equipment etc.

Q6. Extent of Amenity Impacts

The extent of potential amenity impacts such as noise, dust, odours etc. produced by a technology is not directly addressed by the criteria discussed above under the Environment grouping and such impacts vary widely. This is therefore the basis for introducing this additional criteria.

With the exception of the digesters in a wet AD plant, the other technology options are usually contained wholly within a building, which if appropriately designed and operated, should mitigate any issues associated with noise, dust, odours etc. One key factor influencing the effectiveness of any mitigation measure is the location of the plant and its proximity relative to any sensitive receptors, which is a site specific issue.

The visual impacts of different technologies can also be quite significant, typically with a MRF in an industrial building being the least intrusive, followed by the tanks serving AD units and with chimney stacks of thermal treatment facilities being the most intrusive. However, stacks for conventional incineration plants are usually required to be significantly taller than for plants based on gasification/pyrolysis technologies, and buildings housing the latter are normally smaller than for an EfW plant.

4.2 Weightings

Changing the weightings of criteria either within or between the criteria groupings does have the potential to change the outcome of the evaluation process. In discussion with OC, we felt that it would be important to maintain the balance of weightings in the baseline MCA Tool when applied to the four defined criteria groupings (i.e Community, Economy, Environment and Implementation). Thus, although the range of specific issues to be considered under Implementation had been expanded and a number of other criteria had been identified as being neutral in respect of differentiating waste technologies, the overall balance of 25% of the score applying to each criteria grouping was retained.

Following the principles in the baseline MCA Tool, and in discussion with OC, weightings were distributed equally across all of the expanded range of Implementation criteria.

Options evaluation through MCA in respect of multiple scenarios can be enhanced by more detailed consideration of the relative distribution of weightings between criteria. However, this can be quite time consuming, adding cost, and it can often be difficult to achieve a consensus amongst the stakeholder group being consulted. In our view, the even distribution of weightings is appropriate at this stage of the evaluation process and it is doubtful whether much additional benefit could be gained from a greater focus on this issue.

5.0 SCORING

Section 4 sets out the key factors that will impact on each technology scenario under the headings of *Economy, Environment* and *Implementation* and highlights the assessment basis that would be used for subsequently scoring a technology scenario for the questions under each of those headings.

The basis of the scoring assessment is founded on a combination of factual technical data and professional judgement, varying between the specific criteria. Thus, scoring of the *Environment* criterion is based more on professional judgement than purely technical data, as much will depend on the nature of the specific environmental ecosystem. In contrast scoring of the *Implementation* criterion is mostly based on factual technical data, with some professional judgement used for questions 3 and 6.

As discussed above, no scores have been given against the *Community* evaluation criteria or Q3 of the *Economy* evaluation criteria, as they are focussed on general issues which are not easily applicable to the differentiation of waste processing technologies.

6.0 RESULTS

The results of the MCA process, using the adjusted criteria and weightings described above, are set out in **Table 6-1**.

Table 6-1 Summary of Multi-Criteria Assessment Scores

	Weighted Score for Scenario						
Evaluation Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Community							
1. Will the action lead to an Oxford that is accessible for all citizens?	0	0	0	0	0	0	0
2. Will the action improve its citizenry's access to information and/or equity?	0	0	0	0	0	0	0
3. Will the action advance Oxford's creative arts, culture, or recreation?	0	0	0	0	0	0	0
Economy							
1. Will the action improve the vibrancy of the Oxford Economy?	10	10	25	25	25	5	20
2. Will the action enhance entrepreneurship opportunities in Oxford?	10	10	25	25	20	5	15
3. Will the action advance local food production?	0	0	0	0	0	0	0
4. Will the action advance Oxford's green economy?	20	25	15	15	7.5	12.5	25
Environment							
1. Will the action improve Oxford's ecological systems?	17.5	12.5	20	20	12.5	10	12.5
2. Will the action reduce fossil fuel use in Oxford?	5	15	5	5	0	15	25
3. Will the action reduce solid waste disposal demand in Oxford?	5	25	5	5	5	25	25
4. Will the action protect Oxford's water?	25	5	25	25	25	5	10
Implementation							
1. What is the typical average amortised Capital Cost to implement the action?	16.7	13.3	13.3	10	6.7	16.7	3.3
2. What are the typical average Operating Costs of implementing the action?	16.7	16.7	13.3	10	16.7	10	6.7
3. How long will it take to plan and implement the action?	13.3	13.3	10	10	13.3	16.7	6.7
4. What is the level of technology readiness in N. America	16.7	16.7	16.7	13.3	13.3	16.7	10
5. To what extent is the technology capable of being implemented in modular format	13.3	13.3	10	10	10	13.3	10
6. What is the extent of amenity impacts (noise, dust, odours) from the technology	16.7	16.7	13.3	13.3	10	13.3	10
ΣWEIGHTED CRITERIA SCORES = TOTAL SCORE (Score of 400 = Maximum positive impact on community sustainability)	**185.8**	**192.5**	**196.7**	**186.7**	**165**	**164.2**	**179.2**
RANKING	**4**	**2**	**1**	**3**	**6**	**7**	**5**

7.0 DISCUSSION

The results of the MCA indicate that the top three preferred scenarios, in order, are as follows:

- **Scenario 3:** Mechanical Biological Treatment (MBT), i.e. Scenario 1 plus a wet AD processing stage in OC;
- **Scenario 2:** MRF recovering recyclables and producing refuse derived fuel (RDF) for thermal treatment outside of OC;
- **Scenario 4:** MBT, i.e. Scenario 1 plus a dry AD processing stage in OC.

These scenarios will go forward to inform the selection of Case Studies to be considered in **TM 2** and the costings reviewed in **TM5**.

7.1 Interpretation of Results

The separation between the lowest and highest ranked scenarios represents only 8% of the potential total points available. This indicates that the range of performance of the scenarios under consideration is relatively limited and, although there are significant differences between scoring for certain criteria groupings for some scenarios, there are not substantial overall differences between them.

It can also be seen that there is no one specific scenario aspect which is clearly visible in the lower or higher ranked scenarios. For example scenarios involving some treatment outside OC are ranked between 2nd and 7th, while scenarios involving thermal treatment display the same broad range.

7.2 Limitations of the Evaluation

There are inherent limits to the rigour with which the scenarios can be evaluated in an exercise of this nature. These can be summarized as follows:

- The evaluation of scoring for some of the criteria is based upon subjective opinion, albeit this is based upon professional judgement from a team with broad experience of the technologies under consideration;
- It is difficult to get hold of full data sets regarding costs for all technology types in directly comparable formats;
- The GHG Calculator tool uses certain assumptions about the average performance of different technologies which may not fully reflect the range of performance achieved by some technology categories; and
- As discussed below, alternative criteria weightings may give different results in terms of the rankings of the scenarios.

7.3 Influence of Weightings

As stated in **Section 4.2** the weightings applied to the scores have the potential to influence the outcome of the comparative evaluation. As things stand, the weighting applied to the cost-related criteria represents only 8.25% of the overall points allocation. It could be argued that this underplays the importance of financial issues in the evaluation process and in other evaluations that we have undertaken, costs generally feature more heavily, representing up to 33% of the overall points allocation. However, in accordance with OC's stated wishes, we were keen to maintain as much similarity as possible between the MCA applied to this technology comparison and the baseline MCA approach.

If considered helpful, it would be possible to test the sensitivity of the costs criteria in determining the preferred technology mix, by running the MCA using a range of different cost criteria weightings.

APPENDIX A
Waste Composition and Energy Mix Assumptions

Technical Memo 1c
Oxford County
SLR Project No.: 209.40447.00000

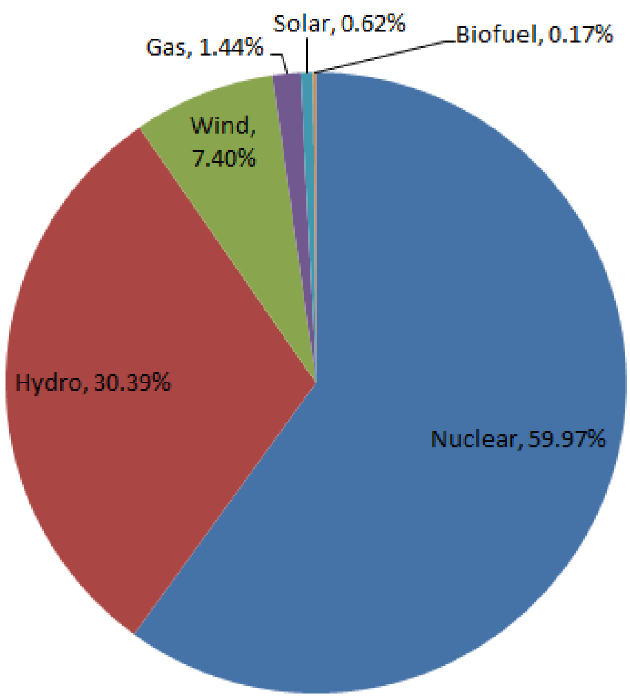
A-1 Waste Composition Assumptions

Material Component	Composition % (2012/13)[1]	Composition % (2017)[2]
Non-acceptable materials	28%	21%
Organics	31%	31%
Glass	4%	4%
Metals	3%	4%
Plastics	7%	13%
Paper / Packaging	11%	28%
Paper	16%	-
Total	**100%**	**100%**

[1] Derived from Ontario data provided by AET, as set out in TM1A.
[2] Derived from AET survey data collected in April 2017.

A-2 Energy Mix Assumptions

Source	Electricity Generated (MW)[3]	Proportion (%)
Nuclear	9,383	59.97
Hydro	4,754	30.39
Wind	1,158	7.40
Gas	226	1.44
Solar	97	0.62
Biofuel	27	0.17
Total	**15,645**	**100.00**



[3] Electricity Generated in Ontario – May 2017