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IMC

**FOOD WASTE STUDY**  
ALBERTA AGRICULTURE AND FORESTRY

IMC (IAN MURRAY & COMPANY LTD.)

## Contents

Scope.....	2
Disclaimer.....	3
1. Introduction .....	4
2. Opportunities and Challenges in Diverting Solid Waste From Landfill.....	7
3. Jurisdictional Overview .....	9
4. High Level Cost and Benefit Analysis .....	13
4.1 Cost Analysis.....	13
4.2 Benefit Analysis.....	16
5. Method of Disposal – Retailers/Food Processors.....	19
5.1 Retail .....	19
5.2 Food Processors .....	20
6. Technology Evaluation.....	23
6.1 Assessment Criteria.....	23
6.2 Upstream Waste Avoidance Evaluation.....	25
6.3 Downstream Technology Evaluation .....	27
6.4 Technology Summary.....	32
7. Clustering Opportunities.....	33
8. Recommendations .....	39
References .....	41

## Scope

Food waste arises at all levels of the value chain. Households are the largest contributor to food waste<sup>1</sup>. The food processing and grocery sectors combined are the second largest contributors to food waste.

There is an opportunity for Alberta's food processing and grocery/ sectors to more aggressively explore options to convert waste streams into higher value products.

This study provides a high level assessment in the following areas:

- Explores opportunities and challenges in diverting waste from landfill (retailers and upstream processing and diversion only),
- Identifies a number of commercial and near commercial technologies available to convert food waste into energy and other products – including a cost/benefit analysis,
- Reviews current methods of disposal,
- Explores options such as reuse, recover, and recycle/repurpose,
- Reviews activities in other jurisdictions, and
- Considers clustering opportunities.

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<sup>1</sup> "Cut Waste Grow Profit," 2012

## Disclaimer

This work is intended solely for Alberta Agriculture and Forestry. Any use which a third party makes of the work, or any reliance on or decisions to be made based on it, are the responsibility of such third parties who should conduct their own due diligence. Decisions made or actions taken as a result of our work shall be the responsibility of the parties directly involved in the decisions or actions.

The information in this report is based on IMC's industry knowledge and what has been gathered from public sources as of May 15, 2017. This information has not been independently verified and while IMC believes that the information is accurate, it cannot guarantee the accuracy of the information.

## 1. Introduction

In Canada, the equivalent of 30 – 40% of the food produced annually along the value chain is wasted. Much of this food ends up in landfills or as compost. This food waste has been estimated to be worth approximately \$31 billion each year<sup>2</sup>. However, when all costs of food production are factored in, including land, water, transportation, energy, etc., the cost of Canada's food waste exceeds \$100 billion annually.

The impacts of food waste can be felt in three key areas: environment impacts, social impacts and economic impacts.

### Environmental:

- If the amount of GHG produced globally from food waste was compared to the top GHG emitting countries, global food waste would third, after USA and China, according to the latest data available<sup>3</sup>. This amount is more than twice the total GHG emissions of all USA road transportation in 2010 (1.5 GtCO<sub>2</sub>e)<sup>4</sup>
- Food waste that ends up in landfills produces a large amount of methane – a potent greenhouse gas that is 25 times more powerful than CO<sub>2</sub>.
- With agriculture accounting for 70% of the water used throughout the world, food waste also represents a great waste of fresh water and ground water resources. Globally, it is estimated that the volume of water used to produce food that is not eaten is approximately equal to three times the volume of Lake Geneva (267 Km<sup>3</sup>). By throwing out one kilogram of beef, 50,000 liters of water that were used to produce that meat will be wasted. In the same way, nearly 1,000 liters of water are wasted when one glass of milk is poured down the drain.
- Approximately 1.4 billion hectares (3.5 billion acres) of land, or one-third of the world's total arable land, is used to grow food that is wasted. In Canada, 8 million acres of land is used to grow food that is wasted.
- Over 400 gallons of oil is used each year to feed a single person in North America. Approximately one-third of it goes into producing fertilizers, 20% to run farm machinery, 16% for transportation, 13% for irrigation, 8% for raising livestock and 5% for pesticides<sup>5</sup>. In Canada alone, this would represent 1.45<sup>10</sup> gallons of oil used to produce food. If 40% of food is wasted, then 5.81<sup>9</sup> gallons of oil are wasted each year.

### Social:

- Increased demand for food raises prices — whether we eat that food or throw it out. This impact low income families the most, since a larger portion of their income goes toward buying food.

<sup>2</sup> "Value Chain Management Centre", 2014

<sup>3</sup> "World Research Institute Annual Report" 2012

<sup>4</sup> "Food Wastage Footprint – Impact on Natural Resources Summary Report FAO", 2013

<sup>5</sup> [www.lisf-leila.org/oil-in-your-plate](http://www.lisf-leila.org/oil-in-your-plate)

- Nutrition and food security are among the top four social indicators of health in Canada, with limited access to nutritious and affordable food linked to poor health.
- 1 in 8 Canadian families struggle to put food on the table. Food insecurity takes an indelible toll on children's health — both physical and mental. 32% of the people requiring food assistance are children.
- Reducing food loss in Canada by just 15% could help feed 2 million Canadians every year.

### **Economic:**

The quantifiable difference in value between what is produced on farms, then processed, distributed and sold every year, compared to what is consumed, exceeds \$31 billion. This equates to approximately 40% of all food produced and 2% of Canada's GDP (Statistics Canada, 2010; Macdonald, 2009).

To put things in perspective, \$31 billion is:

- More than Canadians spent on food purchased from restaurants in 2009.
- 55% of all Canadian agriculture and agri-food exports in 2015.
- 72% of all of Canada's agriculture and agri-food imports in 2015.
- Higher than the combined Gross Domestic Product (GDP) of the world's 32 poorest countries.
- Food wastes reduce business profitability and competitiveness. The greatest financial opportunity for businesses is to reduce food waste at source.
- The cost of food waste impacts farmers' revenues and profitability. The post-farm gate end of the value chain (retailers, food service and hospitality industries) penalizes suppliers for food loss incurred at retail rather than taking accountability for their own operations.

While this number is significant, it only equates to "terminal" food waste - that which mostly goes to landfill or composting. If we used the Lean Manufacturing definition of waste, which is that waste includes any activity that costs more than the value it creates<sup>6</sup>, then the true extent of agri-food waste impacting Canada's agri-food industry, the economy, and the environment exceeds \$100 billion<sup>7,8,9</sup>.

While there are many reasons for the rising cost of food, it is estimated that food waste equates to a 10 to 20% increase in the price of food paid by consumers.

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<sup>6</sup> "Womack & Jones", 2005

<sup>7</sup> [http://www.huffingtonpost.ca/ontario-association-of-food-banks/food-waste-canada\\_b\\_11389730.html](http://www.huffingtonpost.ca/ontario-association-of-food-banks/food-waste-canada_b_11389730.html)

<sup>8</sup> "\$27 Billion Revisited December - Value Chain Management International Ltd.", 2014

<sup>9</sup> "Food Waste in Canada November - Value Chain Management International Ltd.", 2010

Canada generates more municipal waste per capita annually than any of its peer countries in the Organization for Economic Co-operation and Development (OECD). Canada earns a “D” grade and ranks in last place. In 2008, Canada generated 777 kg per capita of municipal waste — well above the 17-country average of 578 kg per capita and twice as much as Japan, the top-performing country. This number has been steadily increasing since 1990<sup>10</sup>. In Canada, Alberta had the dubious reputation of #1 in food waste disposal per capita<sup>11</sup>.

Ten years have passed since the Government of Alberta introduced its roadmap to significantly reduce and divert waste through the *“Too Good to Waste Strategy”* (2007), with very few improvements realized. Environmental initiatives such as zero waste and the Circular Economy principles are gaining traction worldwide. Canada has fallen far behind other developed countries in acting to invest in and develop programs to mitigate the food waste crisis. These principles of zero waste and the circular economy are becoming key drivers in maintaining and establishing new markets worldwide.

In 2014, Alberta Innovates developed a series of policy recommendations for consideration<sup>12</sup>.

In 2015, Alberta Agriculture and Forestry (AF) undertook an inventory of organic waste from Alberta’s agri-food sector<sup>13</sup>. After compiling the data gathered, it was determined that there are significant volumes of organic waste and underutilized by-products available in Alberta. In total, an estimated 3.38 million tonnes of dry organic waste per year (282 thousand tonnes per month) were identified Province wide.

This report augments the work completed in 2015 by AF, with a focus on identifying current and future opportunities to mitigate Alberta’s food waste issues. Recognizing the food production system is an integrated network from farm to fork, the scope presented in this report is focused between the farm gate and consumers.

Ian Murray & Company Ltd. (IMC) was hired by AF to gather information in order to assess various organic (vegetables, fruits, dairy and meat) food waste streams from retailers and food processor. IMC assessed various food wastes between post-farm gate and pre-consumer areas of the supply chain. IMC also assessed potential technologies to convert food waste stream into higher value-added products. This research was primarily done through desk research and recommendations were made about potential technologies. Research was also conducted to determine if there were any regional opportunities to develop a food waste processing cluster.

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<sup>10</sup> <http://www.conferenceboard.ca/hcp/details/environment/municipal-waste-generation.aspx>

<sup>11</sup> “Recycling and Waste Reduction: A discussion paper Manitoba”, 2014

<sup>12</sup> “Zero Organic Waste in Alberta – Policy Recommendations”, 2014

<sup>13</sup> “An Organic Waste Inventory for Alberta’s Agrifood Sector”, 2015

## 2. Opportunities and Challenges in Diverting Solid Waste From Landfill

### Challenges<sup>14</sup>:

- Lack of policy and legislation.
- Investment in research and development is required.
- Infrastructure requirements.
- Lack of cooperation across governments.
- Public resistance.
- Financial barriers.
- The absence of rigorously measured and verifiable data presents an uncomfortable degree of uncertainty for policy development.
- Existing studies related to food waste data indicate that Canada's and Alberta's data on food waste generation and method of disposal is, on the whole, scarce, fragmented and disaggregated.
- There is no clear commonly agreed upon definition of food waste in Canada and therefore no common measures of food waste and its impact on businesses and environment.
- Diminishing landfill space.
- Lack of existing options to divert from landfill.
- Food waste is not a priority for many businesses.
- Recovery of food waste creates food safety challenges.

### Opportunities<sup>8</sup>:

- **Prevention Solutions**

Solutions that prevent waste in businesses and homes have the greatest economic value per tonne and net environmental benefit. The three most cost-effective solutions are: consumer education, packaging adjustments and standardized date labeling. Prevention solutions also provide increased business profit potential (potentially \$20 million nationally) for consumer facing businesses.

- Top solutions by diversion potential: consumer education campaigns, waste tracking and analytics, standardized date labeling.
- Prevention solutions are generally capital light: they involve changing behaviour through packaging changes, software and marketing.
- Estimated annual diversion potential 2.35M tonnes.
- Estimated annual greenhouse gas reduction: 9.7M tCO<sub>2</sub>e.
- Estimated annual water conserved: 120 billion gallons.

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<sup>14</sup> "A Roadmap to Reduce U.S. Food Waste by 20%", 2016



- **Recovery Solutions**

Food recovery initiatives by processors and retailers (grocery, food services, convenience stores, and hospitality) already exist in isolated pockets throughout the country. There are significant opportunities to increase donations.

While prevention strategies can be implemented as one-of solutions, recovery requires an ecosystem approach supported by three pillars: 1) education for food businesses on donor liability protections and safe food handling practices, 2) enabling policy to financially incentivize donations from businesses while providing standardized and science-based food safety regulations, and 3) efficient logistics and infrastructure to transport, process and distribute excess food.

- Top solutions by diversion potential: donation by tax incentive, standardized donation regulation and donation matching software.
- Estimated annual diversion potential in Canada: 1 million tonne.
- Estimated GHGs reduced: 340,000 tCO<sub>2</sub>e.

- **Recycling/Repurpose Solution**

Recycling offers the most scalable path to reducing food waste nationally. After pursuing as much prevention and recovery as possible, food scraps inevitably remain. Currently, the vast majority of wasted food ends up in landfills where it costs cities millions of dollars per year in disposal fees. In addition, the organic wastes also generate methane in the landfill through an anaerobic digestion process. There is tremendous opportunity to harvest and convert these food scraps in a closed loop biorefinery system that supports a vibrant agricultural sector by producing renewable energy and bio-products.

- A number of technologies for managing organic, biodegradable materials have existed for decades, including anaerobic digestion (AD) and composting.
- A number of newer processing technologies and protocols are currently being investigated including inline AD, pyrolysis and cascading biorefineries. In analogy to processing crude oil in oil refineries, biomass also can be refined into valuable products in a biorefinery. Biorefineries can play a key role in the biobased circular economy. Successful biorefineries can potentially lead to sustainable co-production (cascade) of food, feed, energy, fuel and chemicals on an economically sound basis with minimal generation of waste.
- Estimated annual diversion potential in Canada: 861,825 tonnes.
- Estimated annual GHG reduction in Canada: 480,000 tCO<sub>2</sub>e.

### 3. Jurisdictional Overview

Food waste is among the categories identified by national governments as particularly interesting in the context of green growth and environmental impact. While food waste can be a valuable resource when used in the production of renewable fuels and chemicals, experts agree that the most pressing issue is bringing down food waste volumes through sustainable production and consumption. Addressing food waste is high on the agenda in the Nordic countries, the EU, the OECD countries and the Food and Agriculture Organization of the United Nations (FAO)<sup>15</sup>.

On January 1, 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development — adopted by world leaders in September 2015 at a historic United Nations Summit — officially came into force. Over the next 15 years, countries will mobilize to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind<sup>16</sup>.

SDG Goal 12.3 states: “By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.”<sup>17</sup>

The United States (US), the United Kingdom (UK) and the European Union (EU) have recognized that addressing food waste can help deliver solutions to climate change, community resiliency and other resource efficiency issues. The links between reducing food waste and GHG emissions, while improving profit margins, is also being recognized by businesses, including corporate giants like Nestle’, Tesco and Unilever<sup>18</sup>.

In 2013, the EU agreed to reduce food waste by 50% by 2020, providing a focal point and rationale for an array of actions by member states. This is more aggressive than Target 12.3 of the UN SDG defined above. In the EU, food waste prevention is an integral part of the Commission's new Circular Economy Package to stimulate Europe's transition towards a circular economy which is intended to boost competitiveness, foster sustainable growth and generate new jobs<sup>19</sup>. A circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to zero waste principles, while minimizing negative impacts<sup>20</sup>.

<sup>15</sup> <http://www.norden.org/en/news-and-events/articles/multiple-benefits-of-reducing-food-waste-in-the-nordic-region>

<sup>16</sup> <http://www.un.org/sustainabledevelopment/>

<sup>17</sup> <http://www.un.org/sustainabledevelopment/>

<sup>18</sup> <http://www.nzwc.ca/Documents/NZWCSUBMISSIONONPANCANADIANFRAMEWORKFORCOMBATTINGCLIMATECHANGE.PDF>

<sup>19</sup> [https://ec.europa.eu/food/safety/food\\_waste/eu\\_actions\\_en](https://ec.europa.eu/food/safety/food_waste/eu_actions_en)

<sup>20</sup> [www.ellenmacarturfoundation.org](http://www.ellenmacarturfoundation.org)

In the UK, the Courtauld Commitment 2025 represents a voluntary agreement by all major UK food retailers, brands, food service companies, trade bodies and local authorities to reduce food waste by 20% over 10 years. To engage consumers in the realization of this target, the Love Food Hate Waste consumer education campaign was developed by the Waste and Resources Action Program (WRAP-UK). In terms of legislative action, France banned the disposal or destruction of unsold but edible food by supermarkets in 2016; instead, this food must be donated to food banks and other charities. To make the ban effective, large food retailers must have contracts with agencies that provide food to those in need, or face a penalty. Spain has passed similar legislation banning the disposal of edible food by supermarkets, but encourages compliance by providing a tax incentive for donating unsold but edible food.

In the US, another approach is under way. In early 2015, more than 30 business leaders, non-profit organizations, foundations and governments who are committed to reducing food waste created an organization called Rethink Food Waste through Economics and Data (ReFED). Working collaboratively, ReFED developed “A Roadmap to Reduce U.S. Food Waste”, an action plan to tackle food waste on a national scale, which evaluates the economic, social and environmental impacts of over 27 potential tools. In September 2015, the US Department of Agriculture and the Environmental Protection Agency announced a goal to reduce food loss and waste by 50% by 2030. To succeed in reaching this target, the Federal Government acknowledged it will be working with communities, organizations, businesses as well as state, tribal and local governments<sup>21</sup>.

In December 2015, Congresswoman Chellie Pingree introduced a proposed Food Recovery Act. If passed, the Act includes tax incentives for farmers, retailers and restaurants to donate foods, a strengthened Good Samaritan Act, and an infrastructure fund to support construction of large-scale composting to accompany banning organic materials to landfills. Added to the mix, the Natural Resources Defense Council, a major NGO, and the Ad Council, launched a national communication campaign, “Save the Food”, targeting consumer behavior that leads to food waste.

Australia has established an integrated multi-sector approach to manage food waste along the food production chain and, similar to the EU, adopted a circular view of food production and consumption<sup>22</sup>.

Hong Kong has set a target for a 40% reduction of municipal solid waste by 2022<sup>23</sup>. To support efforts in food waste reduction, Hong Kong has established the “Food Wise Hong Kong”<sup>24</sup>.

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<sup>21</sup> <http://www.nzwc.ca/Documents/NZWCSUBMISSIONONPANCANADIANFRAMEWORKFORCOMBATTINGCLIMATECHANGE.PDF>

<sup>22</sup> “How Food Waste is Managed in Australia”, 2011

<sup>23</sup> <http://www.enb.gov.hk/sites/default/files/WastePlan-E.pdf>

<sup>24</sup> <http://www.foodwisehk.gov.hk/en>

One of the eight priorities listed in the Nordic Prime Ministers' green growth initiative is to develop methods and technologies for reducing waste generation, and for processing selected types of waste.

In Canada, as in other middle and high income regions, the majority of food waste occurs in the post-harvest stages of the food chain – in processing, wholesaling, retail and final consumption. This is significant because as the FAO indicates, the later food is wasted along the life cycle, the greater the environmental consequences per tonne of food wasted. Each tonne accounts for all upstream resources, energy, and labour involved in growing, processing, packaging, transport, storage, and cooking. The cost of food waste in Canada, from farms to consumers, has been estimated by Value Chain Management International to be at least \$31 billion annually. Consumers account for 47% of this waste, followed by the processing sector (20%) and the retail sector (10%). The analysis goes on to state that the full cost to the Canadian economy is actually far higher. Using the FAO's estimates of the cumulative cost of food waste associated with the use of energy, water, land, labour, capital investment, infrastructure, machinery, and transport, Value Chain Management International estimates the overall cost of food waste in Canada exceeds \$100 billion annually.

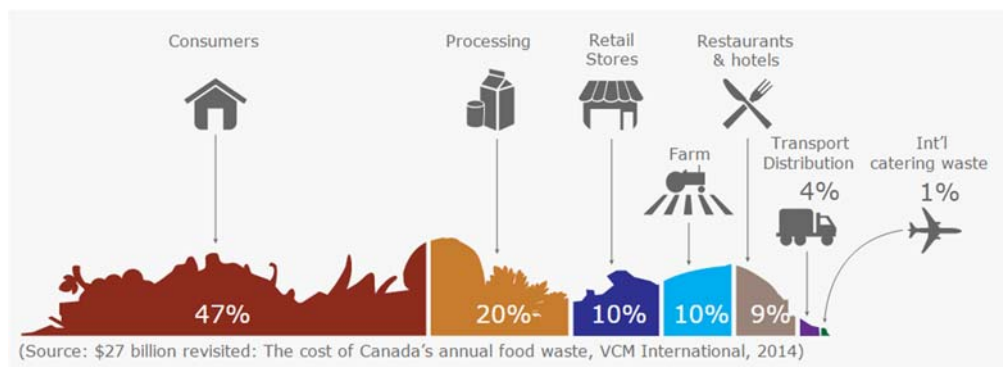


Figure 1 - Where Food Waste Occurs Through Canada's Food Value Chain (% Distribution)

While the opportunity for reducing food waste and its associated climate impact in Canada is similar to the situation in the US and Europe, we currently lag far behind their efforts and lack a coordinated, collaborative approach to tackling the issue. However, there are initiatives under way in various parts of the country that are noteworthy:

- The Provinces of Ontario, Quebec and British Columbia have introduced tax incentives to encourage food donations by agricultural operations;
- The BC Centre for Disease Control has issued guidelines for food donations for both donors and distribution agencies;
- Organics disposal bans are in place in Halifax and Nanaimo and most recently in Metro Vancouver. Quebec is considering a Province-wide organics disposal ban by 2020;
- Metro Vancouver and the York Region of Toronto, have introduced consumer awareness campaigns aimed at changing behaviour so that less food is wasted;

- Manitoba has set targets to become a zero-waste society and to reduce its per capita waste in half by 2020<sup>25</sup>.

While these initiatives begin to chip away at the environmental, social and economic costs of food waste, a national and collaborative approach engaging a complementary and effective set of policies, public engagement, and investments in both innovation and infrastructure is required.

Additional jurisdictionally based initiatives can be found in Section 7, “Clustering Opportunities.”

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<sup>25</sup> Recycling and Waste Reduction: A Discussion Paper. Manitoba 2014

## 4. High Level Cost and Benefit Analysis

### 4.1 Cost Analysis

This section attempts to calculate the true cost of food waste disposal. Food waste happens across the entire supply chain including farm waste, processing waste, transportation and distribution waste, retail and consumer waste. Alberta has the highest per capita waste at 997 kg per capita compared to the national average of 706 kg per capita.

#### Methodology

One of the biggest issues faced in food waste management is the availability of data and method of collection. In order to calculate the total cost of food waste, we will attempt to reconcile the total cost of food waste disposal through a top-down and a bottom-up approach.

- **Top-Down Approach** – As mentioned previously, Value Chain International estimated the total food waste in Canada at \$31 billion and indicated that the true cost of the food waste including labour, energy, transport, infrastructure, audit, disposal, etc. (as shown in figure 2) exceeds \$100 billion.

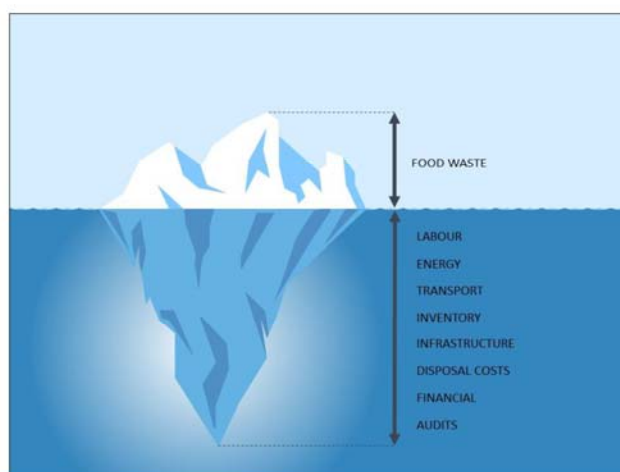


Figure 2 – True Cost of Food Waste<sup>26</sup>

According to Statscan, Alberta contributed approximately 4 million tonnes (16%) of the total waste disposed of in Canada in 2014, which totaled 25 million tonnes<sup>27</sup>. By equating the above-mentioned percentage to the true cost of food waste in Canada (\$100 billion), we estimate that Alberta's contribution to food waste to be approximately \$16 billion, which includes food waste value, labour, energy, disposal cost, audits, etc.

<sup>26</sup> <http://vcm-international.com/wp-content/uploads/2014/12/Food-Waste-in-Canada-27-Billion-Revisited-Dec-10-2014.pdf>

<sup>27</sup> <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/envir32a-eng.htm>

In order to determine the disposal cost component (which is a part of the \$16 billion), we refer to a report published by the Waste and Resources Action Programme (WRAP) that calculated the breakdown of the true cost of food waste in the UK as shown in Figure 3<sup>28</sup>.

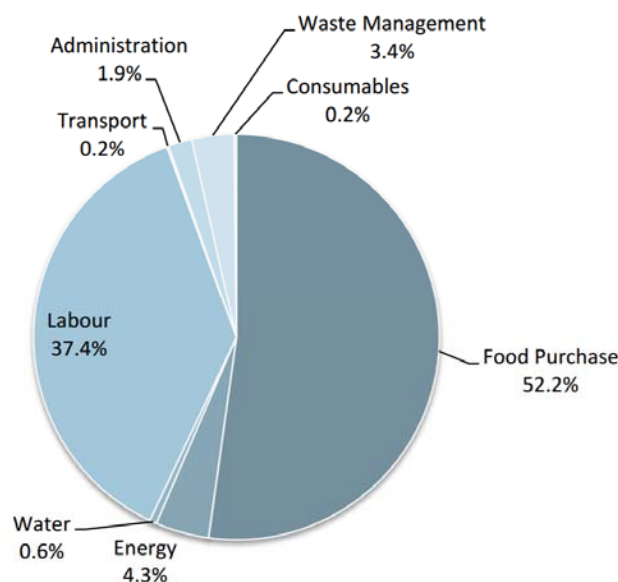


Figure 3 – True Cost of Food Waste<sup>29</sup>

As per the above breakdown, waste management accounts for 3.4% of the total cost. Based on this number, we estimate that Alberta spends approximately \$500 million (3.4% of 16 B) to dispose of food waste.

- **Bottom-Up Approach**

To understand the cost from a bottom-up perspective, we estimate the amount of crops, livestock, milk and fruits and vegetables produced and wasted. In order to determine the waste, research was conducted to estimate production level for grains, fruits and vegetables, livestock and milk (dairy).

- The 10-year average annual crop production in Alberta is approximately 20,211,000 tonnes<sup>30</sup>.
- Annual fruit and vegetable production in Alberta is 711,687 tonnes<sup>31</sup>.

<sup>28</sup>

<http://www.wrap.org.uk/sites/files/wrap/The%20True%20Cost%20of%20Food%20Waste%20within%20Hospitality%20and%20Food%20Service%20Sector%20FINAL.pdf>

<sup>29</sup> <http://vcm-international.com/wp-content/uploads/2014/12/Food-Waste-in-Canada-27-Billion-Revisited-Dec-10-2014.pdf>

<sup>30</sup> [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/sdd12061](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd12061)

- Annual Livestock production in Alberta (Chicken, Turkey, Cattle, and Pigs) is 17,038,919 tonnes<sup>32</sup>
- Annual milk production in Alberta is 701,742,000 litres<sup>33</sup>.

A report developed by the Natural Resources Defense Council (NRDC) in 2012, provided information related to the % loss of food at each stage of the supply chain. For the purpose of this calculation, we have only considered post-farm gate to pre-consumer<sup>34</sup>. As shown in Table 1, the total amount of waste generated between post-farm gate and pre-consumer is approximately 4.5 million tonnes.

Assuming a disposal cost of \$92 per tonne (other costs such as transportation to landfill, etc. is not considered for the purposes of calculation), which is the cost of landfill disposal in Edmonton<sup>35</sup>, this results in a total disposal cost of \$414 million. Table 1 segregates the waste at each phase.

The City of Edmonton's cost of disposal was chosen as the baseline, as it was at the center of the price spectrum of disposing waste in landfill. It should be noted that the City of Lethbridge charges \$85 per tonne<sup>36</sup> and the City of Calgary charges \$112 per tonne<sup>37</sup>, respectively.

	Post-Harvest			Processing and Packaging Losses			Distribution and Retail Losses			Total
	% Losses <sup>38</sup>	Tonne Production	Loss	% Losses	Tonne Production	Loss	% Losses	Tonne Production	Loss	
Grain Product	2%	20,211,000	404,220	10%	19,806,780	1,980,678	2%	17,826,102	356,522	2,741,420
Fruits and Vegetables	3%	71,1687	21,351	1%	690,336	6,903	12%	683,433	82,012	110,266
Meat	2%	17,038,919	34,0778	4%	16,698,141	667,926	4%	16,030,215	641,209	1,649,913
Milk	0.25%	725,785	1,814	0.50%	72,3971	3,620	0.25%	72,0351	1,801	7,235
Total Waste (Tonne)			768,163			2,659,127			1,081,543	<b>4,508,833</b>
<b>Total Cost</b>										<b>\$414,812,707</b>

Table 1 – Cost of Waste Disposal in Alberta

<sup>31</sup> "Profitability of Vegetables, Potatoes, and Fruits"

<sup>32</sup> "Agriculture in Alberta – Teacher's Toolkit" 2015

<sup>33</sup> "Agriculture in Alberta – Teacher's Toolkit" 2015

<sup>34</sup> "Wasted: How America Is Losing Up to 40% of Its Food from Farm to Fork to Landfill", 2012

<sup>35</sup> [https://www.edmonton.ca/programs\\_services/garbage\\_waste/disposal-rates.aspx](https://www.edmonton.ca/programs_services/garbage_waste/disposal-rates.aspx)

<sup>36</sup> <http://www.lethbridge.ca/living-here/Waste-Recycling/Pages/2017-Tipping-Rates.aspx>

<sup>37</sup> <http://www.calgary.ca/UEP/WRS/Pages/Landfill-information/Landfill-Rates.aspx>

<sup>38</sup> "Wasted: How America Is Losing Up to 40% of Its Food from Farm to Fork to Landfill", 2012



### Gaps in Data:

This assessment contains certain gaps:

- Production data for each material is a rough approximation and need to be more carefully quantified.
- Globally, the amount of waste disposed of is measured and reported inconsistently. The need for consistent measurement and accounting must be addressed nationally, if not internationally.
- The environmental, social and economic impact of waste disposal must also be addressed.
- It was assumed that all of the waste goes to the landfill. However, some material is already recycled or diverted to composting, anaerobic digestion, etc. Currently, there is no data available as to how waste materials are diverted in Canada. This requires further analysis.

## 4.2 Benefit Analysis

The following assesses benefits that could be derived from reducing waste in the post-harvest, processing, distribution, retail and transportation.

- **Post-Harvest** – Post-farm gate, once crops have been harvested, culling is the primary reason for losses of fresh produce. Culling is the removal of products based on quality or appearance, including specifications for size, color, weight, blemish level, and Brix (a measure of sugar content). Quantities vary significantly by product and situation. For example, in the 2012 NRDC report, a cucumber farmer estimated that fewer than half the vegetables that are grown in the farm actually leaves the farm and that 75% of the cucumbers culled before sale are edible<sup>39</sup>. Currently, many farms have adopted techniques in order to minimize waste. For example, an Edmonton-based farm ensures total waste of <1% ends up in the waste bin, while the rest is recycled or diverted into the discount stream. In the article, it is mentioned that though this process is labour intensive, most of the culled products end up on a discount table or food kitchen and all the wasted carrot tops and corn husks are directed towards feeding animals<sup>40</sup>.
- **Processing and Packaging Losses** – The biggest contributor to the processing and packaging losses are inefficiencies in the machinery and package design. Some of the contributing issues are<sup>41</sup>:
  - Incoming quality
  - Process losses

<sup>39</sup> “Wasted: How America Is Losing Up to 40% of Its Food from Farm to Fork to Landfill”, 2012

<sup>40</sup> <http://www.gainhealth.org/knowledge-centre/world-environment-day-stopping-food-waste-postharvest-loss/>

<sup>41</sup> <http://nbs.net/wp-content/uploads/Addressing-Food-Waste-in-Canada.pdf>

- Cold chain deficiencies (cold chain is a temperature-controlled supply chain)
- Employee behaviour
- Poor machine set up
- Inaccurate forecasting
- Contamination
- Trimming and culling
- Supply/demand imbalance
- Date codes
- Customer rejection
- Inconsistency in quality of ingredients
- Food safety

Some of these are unavoidable losses. In terms of avoidable losses, inefficient process and machine design are the most important factors. On a daily basis, producing products that require many different ingredients and format changes requires multiple line changes, which leads to production stops and starts and additional cleaning cycles. Inevitably, this leads to more losses. Processing plants should be designed in the most efficient way possible, which means they should be compact and have equipment that can fulfill more than one function. There are many technologies and process improvements available for various products (grain, milk, livestock, etc.). These will be discussed later in this report.

Packaging also plays an important role in preventing food and beverage waste. The choice of package affects environmental impact, shelf life, and resource consumption during transportation and storage. Consider milk in aseptic cartons as an example. It remains safe to drink for up to six months after packaging without refrigeration until opening. On the other hand, chilled milk lasts only two weeks and requires electricity during transport, retail display and home storage. Containers that protect products without refrigeration reduce waste along the chain by averting energy consumption needed for chilled transport and storage. Further, storing goods in ambient condition reduces spoilage risk. Producers must also consider packaging that strikes a balance between protecting product to ensure its sale and consumption, rather than waste, and use an economical amount of material to produce the container. Reducing packaging weight also uses fewer resources in transportation and leaves less material at the end of the package's lifecycle<sup>42</sup>.

- **Retail and Distribution Losses** – Retail is a major contributor of food waste in the overall supply chain. These items are discussed further in the following sections. Some of the other issues faced in retail are<sup>43</sup>:
  - Inaccurate forecasting

<sup>42</sup> <http://www.designworldonline.com/minimizing-production-losses-food-beverage-industry/>

<sup>43</sup> <http://nbs.net/wp-content/uploads/Addressing-Food-Waste-in-Canada.pdf>

- Food safety issues
- Increasing market share of ready-made food
- Date codes
- Fluctuations in delivery from suppliers
- Cold chain deficiencies
- Rejection on arrival at distribution centres or store or during handling
- Increasing merchandising standards
- Product differentiation
- Market over-saturation

Table 2 estimates the value of waste generated if there is a counter measure employed to reduce waste in each stage of the supply chain by 10%, 15% and 20%. This calculation was completed using the bottom-up approach.

% Reduction	\$ Value of Waste Generated
0%	\$ 414,812,707.17
10%	\$ 374,527,768.11
15%	\$ 354,286,413.26
20%	\$ 333,979,007.95

*Table 2 – Value of Waste Generated, if Wastage is Reduced by 10,15, 20% Across the Supply Chain*

## 5. Method of Disposal – Retailers/Food Processors

### 5.1 Retail

In 2016, a survey completed for the Food Waste Reduction Alliance<sup>44</sup> for retailers and wholesalers in the US identified that approximately 27.6% of the food waste in retail is disposed of in landfills, while the rest of the material were diverted (donated or recycled). It should be noted that since the last survey in 2014, the amount of material disposed of has been reduced by almost 25%. In terms of diverted material, the method of disposal varies among retailer depending on scale and other factors. Figure 4 shows how the materials are diverted. We present the US data due to the lack of Canadian data.

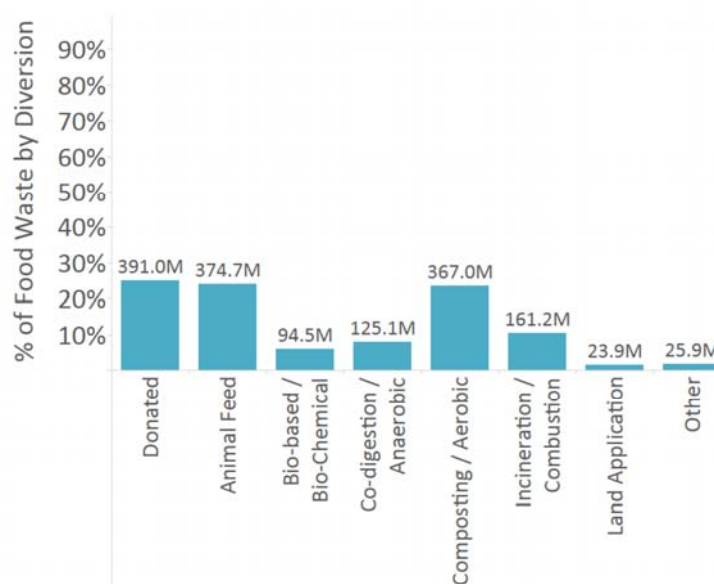


Figure 4 – Destination of Diverted Food<sup>45</sup>

In the same survey, barriers to donation and recycling were identified.

	Retail and Wholesale Sector
Insufficient refrigeration and/or storage at food banks	21%
Insufficient refrigeration and/or storage on sites	25%
Liability concerns	25%
Regulatory concerns	13%
Transportation constraints	46%
Other	42%

Table 3 – Barrier to Donating Food in Retail

<sup>44</sup> [http://www.foodwastealliance.org/wp-content/uploads/2014/11/FWRA\\_BSR\\_Tier3\\_FINAL.pdf](http://www.foodwastealliance.org/wp-content/uploads/2014/11/FWRA_BSR_Tier3_FINAL.pdf)

<sup>45</sup> “Food Waste Reduction Alliance Survey”, 2016

From table 3, the lack of transportation options seems to be a major concern for retailers to donate food. Other major hurdles are both internal and external in nature. Externally, retailers identified that insufficient food banks, insufficient space at the food banks and lack of volunteers to collect food for the food banks as hurdles. Internally, retailers do not have the resources to manage and oversee the donation efforts. Liability concerns are often unavoidable and it is best that the standard of quality of donated food is maintained.

	Retail and Wholesale Sector
Food safety concerns re collection and storage	17%
Insufficient recycling options	38%
Liability concern	4%
Management or building constraints	21%
Regulatory concerns	4%
Transportation concerns	46%
Others	42%

Table 4 – Barrier to Recycling Food Waste in Retail

As shown in table 4, lack of transportation and insufficient recycle options or in other words, lack of location proximity to recycle options, were cited as major barriers to recycling. Many of the respondents indicated that cost associated with recycling is a major impediment to recycling. That being said, they also identified that over the last couple of years, more education and new technology has improved the amount of waste being recycled.

## 5.2 Food Processors

The report developed by the Food Waste Reduction Alliance also included data for manufacturers (food processors) in the US. Food processors generate waste in a single location, as opposed to retail waste which is much more geographically scattered. As shown below, 96.8% of wasted material from food processing is recycled, 1.5% is donated and only 1.7% is disposed of<sup>46</sup>.

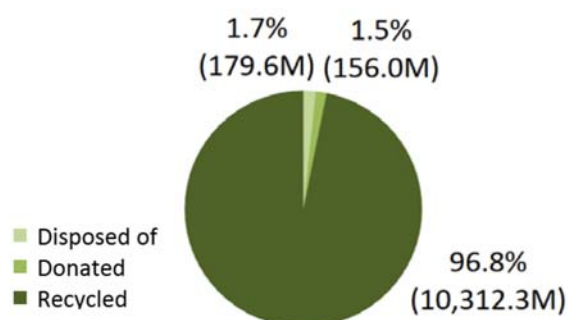


Figure 5 – Destination of Food Waste in Food Processing Sector

<sup>46</sup> “Food Waste Reduction Alliance Survey” 2016

Most of the diverted material (donation and recycling included) becomes animal feed or is used for land applications (to spray onto or bury under land to improve soil quality).

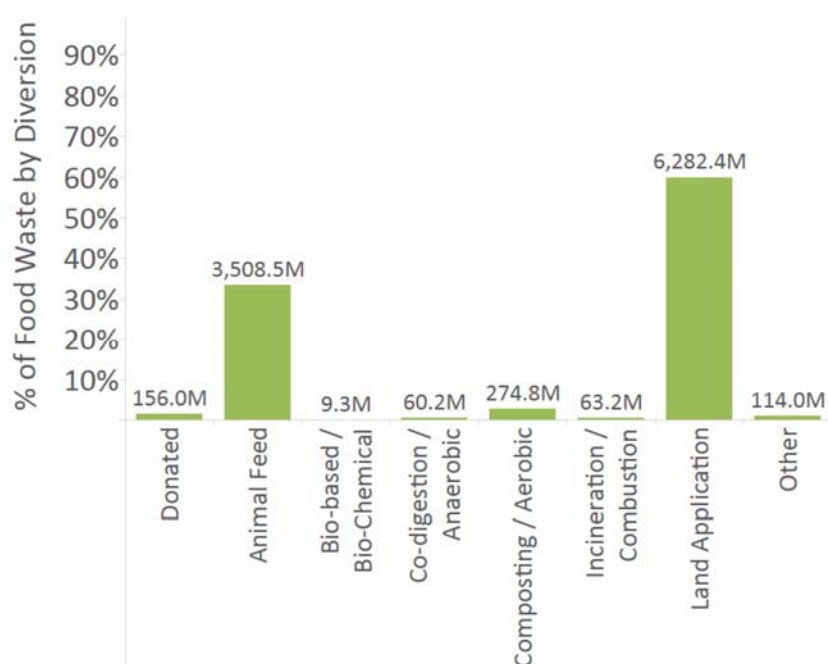


Figure 6 – Destination of Diverted Material in Food Processing

Table 5 shows that the primary concerns of donation are regulatory concerns and liability concerns. Food processors have been under scrutiny most recently, with tightened regulations both in the US and in Canada and their concern is not unwarranted. In general, as more people are being educated about food safety, it was cited as a major concern by the processors.

	Food Processing Sector
Insufficient refrigeration and/or storage at food banks	13%
Insufficient refrigeration and/or storage on site	13%
Liability concerns	50%
Regulatory concerns	63%
Transportation constraint	25%
Others	38%

Table 5 – Barrier to Donating Food in Processing

Table 6 shows that the major problems that food processors face for recycling waste food are transportation and insufficient recycling options. Combining these problems, it can be inferred that food processors do not have a central location to take their waste and convert it to any other product. The recycling options are currently localized. Potential clustering opportunities are discussed in section 7.

	Food Processing Sector
Food safety concerns re collection and storage	50%
Insufficient recycling options	88%
Liability concern	25%
Management or building constraints	0%
Regulatory concerns	13%
Transportation concerns	75%
Others	25%

*Table 6 – Barrier to Recycling Food Waste in Processing*

While modern technology and apps such as 11<sup>th</sup> Hour (Singapore) and FoodCloud (Ireland and UK) are used in letting end consumers know about food waste, it still requires a long-term program to address some of these concerns. The development of and adherence to such programs may require incentives.

## 6. Technology Evaluation

### 6.1 Assessment Criteria

Four criteria were used in evaluating viability of food waste reduction approaches and technologies.

#### 1. Environmental Benefit / Can Process be Implemented at Source of Waste?

This criterion considers sources of GHGs and environmental pollution in the food supply chain stated earlier:

- a. All agricultural inputs required to grow the food that is ultimately wasted
- b. Transporting food that is ultimately wasted
- c. Transporting food waste
- d. Organic waste decomposition in landfills
- e. Transport of products subsequently produced from waste

Reducing consumer demand for food by reducing the amount of safe food erroneously disposed of by consumers due to inadequate labelling can address one root source of subsequent waste, prior to even activating the supply chain. This food does not need to be produced and thus the solution has the greatest net environmental benefit. This criterion thus received a scoring weight of 50%.

#### 2. Economic Opportunity / Financial Viability

By assuming the cost of disposing of food waste for a specific municipality as an economic baseline, any net saving or value generated from that waste represents an economic opportunity. Failing this, the municipality may simply transfer the cost of waste management onto the source. This may be by simply refusing to pick up food waste from them or charging a higher fee.

For the Downstream Technologies assessment, note that the economic opportunity / viability column has 3 columns to the right labelled CAPEX, OPEX, Product Value. As the scope of this study precludes economic viability assessments of each technology / approach, we have used our experience to estimate the capital and operating costs and end product value as a rough rule of thumb from which to assess overall viability. The “H” (High), “M” (Medium) and “L” (Low) ratings are not necessarily directly comparable between technologies. For example, the absolute capital cost of a gasification facility is far greater than that of a pyrolysis facility, even though the CAPEX for both may be rated as “H”.



For the purpose of this evaluation, we will assume that each waste processing technology facility being evaluated is located at the current municipal waste management centre with zero cost of waste transport.

This is a highly preliminary assessment based on our experience investigating these technologies since 2009. However, recent breakthroughs in capital or operating cost reductions or improvement in the value of products for any one of these technologies may change their scoring. Thus, further research is required.

It is important to note that each municipality must carry out their own economic assessment on these opportunities. Those currently paying large tipping fees may find several technologies can deliver a positive return on investment (ROI); while those with low tipping fees may find none to be financially viable and would require perpetual subsidies.

For Upstream waste avoidance technologies and systems, the economics / viability assessment considers overall cost effectiveness of the solution and the general benefit to the entire economy, rather than specific project economics.

This criterion was weighted at 20%.

### **3. Technology Readiness – Commercially Available or Near Commercial**

Most technologies considered are commercially available, however a few are in developmental and early stages. Given the numerous R&D efforts on these newer technologies, the scope of this study precluded determination or researching TRL levels and required a general estimation the maturity of those technologies.

This criterion was considered important to minimize project risk and was weighted at 20%.

### **4. Ease of Implementation**

This considered aspects such as complexity of process, labour requirement, permitting, utility and other input requirements, brownfield conversions and locational constraints.

This criterion was given a weight of 10%.

The upstream waste avoidance and downstream waste management technologies and systems are presented separately as the economic / viability scoring differ, as per the scoring criteria explanation above.

## 6.2 Upstream Waste Avoidance Evaluation

Table 7 presents the raw scores (0-10) and table 8 shows the weighted values to facilitate ranking.

UPSTREAM WASTE AVOIDANCE RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability
<b>Score Weighting</b>		<b>Min Score = 0 Max Score = 10</b>	<b>50%</b>	<b>20%</b>	<b>10%</b>	<b>20%</b>
Nanotechnology	A food spray that uses a nanotechnology-based application of hexanal, a natural plant extract that prevents fruit spoilage by preserving a fruit's cellular walls, extending shelf life by as much as 50%.		10	10	6	4
Applications (Apps)	Flashfood is essentially the discount food rack on your cellphone and it is a means for grocery stores, restaurants, food vendors, being able to resell their surplus food before they are going to throw it out. Ubifood, currently exclusive to Montreal, Ubifood gives geolocation based real time push notifications to inform users of discounted food in their area – benefiting consumers and retailers both while keeping food out of the landfill.	Need strategies to make this more than a cost center - advertising?	10	6	6	6
Hyperspectral Chemical Imaging	Approximately 18% of food waste in Canada happens at the manufacturing level. One solution to reducing that waste may be hyperspectral chemical imaging technology for production line grading and sorting of leafy greens, carrots and potatoes.	In testing pilot stage	10	6	6	10
Sensors	Food processors have little control over their products throughout the supply chain, so as a precautionary measure they give their products a shorter shelf life. As a result, food is often disposed of when it is still perfectly safe and edible. New sensor technology/label is applied at packaging and will tell retailers and consumers if the product has been kept at the right temperature from the time it was made and can tell consumers how to store the product at home. The label also shows retailers and consumers how much time is left before the product expires.	Would reduce consumer demand for product, thus best possible waste reduction schema. What is economic incentive for processor to put sensors inside packaging? May need to be regulated? Will become easier and cheaper	10	8	4	8
GMOs	Genetically Modified Food – for e.g. For example the Artic Apple, which extends shelf life and is non browning.	Regulatory and consumer acceptance hurdles	10	10	8	4

UPSTREAM WASTE AVOIDANCE RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability
Irradiation	Health Canada, on Feb 13 accepted to test irradiation on ground beef. Irradiation is already in use in Canada for onions, wheat, flour and spices. As well as increasing food safety, irradiation also prevents premature spoilage to increase shelf life and reduce food waste.	Already in use - significant spoilage delay	10	10	10	4
Labelling	“sell by”, “use by”, “best by” – almost none of those dates indicate the safety of food, and generally speaking they are not regulated in the way people believe. The current system of expiration dates misleads consumers to believe they must discard food in order to protect their own safety. In fact, these dates are only suggestions by the manufacturer for when the food is at its peak quality, not when it is unsafe to eat. 20% of food wasted in British households is due to misinterpretation of date labels. If the same were true in the US, it would mean that the average household is discarding \$275-455/year of good food because of confusion over date labels	Must be combined w consumer education	10	10	6	4

Table 7 – Upstream Waste Avoidance Evaluation - Raw Score Table

UPSTREAM WASTE AVOIDANCE WEIGHTED SCORES	Environmental Benefit / Can Process Be Implemented at Source of Waste? (0-5)	Technology Readiness – Commercially Available or Near Commercial (0-2)	Ease of Implementation (0 - 1)	Economic Opportunity / Financial Viability (for larger economy - not project specific viability) (0 -2)	SCORE (0-10)
Sensors	5.0	1.2	0.6	2.0	8.8
Labelling	5.0	2.0	1.0	0.8	8.8
GMOs	5.0	1.6	0.4	1.6	8.6
Irradiation	5.0	2.0	0.8	0.8	8.6
Apps	5.0	2.0	0.6	0.8	8.4
Nanotechnology	5.0	1.2	0.8	1.2	8.2
Hyperspectral Chemical Imaging	5.0	1.2	0.6	1.2	8.0

Table 8 – Upstream Waste Avoidance Evaluation – Weighted Rankings

### 6.3 Downstream Technology Evaluation

Table 9 presents the raw scores (0-10) and table 10 shows weighted values on which the ranking is based.

DOWNSTREAM WASTE MANAGEMENT RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability	CAPEX	OPEX	PRODUCT VALUE
<b>Score Weighting</b>		<b>Min Score = 0 Max Score = 10</b>	<b>50%</b>	<b>20%</b>	<b>10%</b>	<b>20%</b>			
Landfill - no methane recovery	Landfill biowaste leads to the release of CO2 and methane.	Baseline current situation; a cost centre w marginal revenue	0	10	10	0	H	H	L
Landfill – Methane Recovery w/ Elec. Gen.	Landfill biowaste leads to the release of CO2 and methane. The methane can be collected and combusted for energy production.	Marginal economics - requires larger population centre; Methane recovery scores some Environmental Benefit but waste still needs to be transported	3	10	6	4	H	H	M
Anaerobic Digestion (AD-) w/ Biogas Elec. Gen.	This process use bacteria to break down organic matter in an oxygen-free environment. Digesters can be used to digest food waste alone, or it can be co-digested with biosolids at wastewater treatment plants and used to supplement manure at farms. Digestate from anaerobic digestion can be land applied as a soil amendment or composted. Digestate is often landfilled. Anaerobic digestion can be combined with pyrolysis to further process the digestate into biochar.	Marginal economics - requires larger population centre; Methane recovery scores some Environmental Benefit but waste still needs to be transported	2	10	4	4	H	M	M
Aerobic Digestion (AD+)	Aerobic digestion uses micro-organisms in the presence of oxygen to oxidize and decompose the organic component of a waste stream. Bacteria rapidly consume and convert organic waste to CO2. Aerobic digestion is used to stabilize organic material, reduce its mass and volume, and remove pathogenic organisms. The organic matter remaining is generally landfilled or spread on agricultural land.	Waste still needs to be transported	2	10	4	4	M	L	L
Microbial / Enzymatic Conversion without biogas Electricity Generation.	Microbial conversion and enzymatic processes are used in conjunction with other technologies as described.	Minor Environmental Benefit from lifecycle	0	10	8	2	M	M	L

DOWNSTREAM WASTE MANAGEMENT RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability	CAPEX	OPEX	PRODUCT VALUE
Compost	Composting is an aerobic process that decomposes organic material into a nutrient rich soil amendment. Different types of composting include; backyard or on site, vermicomposting, aerated windrow composting, aerated static pile composting, and in-vessel composting.	Assumes this is centralized - not done at food processor or retailer locations. Sell compost - lower value product. GHG of consumers picking up compost	2	10	10	4	L	L	L
Pyrolysis (P) w/ Elec. Gen	Pyrolysis is the thermal decomposition of a feedstock at temperatures greater than 4000 F in the absence of air. The chemical compounds that make up an organic feedstock thermally decompose into combustible gases and charcoal. Electricity co-gen has been proposed but economics uncertain.	Avoid GHGs of decomposing. If done with careful waste pre-sorting can produce carbon black (and electricity). Viability dependent on power prices. Denver, CO example?	4	8	4	4	H	M	M
Gasification w/ Elec. Gen.	Gasification is a partial combustion process that uses air or oxygen and high heat to convert feedstock into a synthetic gas (carbon monoxide, hydrogen) or fuel gas (methane and lighter hydrocarbons).	Requires expensive pre-processing, complex process w/ significant downtime; must be on large scale	0	8	2	4	H	M	M
Incineration	Incineration is the controlled combustion of solid waste at extremely high temperatures.	Can be implemented at processor or retailer site. Reduces disposal costs for processor/retailer	8	10	10	4	L	L	L
Incineration w/ heat recovery	Incineration is the controlled combustion of solid waste at extremely high temperatures. These wastes burning facilities have evolved to include energy extraction from the combustion process.	Can be implemented at processor or retailer site. Reduces disposal costs for processor/retailer	8	10	6	6	M	L	M
Bioconversion - Insect Based	Enterra – rescued from landfills, food waste is fed to millions of indigenous black soldier flies and the subsequent insect larvae are then turned into nutrient-rich protein meals and feed oil, and natural fertilizer by-product.	Apparent commercial model in operation	2	10	8	8	L	L	M

DOWNSTREAM WASTE MANAGEMENT RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability	CAPEX	OPEX	PRODUCT VALUE
Liquefaction	Liquefaction is the conversion of solid waste to a liquid. Liquefaction can be performed by various methods including hydrothermal, enzymatic and biological. Biological liquefaction systems use mechanical grinders to shred food waste, which is then mixed with water, and proprietary additives to aid decomposition. Ultimately the liquid effluent can be discharged into the municipal wastewater systems after about 14 days.	Transfers solids management into water treatment system	0	10	8	2	M	L	L
Hydrolysis	Hydrolysis is the process in which cellulose in organic matter is converted to simple sugars (such as glucose). These sugars can then be fermented to ethanol. Cellulose can be hydrolyzed by several means including acids and enzymes. Well established technology, but expensive and there are difficulties in converting food wastes to sugars.	Greenfield ethanol project w/ MSW feedstock not economic in current fuel price environment	0	10	6	4	H	M	M
Dehydration	FoPo food powder is a shelf stable freeze dried fruit and vegetable powder. Developed as a student project in Sweden and the technology is now being tested in a pilot project in the Philippines in conjunction with the FAO. FoPo food powder can turn ugly, unsellable and almost expiring produce food into a food powder with a shelf life of two years.	Can be deployed at processor or retailer sites	8	10	6	6	M	L	L
Briquetting	Briquetting is a process in which ground waste is forced through a heated conical-shaped die. The material forms into a continuously long, three-inch-wide piece of biomass. The log is then broken into chunks of renewable fuel. These can be bagged and distributed for private wood burners or used in boilers for industrial cogenerations.	Energy intensive if biomass drying required. May be deployable at processor sites if sufficient material available. End product is combusted so limited GHG benefit?	4	8	6	4	M-L	M	M
Source Reduction at Processor/Retailer	Disposal costs are reduced, by decreasing the amount of food entering the solid waste stream. Resources associated with producing food can be reduced if the amount of food purchased is more closely aligned with food use. Tracking systems – track the amount of food waste with an assessment – at both retail and consumer levels.	Waste reduction in processor and retailer operating procedures.	10	10	10	10	L	L	M

DOWNSTREAM WASTE MANAGEMENT RAW SCORES	DESCRIPTION	Comments / Scoring Rationale	Environmental Benefit / Can Process Be Implemented at Source of Waste?	Technology Readiness – Commercially Available or Near Commercial	Ease of Implementation	Economic Opportunity / Financial Viability	CAPEX	OPEX	PRODUCT VALUE
Recycling / Re-use of unused or partially used inputs at the Processor	Recycling unavoidable food waste (food waste generated at the manufacturing level such as unused ingredients, unfinished product, trimmings, peel) easier to divert from landfills because of economies of scale that allow manufacturers to recover waste at a high rate (urban centres).	Effective for processors but not retailers. Reduces input costs for processor yielding fast payback albeit on a small scale.	8	10	8	8	L	L	M
Donation & Recovery	Divert food waste through food donation to people, as animal feed, industrial uses (such as rendering fat into value added materials), or compost. Donation: Non-perishable or unspoiled perishable foods can be donated to local food banks, soup kitchens, pantries and shelters. Food bank donors typically include manufacturers, grocery store chains, food service entities, restaurants, wholesalers and famers. Animal Feed: Depending on proximity and suitability as feed, to farms and zoos, it may be viable to recover discarded food as feed for livestock, poultry, or other animals. Rendering: Food wastes composed of animal by-products, fats, and oils can be rendered into saleable commodities such as high-protein meat, tallow, or grease, which are used in the production of animal feed, soap, paints and varnishes, cosmetics, explosives, toothpaste, pharmaceuticals, leather, textiles, lubricants, biofuels and other valuables products.	Requires transport of materials	6	10	8	6	L	L	L

Table 9 – Downstream Technology Evaluation – Raw Score

<b>DOWNSTREAM WASTE MANAGEMENT WEIGHTED SCORES</b>	<b>Environmental Benefit / Can Process Be Implemented at Source of Waste? (0-5)</b>	<b>Technology Readiness – Commercially Available or Near Commercial (0-2)</b>	<b>Ease of Implementation (0 - 1)</b>	<b>Economic Opportunity / Financial Viability (0 -2)</b>	<b>SCORE (0-10)</b>
Source Reduction at Processor/Retailer	5.0	2.0	1.0	2.0	10.0
Recycling / Re-use of unused or partially used inputs at the Processor	4.0	2.0	0.8	1.6	8.4
Incineration	4.0	2.0	1.0	0.8	7.8
Incineration w heat recovery	4.0	2.0	0.6	1.2	7.8
Dehydration	4.0	2.0	0.6	1.2	7.8
Donation & Recovery	3.0	2.0	0.8	1.2	7.0
Bioconversion - Insect Based	1.0	2.0	0.8	1.6	5.4
Briquetting	2.0	1.6	0.6	0.8	5.0
Landfill – Methane Recovery w Elec. Gen.	1.5	2.0	0.6	0.8	4.9
Compost	1.0	2.0	1.0	0.8	4.8
Pyrolysis (P) w Elec. Gen	2.0	1.6	0.4	0.8	4.8
Anaerobic Digestion (AD-) w Biogas Elec. Gen.	1.0	2.0	0.4	0.8	4.2
Aerobic Digestion (AD+)	1.0	2.0	0.4	0.8	4.2
Hydrolysis	0.0	2.0	0.6	0.8	3.4
Microbial / Enzymatic Conversion without biogas Elec. Gen.	0.0	2.0	0.8	0.4	3.2
Liquefaction	0.0	2.0	0.8	0.4	3.2
Landfill - no methane recovery	0.0	2.0	1.0	0.0	3.0
Gasification w Elec. Gen.	0.0	1.6	0.2	0.8	2.6

Table 10 – Downstream Technology Evaluation – Weighted Score Ranking



## 6.4 Technology Summary

Upstream systems and technologies described herein, especially those that reduced demand for food such as labelling and packaging sensors, avoid activation of the supply chain and obviously have the greatest impact on reduction in waste, associated GHG production and environmental pollution. Genetically Modified Organisms (GMOs) can reduce agricultural inputs, improve nutrition, reduce storage costs and delay spoilage. Consumer understanding of the various types of GMO, slow consumer acceptance and regulatory delay make this more difficult to implement. Without public education about GMOs, Canada will remain a global laggard in adoption. Irradiation is already being applied to a number of crop and meat products and can significantly reduce spoilage rates<sup>47</sup>.

Downstream systems and technologies rated highest were those that minimized generation of food waste at the processor and retailer or enabled on site processing, thus avoiding subsequent transport of wet waste. Thus, “Recycling / Re-use of unused or partially used inputs at the Processor” and “Source Reduction Strategies” ranked highest, followed by onsite treatments such as “Incineration” and “Incineration with Heat Recovery”. On site dehydration also ranked highly, as this greatly reduces transport cost of the waste.

A review as to applicability and possible gaps in these technologies for waste management in Alberta is recommended.

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<sup>47</sup> <http://www.hc-sc.gc.ca/fn-an/securit/irradiation/beef-irradiate-boeuf-eng.php>

## 7. Clustering Opportunities

Conventional food waste processing traditionally involves landfill, incinerating for energy recovery, conversion to animal feed or composting. These processes, however, miss the large opportunity to exploit the molecular complexity that exists in bio-waste for value-added products. Bio-waste materials should be considered a resource rather than waste.

A biobased economy aims to deploy biomass with as much value-add as possible and for the most appropriate application. This principle is called cascading. Various components in biomass can be isolated using biorefining technologies including pretreatment, fractionation and separation, anaerobic digestion, pyrolysis, gasification, etc. These various components are assigned their own possible applications depending on their market values. In this way, cascading and biorefinery concepts allow us to increase the economic value of biomass.

“Biorefinery is the sustainable processing of biomass into a spectrum of marketable products” as defined by IEA Task 42<sup>48</sup>.

“Biorefinery” is a term that draws from GreenTech, Industrial Biotech and Synthetic Biology. The core concept behind it is relatively simple: these plants mimic the traditional petroleum refinery, but using **biomass** instead. The biorefinery can help us produce energy and co-products while reducing pollution and greenhouse gas emissions from hydrocarbon based production. Just as petroleum refineries transform crude oil into fuels and chemical building blocks that become a part of many different end products, a biorefinery can use all kinds of biomass from forestry, agriculture, aquaculture, and residues from industry and households including wood, agricultural crops, organic residues (both plant and animal derived), forest residues, and aquatic biomass (algae and seaweeds) to make bioproducts.

A biorefinery is not a new concept. Many of the traditional biomass converting technologies such as the sugar, starch, and pulp and paper industry can be (partly) considered as biorefineries.

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<sup>48</sup> <http://www.iea-bioenergy.task42-biorefineries.com/en/ieabiorefinery.htm>

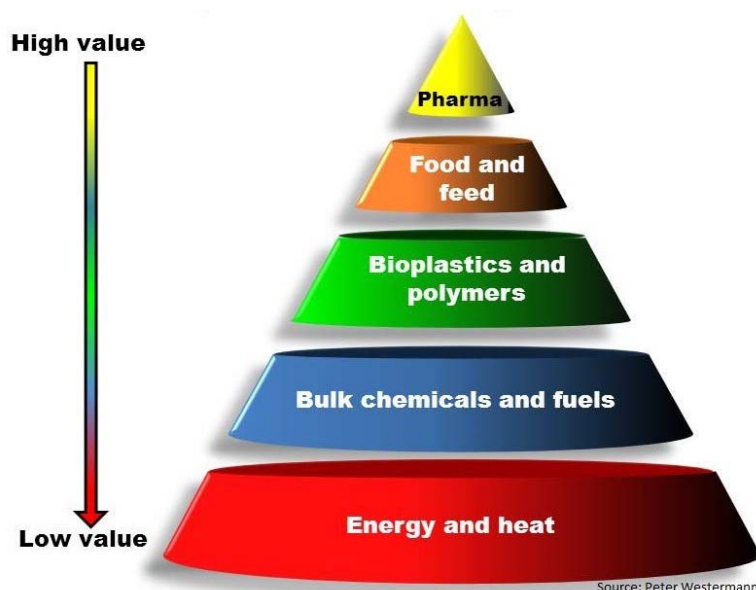


Figure 7 – Biomass Value Pyramid

Unlike in a standalone bioprocess, an integrated biorefinery can transform biomass into all these different products – making the most of its raw materials and adapting to **market** conditions.

The Biomass Value Pyramid above shows the entire cascade of value-adding products which can be produced from agricultural crop residues and other left over bio materials. The lowest value is achieved by burning the biomass and converting it into heat and electricity. Higher value products can be achieved by converting the biomass through treatment with fungal enzymes or other means<sup>49</sup>.

Biorefinery models for the conversion of biomass into energy and high value products were originally proposed in 2004. “Biorefineries combine the necessary technologies between biological raw materials and industrial intermediates and final products. The principal goal in the development of biorefineries is defined by the following: (biomass) feedstock-mix + process-mix -> product-mix. Here, particularly, the combination between biotechnological and chemical conversion of substances will play an important role.<sup>50</sup>”

New biorefineries are mainly based on two principles: the sustainability and cascading principles.

<sup>49</sup> [https://www.researchgate.net/figure/233424554\\_fig1\\_The-Biomass-Value-Pyramid-shows-the-entire-cascade-of-value-adding-products-which-can-be](https://www.researchgate.net/figure/233424554_fig1_The-Biomass-Value-Pyramid-shows-the-entire-cascade-of-value-adding-products-which-can-be)

<sup>50</sup> “Kamm, B. and Kamm, M.”

The principle of cascading consists of the use of organic wastes as raw material in sequencing processes for maximum product yields and profits. There are two cascading modes, direct and inverse cascading. In the direct or traditional cascading, the organic wastes are first used for production of value-added bioproducts, and afterwards the remaining residues of these processes are subjected to bioenergy-generating processes. In the inverse cascading (Figure 12), the organic wastes enter a bioenergy–bioproduct–bioenergy approach. The selection of cascading type depends on regional/national needs and priorities.

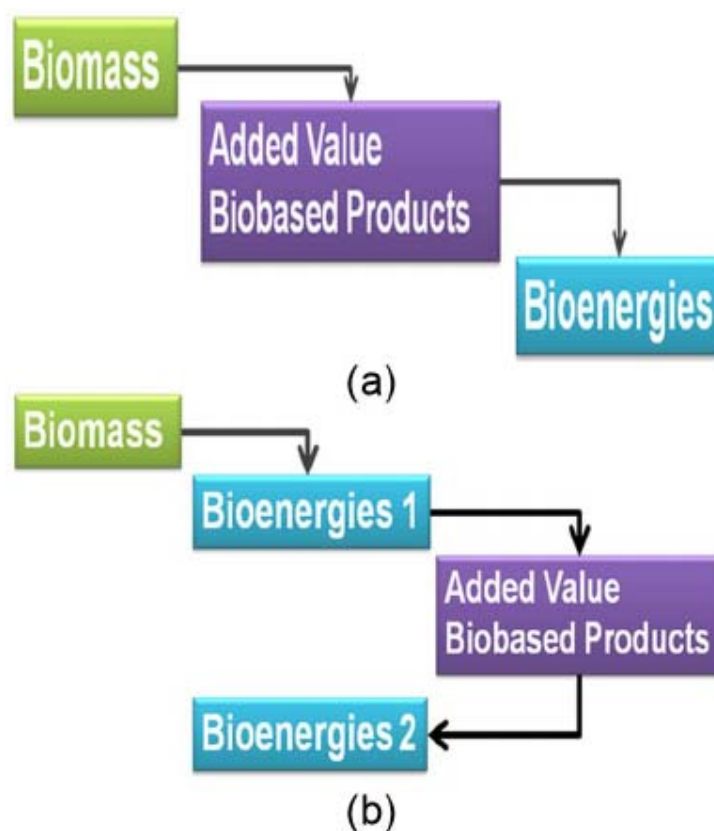


Figure 8 – Diagram of Cascading Biorefineries: (a) direct cascading; (b) inverse cascading

Food waste generated from household, retail and commercial sectors is often rich in nutrients such as starch, proteins and lipid, making it a potential feedstock for fermentative production of chemicals, materials and biofuels. Through enzymatic hydrolysis, for example, significant amounts of fermentable nutrients such as glucose, amino acids and fatty acids can be produced and used for chemicals or biofuels production. Food waste hydrolysis can be effectively achieved via chemical and enzymatic approaches for nutrient recovery. The overall food waste biorefinery concept is illustrated in the utilization of food waste for energy and chemicals

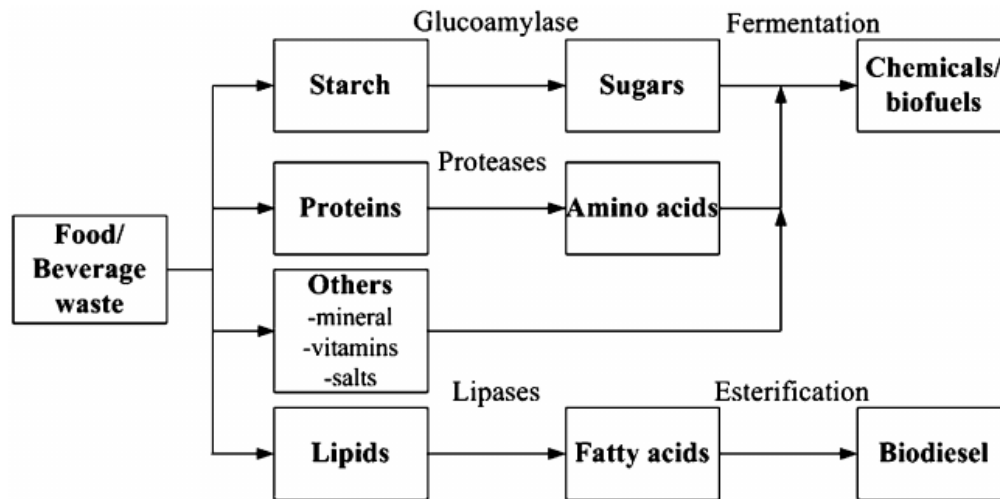


Figure 9 – Food Waste Based Biorefinery for Chemicals and Biofuels Production.<sup>51</sup>

In Europe, France, Finland and Denmark have begun to utilize integrated biorefineries for food waste.

**Ynsect** (France) is a particularly interesting model. At its biorefinery, at Dole, Ynsect will raise and process mealworm beetles and other insects, turning them into protein, fats and chitin. Insects eat agriculture waste, such as fruit, that did not meet the standards of supermarkets, and the waste is then transformed into products from aquaculture feed to nutraceuticals.



Figure 10 – Ynsect Biorefinery<sup>52</sup>

<sup>51</sup> [https://www.researchgate.net/figure/277696034\\_fig1\\_Figure-1-Food-waste-based-biorefinery-for-chemicals-and-biofuels-production](https://www.researchgate.net/figure/277696034_fig1_Figure-1-Food-waste-based-biorefinery-for-chemicals-and-biofuels-production)

Improving the capture of food waste and using cascading biorefineries could be worth between €450-750 million in value to Denmark’s economy according to analysis completed as part of the Ellen MacArthur Foundation’s recent report, *Delivering the circular economy: a toolkit for policymakers*.

### FOOD & BEVERAGE OPPORTUNITIES IN DENMARK

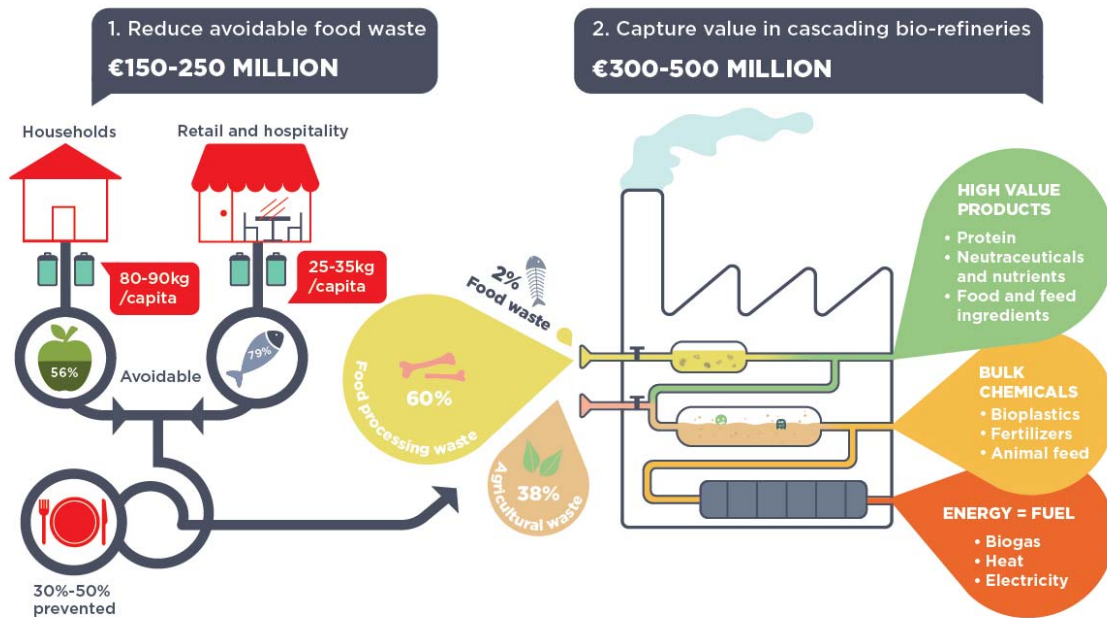


Figure 11: Value Creation from Cascading Biorefineries<sup>53</sup>

<sup>52</sup> <http://labiotech.eu/ynsect-whats-behind-this-yellow-biotech-champion/>

<sup>53</sup> <http://circulatenews.org/2015/12/circular-economy-could-add-e500m-to-denmarks-food-sector/>

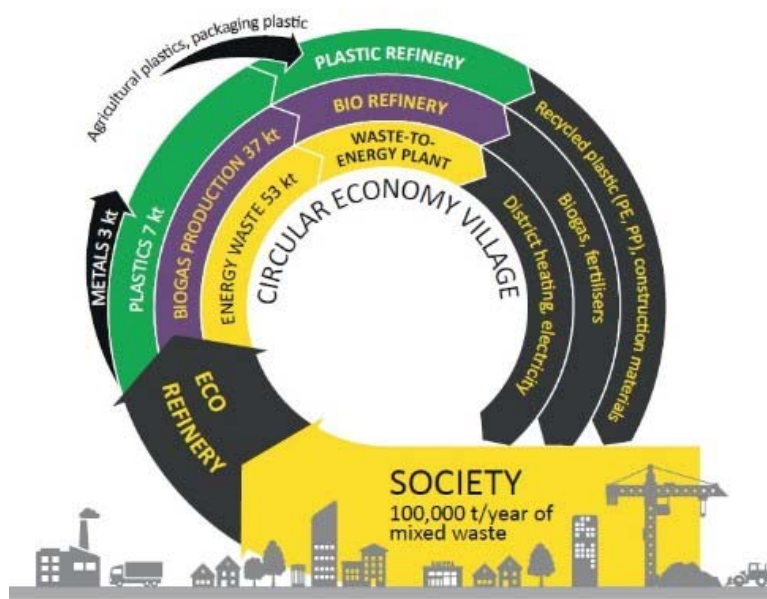


Figure 12: Ekokem, Finland Circular Economy Village

In Finland, Ekokem has built a Circular Economy Village. Materials included in municipal waste will be processed further through the Eco Refinery, Finland's first Plastic Refinery and the Bio Refinery.

The Bio Refinery will use bio-waste to produce biogas for transport purposes. It can also recover nutrients, such as nitrogen. An estimated 400,000 tonnes of bio-waste has previously remained unexploited from municipal waste every year. If it was all processed at a plant such as the Bio Refinery, the production of energy would equal the annual consumption of 12,500 detached houses.

The Plastic Refinery will process not only plastics separated from municipal waste but also separately collected household plastic packaging. At the refinery, the plastics will be separated, crushed, washed and granulated. The plastics will be redirected back to the plastics industry as raw material to replace virgin raw materials. Recycling plastic takes only about 15% of the energy that was required to make the plastic.

## 8. Recommendations

The scope of this study permitted only a cursory review of issues and options related to food waste avoidance and management for food processors and retailers. However, it revealed that numerous cost-effective options are being implemented globally to address this issue at all points along the supply chain.

The following recommendations attempt to focus approaches with maximum environmental benefit and highest return on taxpayer investment:

1. Waste avoidance systems and technologies that eliminate fundamental consumer demand for food, such as better labelling to avoid premature disposal by the consumer, should receive top priority. Reducing basic consumer demand in this way eliminates waste at its most fundamental source, even before agricultural inputs are required.
2. A more detailed assessment of what large municipalities around the world are planning and doing to manage food waste should be undertaken. This will avoid “reinventing the wheel” and will open doors for collaboration.
3. Food Waste Management Partnerships with the Alberta Food Processors Association, Agriculture and Food Council, Municipal Affairs, and Alberta Innovates should be initiated to reach industry, coordinate allocation of resources on highest impact areas, consider self-tracking standards and systems for industry and avoid duplication of effort.
4. Successful programs for upstream waste avoidance from other jurisdictions that can be implemented provincially should be evaluated, copied, piloted and monitored in Alberta. The reports below provide some examples of places where different technologies are being piloted/used.
  - Spanish Strategy: More Food, Less Waste<sup>54</sup>,
  - A Roadmap to Reduce U.S. Food Waste by 20%<sup>55</sup>,
  - How Food Waste is Managed in Australia<sup>56</sup>,
  - Food Waste Management Scoping Study – US EPA<sup>57</sup>.
5. For downstream food waste management, a more rigorous assessment of the technological maturity, operating record, if any, and economics of the technologies considered herein will enable a more accurate prioritization. One area may be reducing the economic scale of biorefining or mass reduction processes so they can be utilized at the source of waste. The study “Inventory of Existing Studies Applying Life Cycle

<sup>54</sup> “Spanish Strategy: More Food, Less Waste” pp 26-41

<sup>55</sup> [https://www.refed.com/downloads/ReFED\\_Report\\_2016.pdf](https://www.refed.com/downloads/ReFED_Report_2016.pdf)

<sup>56</sup> <http://www.environment.gov.au/protection/national-waste-policy/publications/infographic-how-food-waste-is-managed-in-australia>

<sup>57</sup> [https://www.epa.gov/sites/production/files/2016-01/documents/msw\\_task11-2\\_foodwastemanagementscopingstudy\\_508\\_fnl\\_2.pdf](https://www.epa.gov/sites/production/files/2016-01/documents/msw_task11-2_foodwastemanagementscopingstudy_508_fnl_2.pdf)



Thinking to Biowaste Management<sup>58</sup>”, reviews the literature regarding technologies and biowaste management.

6. While numerous studies have been conducted globally as to the economic viability of biorefineries, rapidly changing technology is reducing costs and enabling production of new, more valuable bioproducts. A survey of actual funded and operating biorefining projects should be undertaken in the context of food waste feedstock available in Alberta.
7. A common system of tracking and measurement should be implemented and adopted across the supply chain to enable a better waste accounting system.
8. Evaluation of needs at each part of the value chain should be undertaken. Some players in the value chain may want to reduce costs, others may want to find new revenue streams, while others may feel that improving a customer experience or reducing environmental impact is a worthy goal. For example, a public utility company could become the system integrator across energy/water usage and waste management.

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<sup>58</sup> <http://eplca.jrc.ec.europa.eu/uploads/Waste-Inventory-of-existing-studies-applying-life-cycle-thinking-to-biowaste-management.pdf>

## References

1. Zero Organic Waste in Alberta: Policy Recommendations, 2014 Behrens & Sultana, Alberta Innovates – Energy and Environment Solutions
2. How Food Waste is Managed in Australia – Infographic. Department of the Environment, 2016
3. National Food Waste Assessment – Final Report 2011 Institute for Sustainable Futures, UTS
4. Developing an Industry Led Approach to Addressing Food Waste in Canada. 2014 Uzea, Gooch & Sparling
5. National Food Waste Strategy. National Zero Waste Council. 2017
6. Recycling and Waste Reduction – A Discussion Paper. Manitoba 2014
7. Spanish Strategy – “More food, less waste” Program to reduce food loss and waste and maximize the value of discarded food. Government of Spain Madrid 2013
8. Inventory of Existing Studies Applying Life Cycle Thinking to Biowaste Management. EUR 23497 EN 2008
9. Food Loss and Waste in the Agro-Food Chain. Agriculture Policy Note. OECD 2016
10. Towards a Food Strategy for Saskatoon. Highlights
11. Deriving Increased Value from food waste and co-products. FoodWasteNet
12. A Roadmap to reduce U.S. food waste by 20%. ReFED 2016
13. Reducing Food Waste & Cutting Canada’s Carbon Emissions: Policies for Reaping the Environmental, Economic and Social Benefits. National Zero Waste Council 2016
14. An Organic Waste Inventory for Alberta’s Agrifood Sector. Alberta Agriculture and Forestry 2015
15. Food Waste in Canada. Opportunities to Increase the Competitiveness of Canada’s Agrifood Sector, While Simultaneously Improving the Environment. Value Chain Management Centre. 2010
16. \$27 Billion Revisited – The Cost of Canada’s Annual Food Waste. Value Chain Management Centre 2014
17. Reducing Waste One Person at a Time – Edmonton Food Council 2017
18. Food Waste Behaviours: Influences and Impacts on Residential Waste and Waste Reduction – A Preliminary Report. Evans & Siemens 2016
19. Stop Trying to Solve Hunger with Corporate Food Waste N. Saul 2016
20. Organic Waste for Compost and Biochar in the EU: Mobilizing the Potential. Meyer-Kohlstock, Schmitz & Kraft, *Resources* 2015, 4, 457 – 475
21. How Canadian Technology is Tackling the Food Waste Crisis. J. Ostroff 2016
22. Taking Action to Prevent Food Waste and Combat Climate Change. K.Deily, 2016

23. The Dating Game: How Confusing Labels Lands Billions of Pounds of Food in the Trash. NRDC Issue Brief 2013
24. Team Turns Food Waste into Usable Food Power Called FoPo. Food In Canada 2016
25. Product Based Evaluation of Pyrolysis of Food Waste and Its Digestate <http://dx.doi.org/10.1016/j.energy.2015.02.098>
26. Thermochemical Conversion: Using Heat and Catalysis to Make Biofuels and Bioproducts. U.S. Department of Energy DOE/EE-0949 2013
27. Food Waste Management Scoping Study. U.S. Environmental Protection Agency, Office of Resource Conservation and Recovery April 2014
28. Norwegian Technology could Help Cut Food Waste. Food in Canada 2016
29. Food Waste Fight. Food In Canada 2016
30. 3 Ways Technology and Data Can Help us Tackle Food Waste. K. Deily 2016
31. Assessing the Use of Food Waste Biochar as a Biodynamic Plant Fertilizer. R. Hamline <http://digitalcommons.hamline.edu/dhp> 2016
32. Implementing Strategies of Biorefineries in the BioEconomy IEA Task 42 2016
33. Global food losses and food waste. FAO 2011
34. Biochar: Origins, Markets, Products and Process. Future Energy Conference 2010
35. National Zero Waste Council Circular Economy Business Toolkit 2016
36. Estimates of European food waste levels. Fusions 2016
37. Working together to reduce food waste in Australia. Government of Australia 2016
38. Food Wastage Footprint, Impact on Natural Resources FAO 2013
39. FUSIONS Definitional Framework for Food Waste Full Report 2014