WASTE TO ENERGY IN SMALL RURAL MUNICIPALITIES

A Cost-Benefit Analysis of Biodiesel Production from Waste Oils in the District of Central Saanich

Prepared by: Timio Colistro, UBC Sustainability Scholar 2021

Prepared for: Ali Rivers, Climate Action Specialist
District of Central Saanich

August 13, 2021

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of the District of Central Saanich staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the District of Central Saanich or the University of British Columbia.

Acknowledgements

This report would not have been possible without the support of several individuals working in academia, municipal government, and private industry. Projects like these survive on the generosity of strangers – in this case, professionals who took the time out of their busy days to patiently educate someone, like the author, who is largely new to the inner workings of waste management. Dozens of individuals helped fit various pieces of the puzzle that, collectively, made an initially complicated topic become clear. Particular thanks go to Johnny Grimes, Joshua Prouty, Matthew Roberts, Ray Stevens and Rory Tooke for selflessly taking the time over email, phone or Zoom to respond to my multiple queries. Any remaining errors in this final report are mine alone.

Lastly, special thanks go to three individuals: Richard Barichello, for helping me navigate the surprisingly complex art and science of cost-benefit analysis; Carol McAusland, for her many insights over the course of this project, and for her calming presence of support and encouragement throughout; and lastly, Ali Rivers, who besides being a superb supervisor and shrewd editor, showed me through actions as much as words what it looks like to live out one's values with purpose inside a professional setting.

1. Executive Summary

The District of Central Saanich is a small, rural municipality on southern Vancouver Island that has committed itself to 100% community greenhouse gas reductions by 2050. This report is meant to inform and support the District's goal by investigating technology options that can potentially be used to implement a local circular economy by diverting food waste, creating biofuel, and using it in the municipal fleet and equipment. The circular model takes cheap or costless outputs and uses them as inputs to create something of value, thus conserving society's scarce resources. In this case, food waste is diverted from landfill and is instead converted into gaseous or liquid biofuels. It is an approach that has been widely adopted in Europe and is beginning to see broader uptake in North America.

Many technological processes have been designed to support a circular economy with respect to food waste. Unfortunately, several options remain closed to small districts because of the scale that is required to justify the capital expenditures. Anaerobic digestion facilities, bioethanol plants and composting are examples of solutions that require large volumes of food waste to make investment worthwhile, and small districts generally are compelled to contribute to larger regional efforts as a result. Biodiesel, however, is a unique waste-to-energy solution that can be designed and implemented on a small scale. The chemical process of transesterification converts vegetable oils to liquid biodiesel, which can then be used in any vehicle or piece of equipment that runs on conventional diesel. Microscale production has been run successfully over the past two decades by universities, businesses, and a handful of municipal governments. As case studies demonstrate, a well-coordinated local program that allows residents and businesses to recycle oil can generate biodiesel at a fraction of the cost of regular diesel. Community engagement, fewer sewer clogs and cleaner air are positive spillover effects that complement financial savings.

A cost-benefit analysis is conducted to estimate the private and economic (social) returns of local biodiesel production within the District of Central Saanich. Under a given set of assumptions, private returns to the District are positive owing to the appreciably lower cost of biodiesel production compared to purchasing identical volumes at current market prices. Broader social returns are also strongly positive, given that oil is diverted away from landfill, preventing the release of CH_4, and fewer emissions are generated from diesel combustion, primarily CO_2. Two alternatives are also analyzed: an outright switch to B20 biodiesel from a local distributor, and a municipal subsidy for at-home countertop composters. Both have positive returns, and their pros and cons are compared with that of local biodiesel production.

This report, and the cost-benefit analysis it contains, is complemented by a spreadsheet tool that displays all of the parameters and assumptions that underpin the financial and economic calculations. These can be updated as market prices change and the current environment evolves. As email correspondence and interviews with various government and industry professionals were integral to the success of this report, a call log and key contacts list is also provided. Moving forward, the District can use the spreadsheet and supporting documents to help make a fully informed decision about which solution to pursue as part of its broad overall strategy for reducing greenhouse gas emissions within the community.

2. Table of Contents

3. Acronyms

AD	Anaerobic Digestion
ALR	Agricultural Land Reserve
BC	British Columbia
CBA	Cost Benefit Analysis
CBC	Cowichan Biodiesel Co-op
CEAP	Circular Economy Action Plan
CHP	Combined Heat and Power
CI	Carbon Intensity
CLP	Climate Leadership Plan
CNG	Condensed Natural Gas (also known as Compressed Natural Gas)
COIL	Circular Opportunity Innovation Launchpad
CRD	Capital Regional District
EPA	Environmental Protection Agency
FFA	Free Fatty Acid
FOG	Fats, Oils, Greases
GHG	Greenhouse Gas
MF	Multi Family
MSW	Municipal Solid Waste
NG	Natural Gas
NPV	Net Present Value
OMRR	Organic Matter Recycling Regulation
P3	Public-Private Partnership
RFP	Request for Proposals
RNG	Renewable Natural Gas
SF	Single Family
UCO	Used Cooking Oil
WTE	Waste-to-Energy
WWTP	Wastewater Treatment Plant

4. Introduction

Around the globe, approximately one-third of all food produced annually is wasted, and in Canada that fraction currently stands at over 50% (Agriculture and Agri-Food Canada, 2020). While estimates of scale differ, it is generally accepted that around 0.9 to 1.3 billion tonnes of food is lost or wasted each year, with per-capita rates varying very little across all but the poorest countries (UNEP, 2021).[1] Besides the loss in economic value, estimated at over $160 billion in the United States alone, this organic waste puts immense stress on waste management systems and the environment. As a recent academic article noted, "landfilling of organic waste is still the predominant waste management method in Canada" (Malmir et al, 2020). Discarded food that is sent to landfills will generate methane gas (CH_4), a powerful greenhouse gas (GHG) that is 25 times as potent as carbon dioxide (CO_2) and a major contributor to climate change. Indeed, the FAO has calculated that if food waste were a country, it would be the world's third-largest GHG emitter. The link between food waste, climate change and local governance has refocused the attention of governments and various organizations on food production systems and consumer behaviour, with reduction and reuse taking center stage as broad primary strategies.

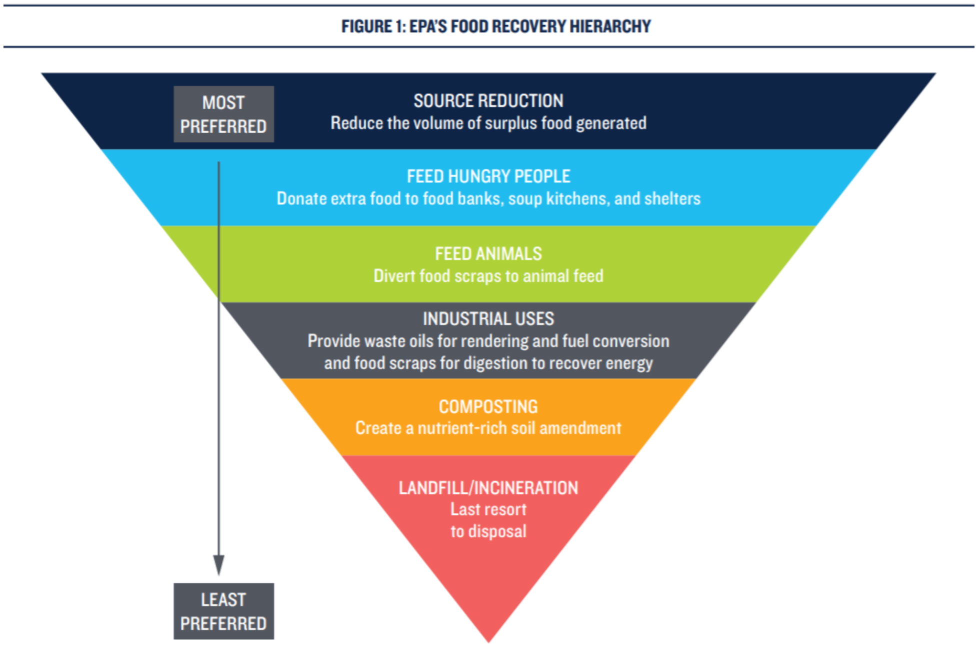
Organic waste can be defined as any biodegradable material, originating from a plant or animal, that is removed from the food system.[2] Much of today's current waste is avoidable, whether at the level of agricultural output, storage, processing, distribution or consumption. As a result, food waste prevention initiatives and campaigns have received increasing attention: non-profit organizations like Net Zero Waste and the Zero Waste Council count many businesses and local governments as members, the United Nations Sustainable Development Goal 12.3 aims to halve food waste by 2030, and the Government of Canada launched its Food Waste Reduction Challenge in late 2020 to tackle the 50% of the country's food supply that currently goes to waste. These collective efforts aim to educate and induce behavioural changes in the population that will encourage prevention, generally agreed as the most important first step to reducing food waste. Beyond prevention, many strategies focus on the segment of so-called "waste" that is in fact still edible, and aim to find channels for directing this "value-less" product, such as addressing food security or using as livestock feed. A widely used waste reduction hierarchy (also referred to as a food recovery hierarchy) is presented in Figure 1 as a pyramid of strategies from most to least preferred:

---

[1] The Food and Agriculture Organization (FAO) separates food that is removed from the food system into two categories based on when it occurs. *Food loss* refers to the reduction at the farmgate, in storage or during processing, while *food waste* refers to the reduction at the retail, restaurant or consumer level. For simplicity, throughout this report both categories will collectively be referred to as food waste.

[2] This definition of waste encompasses kitchen scraps, yard and garden waste (such as leaves, branches and grass), and some paper-based products.

Figure 1: Food Recovery Hierarchy



Note. Copied from Food Recovery Hierarchy, by the United States Environment Protection Agency, 2021 (https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy)

Unavoidable food waste, however, will always exist, and this reality has sparked creative thinking and innovation around how to repurpose and use it for productive ends, such as biofuels or soil amendments – examples of the circular economy in practice that that are seen as alternatives to landfilling and incineration. Municipal governments that provide waste management as a service have been eager to capitalize on these developments in order to reduce landfill constraints, prolong the useful life of facilities, save money and address their environmental footprint; meanwhile, private technology firms in the nascent waste-to-energy (WTE) space see an opportunity for "triple bottom line" profits – that is, the ability to deliver a financial return that benefits society and the environment. In effect, two benefits could simultaneously be realized: the reduction of methane emissions from diverted waste away from landfills, and the reduction of several GHGs from lower fossil fuel consumption. The problem, though, is one of scale. When the facilities required to support these solutions reach beyond the budgets of most local governments, scale – often with private backing – is needed to secure investment. Unfortunately, this places some solutions out of the reach of smaller municipalities, which must wrestle more than larger districts with how to reconcile responsible waste management with environmental ethics in a cost-effective way.

The District of Central Saanich is a small municipality of about 18,000 people on southern Vancouver Island, covering an area of 43 square kilometers situated between Saanich and North Saanich. The District is sparsely populated and rural, with about 66% of its land within the Agricultural Land Reserve.

It has set an ambitious target of 100% community-wide GHG reductions by 2050 (relative to 2007), as outlined in its Climate Leadership Plan, with multiple strategies suggested to tackle various sources. Currently about two-thirds of the District's GHG emissions arise from transportation, and 12% due to organic waste. Meanwhile, the Capital Regional District (CRD) – the regional authority that oversees 13 municipalities on southern Vancouver Island – instituted a ban on landfilling yard waste and kitchen scraps in 2006 and 2015, respectively. Even though the region has made significant progress on waste-related GHG emissions, organics remain the largest component of municipal solid waste by weight, at 21% (CRD Solid Waste Management Plan, 2021). The District's goal is to divert its food waste away from Hartland Landfill by converting it into biofuel, thus tackling two sources of GHG emissions simultaneously.

This report aims to explore the technological landscape of WTE solutions, investigate current practices across a range of municipalities, and analyze one solution for the District of Central Saanich that may be viable for small districts that wish to divert some of their waste to create energy. The resulting solution, biodiesel production from waste oil, is subjected to a cost-benefit analysis (CBA) that incorporates the financial return to the District and the broader returns to society. Two alternative solutions unrelated to biofuel production are also analyzed. While the ultimate decision to implement any solution will depend also upon a host of minute contextual details that go beyond the scope of this analysis, the report offers a basic blueprint that can help small sparsely populated districts evaluate which of several waste diversion strategies to pursue. As part of a broader arsenal of tools and projects to address climate change, this endeavour can reduce stress on landfills and contribute to ongoing local GHG reduction efforts.

5. Technology Options

Increasingly over the past three decades, various technological solutions have been theorized, tested and developed to convert organic biomass into energy. The biomass can be anything organic in nature, though attention has naturally been directed toward inputs that are either free or very cheap – waste (as defined above) or corn, for example. A common historical trend is for a new technique to be tested in an engineering lab, developed commercially by the private sector, and ultimately supported by various levels of government, whether through public-private partnerships ("P3"), grants or tax credits. With various processes available, municipal governments, private haulers, city planners and chemical engineers have asked the key question: what is the optimal use for a city's organic waste? In broad terms, organic waste can be converted into compost, heat, electricity, organic fertilizer, and biofuel.[3]

The following section outlines the key technologies available today to convert organic waste into a value-added product. For this project, all technology options were investigated through a combination of online research and consultations with industry experts at private firms in the waste-to-energy (WTE) sector. Consultations were conducted via phone, video conferencing (e.g., Zoom, Microsoft Teams, etc.) and email. A list of key industry contacts is supplied in a separate appendix, along with call log notes.

---

[3] The Ellen MacArthur Foundation defines a biofuel as "any liquid or gaseous hydrocarbon fuel produced from biomass in a short time, i.e. not over geological time as with fossil fuels" (Ellen MacArthur Foundation, 2017).

Biogas and Digestate

Method	Anaerobic Digestion (AD)
Inputs	Kitchen scraps, manure and agricultural waste preferred; yard waste acceptable
Output	Biogas, Digestate
Pros	Wide range of uses (heat, electricity, gaseous fuel, liquid fuel, fertilizer); large GHG reductions; speed of conversion
Cons	Capital-intensive; large and reliable volume required; consistent feedstock mix required
Examples	Vancouver, Surrey, Toronto, Edmonton
Capex Cost	$10 million - $100+ million
Notable Firms	Andion, Anaergia, Blue Sphere, CDM Smith, CH Four Biogas, Convertus, Enerkem, EverGen, PlanET Biogas Solutions[4]

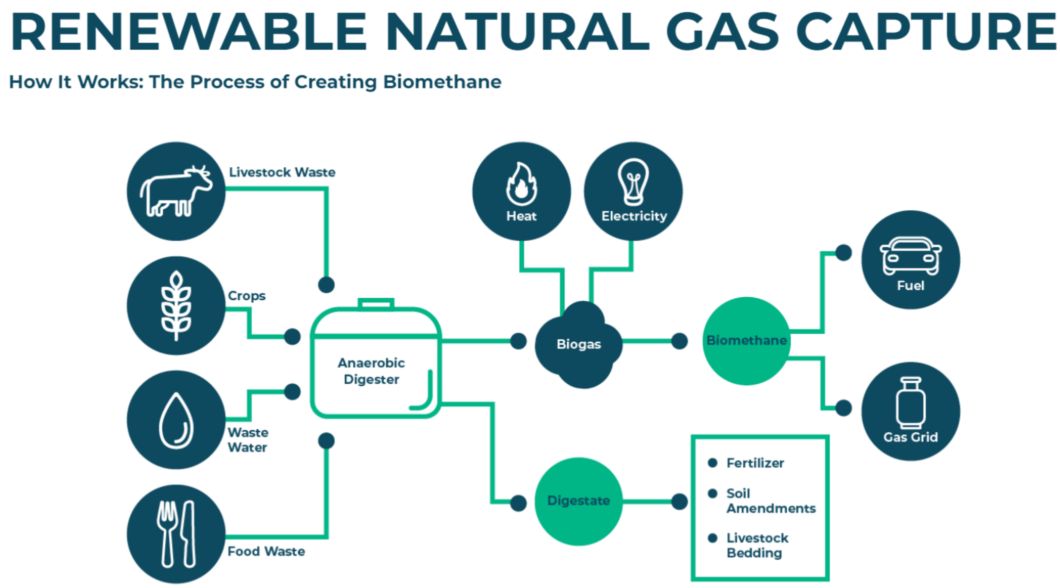
Anaerobic digestion (AD) is a process that allows bacteria to decompose organic matter in the absence of oxygen. The organic matter (or "feedstock") can include agricultural waste, kitchen scraps, wastewater, and yard waste. From within a heated sealed container, AD will naturally produce biogas, a gaseous fuel composed of approximately 60-65% methane, 35-40% carbon dioxide and trace impurities. The unprocessed biogas can be used to generate heat and electricity for homes and buildings (and often the AD facility itself), or it can be refined into renewable natural gas (RNG), a process that removes most of the impurities and carbon dioxide, leaving approximately 99% methane. Due to the renewable source and composition of RNG, the terms sustainable natural gas (SNG) and biomethane are used interchangeably with it as well.

RNG has the same chemical composition as traditional natural gas provided by local utilities to heat homes and buildings. For this reason, RNG can be injected into the natural gas grid system, and utility providers like FortisBC will pay a premium per gigajoule (GJ) above normal market rates, depending on the carbon intensity (CI), because of its sustainable source.[5] The gas can also be used as a transportation fuel for compatible vehicles (typically lighter, newer models) or can be compressed into condensed natural gas (CNG), a liquid transportation fuel for heavier or older vehicles. A final by-product of AD is digestate, the leftover nutrient-rich liquids or solids that can be processed into organic fertilizer. While the fertilizer must first obtain certification from the Canada Food Inspection Agency (CFIA), as outlined through various standards in the Fertilizers Act and Regulations, it can then be used safely in agriculture, parks maintenance and landscaping.

[4] A list of 270 companies can be found on the American Biogas Council's Business Directory site, and a similar list can be found on CBA's Our Members site.

[5] Two industry professionals cited the premium as 5x and 10x the market rate. Meanwhile, The FortisBC RNG Supplier Guide states on page 8 that the utility "can pay up to $30 per GJ for pipeline quality, purified methane" which, at the time of writing, is approximately 10.5x the regular listed rate of $2.844/GJ. Ultimately, as a representative wrote about premiums, "We tend to negotiate case by case for projects in BC, especially where organics diversion is concerned because of the way methane avoidance is calculated".

Figure 2: Anaerobic digestion inputs and outputs



Note. Copied from Renewable Natural Gas Capture, by EverGen Infrastructure Corp., 2021 (https://www.evergeninfra.com)

AD facilities have several features that make them conducive to densified urban settings:

1) A smaller physical site and footprint relative to composting facilities
2) Less odour and faster conversion than composting
3) Lower labour costs than composting, which tend to be higher in urban areas
4) Very high capital costs that necessitate high volumes of waste to achieve economies of scale.

As the Food Waste Cities Policy Toolkit Report notes, "organics recycling infrastructure planning is often a regional effort" which means "it is worth reaching out to neighboring cities, as well as county and state agencies, to leverage this effort at a larger scale" (Mugica & Rose, 2019). This was echoed by industry professionals; as an engineer at Blue Sphere noted, "if you have under 100,000 gallons of waste per day, this is where the numbers start to get iffy."

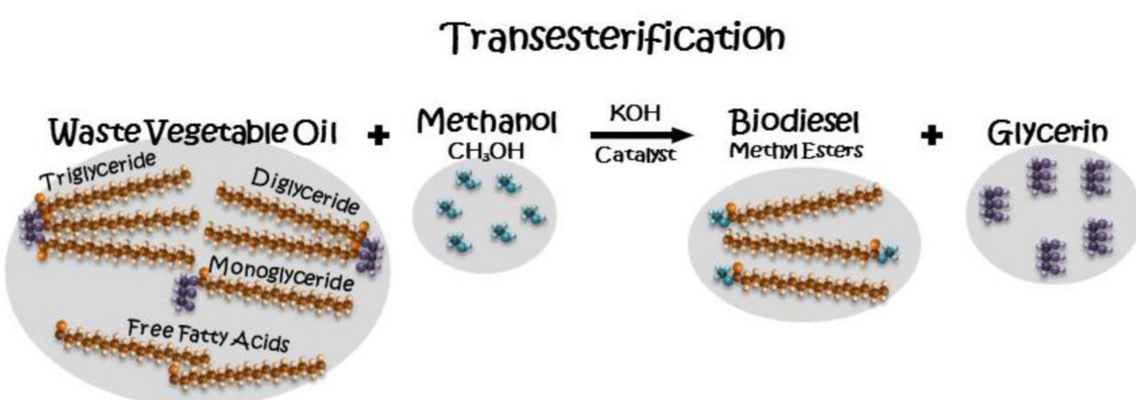
The American Biogas Council and Canadian Biogas Association are the collective voice of the industry in their respective countries and provide several online resources. Both organizations share news releases affecting the industry, publish market reports, and offer multiple guidance documents for public and private actors wishing to enter the biogas energy space. Overall, the industry is still in its infancy in North America. As Canada's Energy Regulator states, "Very few Canadian landfills recover methane emissions for energy purposes" but "increasingly, Canadian landfills and waste-to-energy facilities generate electricity for nearby utilities and industries, or convert landfill gas to natural gas to be moved in natural gas pipelines."

Biodiesel

Method	Transesterification
Inputs	Used cooking oils (UCO)
Output	Biodiesel (ASTM D6751), glycerin
Pros	Fit to scale; ease of operation; GHG reduction
Cons	Limited feedstock; UCO collection logistics
Examples	Various businesses and universities; Cowichan Valley Co-Op; Lower Mainland Biodiesel
Capex Cost	\$50,000 – \$50 million
Notable Firms	Crown Iron Works, Desmend Bellestra, Bratney Companies, GEA Westfalia, BDI BioEnergy International, Energia Tech, Sustane, BioCube, Springboard Biodiesel

Biodiesel is a renewable fuel derived from used cooking oils (UCO) that can be used in virtually all vehicles and equipment that run on conventional diesel. Lipids and free fatty acids (FFA) must first be extracted to achieve a low FFA content – ideally under 5% (Barik, 2018). Using either an acid or base catalyst, the fatty oils are reacted with an alcohol, typically methanol, to form methyl esters and glycerin in a process known as transesterification. The methyl esters, or biodiesel, are chemically identical to conventional petroleum-based diesel, and are therefore often blended together. The resulting blend, BXX, denotes the percentage from organic sources; for example, B20 blend would be 20% biodiesel, a common blend that is often used in buses, trucks and military vehicles (Nunez, 2019). The glycerin by-product can be turned into soap, used as livestock feed, or sent to wastewater treatment plants.

Figure 3: Transesterification chemical conversion process



Note. Copied from Transesterification, by UBC Engineers for a Sustainable World Biodiesel Project., 2013 (http://blogs.ubc.ca/sustainabilityclub/biodiesel-project)

Turning vegetable oil into fuel has been done since the early 20th century, when the French Otto Company first ran a diesel machine on peanut oil in 1900. In order to call the product biodiesel and distribute it to today's public, it must meet the fuel quality standard ASTM D6751. This North American standard is used widely around the globe and defines biodiesel as "mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats" and thereby provides assurances that it can be blended with conventional diesel and used in diesel engines. By contrast, even though both come from renewable sources, *renewable diesel* is "a hydrocarbon produced through various processes such as hydrotreating, gasification, pyrolysis, and other biochemical and thermochemical technologies" (US Alternative Fuels Data Center) and meets ASTM D975 in North America.

There are 645 distributors and 1,715 biodiesel retailers in the US alone, where national production was 2.6 billion gallons in 2018. Nearby retailers include Lower Mainland Biodiesel and Cowichan Biodiesel Co-op.

Bioethanol

Method	Fermentation
Inputs	Corn, sugar cane, sugar beets, wheat, barley, woody biomass
Output	Bioethanol
Pros	Reduced GHGs, enhances national energy security
Cons	Primarily uses virgin crops, pressures on land and food prices
Examples	Swedish public transportation, Reading Buses (UK), Nissan
Capex Cost	$40+ million
Notable Firms	Notable firms: Greenfield Global, Archer Daniels Midland, Green Plains, Cargill Inc, Poet Biorefining, Valero Energy

Bioethanol is currently the most commonly used biofuel in Canada and the United States, where it is derived largely from corn but can be made from several other crops (for example, other countries like Brazil rely on sugarcane). Hydrolysis is used to first break down the cellulosic matter into sugars, which are then fermented into ethanol using yeast and heat as catalysts. Because the resulting ethanol can be, and often is required to be, blended with petroleum fuels like gasoline, it has become an important tool for some governments to reduce their reliance on conventional crude imports while also helping to lower their country's carbon footprint.[6]

To ensure the consistency of the feedstock, bioethanol uses almost exclusively first-generation crops. Because of this practice, the process has come under scrutiny for diverting food resources, adding increased pressures on land use, contributing to deforestation and food scarcity, and inflating food prices – indeed, regulations legislating a minimum use of bioethanol in conventional fuels were blamed as a major cause of the 2008 - 2011 global food crisis (IMF, 2008; Mitchell, 2008; Mittal, 2009; Wise & Murphy, 2012). While research is ongoing to develop processes that convert wood-based cellulosic materials (of which Canada has plenty) and municipal solid waste into bioethanol, such technologies remain solidly in the development stage.

[6] For example, the United States 2020 Renewable Fuel Standards federal policy requires any transportation fuel to contain a minimum fraction of renewable fuels.

Compost

Method	Windrow, in-vessel, extended aerated static, Gore-Tex cover, residential application
Inputs	Leaf & yard waste preferred; all kitchen scraps acceptable
Output	Compost
Pros	Relatively inexpensive; supports regenerative agricultural practices
Cons	Siting challenges, length of conversion, low GHG reductions, odours, contamination risk
Examples	Capital Regional District, Abbotsford, Kamloops
Capex Cost	$500 - $30 million depending on scale
Notable Firms	Engineered Compost Systems (ECS), Convertus, Green Mountain Technologies, Maple Reinders, Net Zero Waste

Composting is the process of decomposing waste in the presence of oxygen to produce soil amendments. It returns nutrients to the nutrient cycle and can "improve soil structure, restore depleted soil, offer erosion control, increase water retention, and reduce the need for chemical fertilizers" (Mugica & Rose, 2019). Besides landfilling, composting is perhaps the most commonly utilized approach to food waste diversion in Canada, with approximately 370 facilities spread across the country (van der Werf & Cant, 2006). Most use the open-air windrow method, though more modern practices of using large Gore-Tex covers to control odours are becoming popular despite the additional cost (see Figure 4 below). The duration of the process can take anywhere from a few weeks to several months, a lengthier treatment process owing to the presence of oxygen, though most facilities' turnaround time is around 45-60 days.

Figure 4: open-air windrow (left) and GORE cover (right)

Note. First image copied from Windrow Composting, by Recycle Track Systems, 2020 (https://www.rts.com/blog/what-is-commercial-composting-and-how-can-cities-manage-organic-waste). Second image copied from GORE® Cover for Organic Waste Treatment, by GORE, 2021 (https://www.gore.com/products/gore-cover-for-organic-waste-treatment)

Even though it is less expensive, like other technologies, composting as a municipal strategy benefits from economies of scale, and therefore from regional efforts to coordinate and fund infrastructure investments. Each province has regulations governing the construction and operation of compost facilities, as well as its distribution, storage, sale and usage. At the same time, it remains a cost-effective option for municipalities that wish to move away from landfilling their organic waste, while avoiding the relatively large capital investments required to build biogas plants and refineries. Tipping fees from haulers and revenue from compost sales generally fully offset operating expenses, which tend to be more labour-intensive than other processes discussed here. Profits may be earned depending on the demand for and market price of compost.

From an environmental standpoint, composting represents a circular endeavour – organic waste is made into a value-added product – but it requires the presence of oxygen to aid decomposition. As a result, the aeration releases methane into the air. For this reason, some environmentalists and city government officials have advocated to landfill waste where the methane can at least be captured, acknowledging that the site will fill up more quickly as a result. It is also important to distinguish compost from fertilizer. While many resources will use the terms interchangeably, there are very strict legal definitions outlined in Canada's Fertilizers Act on what can be considered, marketed, labeled and distributed as fertilizer. It is common to say that compost "fertilizes" soil, but it cannot be labeled as fertilizer.[7]

Lastly, composting is a food waste management technique that can be applied on a very small scale. Indeed, while some farmers will use on-site digesters or re-purpose some waste into animal feed, composting is a cheap, easy, practical solution open to ordinary residents in any municipality. Kitchen scraps, once composted, can be added as a soil amendment to gardens, lawns and flowerbeds. This established practice, alongside increasing concern about food waste, has incentivized some private sector companies to develop at-home countertop composters – easy-to-use household appliances that expedite the aeration process to produce compost for everyday residents to use. This small-scale example of composting is profiled in "Alternative Technologies" below and is analyzed later in the cost-benefit analysis spreadsheet.

Alternative technologies

There are several promising technologies currently in development that may see large-scale commercialization and adoption in the decade ahead. Generally speaking, these technologies take novel approaches in one or more of the following ways.

1) **Explore new inputs and processes**

Research conducted by universities and private firms is seeking to find viable, cost-effective ways to expand the feedstock to include algae, woody biomass, wood waste and other plant materials that are preferred for composting but are currently not good candidates for biofuel generation. These materials are cheap and in abundant supply, but separating the cellulosic sugars from the lignin (the stringy fibrous material in plants) remains a hurdle. Other researchers are refining the process of hydrothermal liquification to accelerate the process of anaerobic digestion (Treacy, 2018). The additional energy

[7] Regarding usage, the Ellen MacArthur Foundation succinctly states, "Generally, compost is viewed as having superior soil-improving qualities, while digestate is better suited as a biofertilizer" (2017).

requirements have prompted some to question whether or to what extent this process is energy neutral, and it remains largely in the development stage.

2) Market directly to consumers

Several private companies such as VitaMix, Tero and Whirlpool are appealing directly to consumers in the fight against food waste by marketing household appliances that convert kitchen scraps directly into nutrient-rich soil amendments. Retailing for around $500 CAD each, the devices are odourless, sterile and easy to use. In at least one municipal example, the City of Nelson partnered with FoodCycler and ran a pilot project in which residents were sold food waste recyclers at subsidized rates. After significantly reduced waste for curbside collection in the first year, the city is expanding the program to more homes and businesses. A presentation on the program's results is publicly available.[8]

3) Create different end products

Driven by recent initiatives in municipal organic waste management and directives in packaging legislation, a unique intersection has emerged to develop biodegradable packaging made from food waste. Despite large investments in research and development, cost remains a challenge, as does the lengthy period required to break down food-based packaging in compost (FoodPrint, 2019). As such, some projects are in the development stage – such as compostable coffee pods or Styrofoam made from popcorn – but the industry remains "extremely fledgling" and widespread use remains "probably 5 – 10 years" off, according to an interview with a PAC Packaging Consortium representative. And as he emphasized, even despite the slow technological progress, a major hurdle remains educating consumers to compost the packaging rather than recycle it, an awareness campaign that will likely take a long time to unfold.

6. Municipal Case Studies

The snapshot of solutions demonstrates that there exist several alternatives to landfilling organic waste – proven technologies that have government support (financial or regulatory) and an available market for their outputs. While private engineering firms are at the forefront of these efforts, adoption and implementation by local government is critical. Given their essential responsibility to manage municipal waste, pledging feedstock commitments are a key means of achieving the scale that makes circular projects economically viable. Unfortunately, the largest impediment remains the capital expenditures required to implement solutions other than landfilling. As the National Zero Waste Council states, "Composting and biofuel facilities are capital intensive, and could be beyond the reach of many local governments" (NZWC, 2018). However, as the following municipal case studies will demonstrate, solutions are possible when coordinated efforts and political willpower are combined with the right financial incentives.

While landfilling remains the most common approach to organic waste management in Canada, several municipalities have taken creative steps to tackle the issue within their districts. Overall strategy begins with preferred approaches – such as reduction at source or donating to those in need – but it is acknowledged that there will always be some unavoidable waste, and the question becomes how to

---

[8] See their website: https://www.nelson.ca/DocumentCenter/View/4286/FoodCycler-Pilot-Program-Presentation

process and re-purpose it. Forward-thinking municipalities have taken three primary measures, each progressively more difficult: they have 1) placed a disposal ban on organic materials (and other recyclables) to encourage recycling and reduce methane emissions at landfills, 2) organized collection of source-separate organics, either by providing an "in-house" service or by contracting out to private haulers, and 3) re-envisioned "waste" as a resource that holds value, and invested in facilities that exploit that resource's value.

As the following case studies demonstrate, the districts that were contacted have all done the first, are constantly seeking to improve the second, and have taken different approaches to the third. Indeed, a clear theme that emerges is how individual approaches are adapted to local context, so that a particular district's adopted solution is a function of its size, resources, mix of feedstock, volume commitments and cost structure. Factors such as history and geopolitics also constrain the range of politically viable options. For this project, all municipal case studies were conducted through a combination of online research and consultations with waste management representatives in local government. Consultations were conducted over the phone, video conferencing (e.g., Zoom, Microsoft Teams, etc.) and email. Where consultation was not possible, as with international examples, online research was used. A list of key industry contacts is supplied in a separate appendix, along with call log notes.

6.1 Canada

Abbotsford, BC

Population	150,000
Technology	Composting with GORE Cover
Capacity	40,000 mt
Key Partners	Net Zero Waste
Implementation	2013
Cost Range	~$20 million
Financing Model	Privately owned and operated

In 2013, the City of Abbotsford awarded the contract to Net Zero Waste (NZW) to design, build, own and operate their composting facility. In operation for over 7 years and able to process 40,000 tonnes of organic waste per year, the facility utilizes GORE Cover technology (like the Gore-Tex in ski jackets) using prefabricated covers from Germany to cover the compost during aerobic decomposition. As the founder of Net Zero Waste stated, "the critical technology is odour control" – a major concern of local residents – and the cover technology is the firm's competitive advantage. NZW has plans to build an on-site digester in the future, and is currently working on projects with other municipalities across BC, including smaller ones such as Powell River and Campbell River.

The company operates the facility and therefore determines the tipping fees, earning revenue from those fees and from compost sales. Although their business model sees upfront capital expenditures paid by the municipal government, the district in question would recoup costs by saving on reduced tipping fees at the independently operated facility. Depending on size, siting, and any extra features (e.g., additional layers of odour control), an entire project from design to building completion can cost as little as $1 million or can easily be upwards of $10 million. As the founder emphasized, though, community outreach is important to convince residents that the technology eliminates smell, as this "perception issue" is politically explosive enough to kill several projects before they have even begun, as happened to NZW's contract with Saanich given the recent history of litigation in the area.

Chilliwack, BC

Population	92,000
Technology	Co-digestion
Capacity	6,000 mt/year
Key Partners	Associated Engineering and GHD (consultants); NAC Constructors Ltd/WSP and Tritech Group/Stantec (design-build firms shortlisted to submit proposals)
Implementation	Estimated 2022
Cost Range	$9 million
Financing Model	Clean BC Communities Fund (73.3%), Chiliwack Sewer Fund (26.7%, assuming no further funding secured)

The City of Chilliwack is an example of a relatively small municipality that has been able to take unusually progressive steps toward organic waste management by taking advantage of provincial grant programs. The City is currently preparing itself to issue a Request for Proposals (RFP) for the design and construction of an organic waste pre-processing facility and new anaerobic digester capable of handling up to 6,000 tonnes per year of organic waste. The challenge is dealing with multi-family (MF) and industrial-commercial-institutional (ICI) waste streams, which tend to be more contaminated. The project will allow the waste to be preprocessed (ie, sorted for contaminants) before being composted or sent to the digester.

With a transfer station for organics at their landfill and a wastewater treatment plant (WWTP) at capacity, the plan is to add to existing infrastructure and facilitate co-digestion of source-separated organics from MF and ICI sources with WWTP sludge, as wastewater has a high organic component useful for digestion. The outputs will be biogas and digestate. The budget for the project is about $9 million, but the "game changer", according to a city engineer, was a grant from the Clean BC Communities Fund, part of the Investing in Canada Infrastructure Program, to cover 73.3% (about $6.6 million) of the total cost. The City has also submitted other applications to secure additional funding.

Edmonton, AB

Population	1.3 million
Technology	Anaerobic Digestion
Capacity	48,000 mt/year
Key Partners	Enerkem, Maple Reinders, Suncor
Implementation	2018
Cost Range	$42 million
Financing Model	Privately owned

The City of Edmonton has two major facilities for diverting waste. The Waste to Biofuels and Chemical Facility was built, and is currently owned and operated, by Quebec-based Enerkem. Unlike all other facilities profiled in this review, Enerkem's $100 million plant converts *non-recyclable non-compostable refuse* (essentially, any garbage) into biofuels and renewable chemicals. With the ability to convert 100,000 tonnes of MSW into 38 million litres of ethanol per year, which is used by Suncor for transportation, the facility is "the world's first commercial-scale waste-to-biofuels facility of its kind," according to the City's website. The City also owns the High Solids Anaerobic Digestion Facility. Designed, built and operated by Maple Reinders, the $42 million project was completed in 2018 and became fully operational in 2020 as part of the Edmonton Waste Management Centre. The facility can process up to 48,000 wet tonnes of feedstock annually. The biogas produced is used to generate heat and electricity through a combined heat and power (CHP) unit used to run the Edmonton Waste Management Centre. The digestate by-product is used only in industrial applications, owing to the small amounts of contamination (e.g., plastic) still present.

Edmonton collects kitchen scraps separately from yard and garden waste so that as much of the latter as possible is diverted from AD treatment. Instead, "our cheapest, most affordable option is composting," according to an engineer in waste management. The yard waste is easy to process in windrows (open-air composting) and produces high-quality compost, much of which is given back to residents for free, though the City is currently debating whether to continue this program because of the opportunity cost.[9] While source separation and use of yard waste with open windrows ensure that decomposition remains aerobic and therefore that odours are kept to a minimum, the City also has enclosed composting facilities equipped with biofilters – the representative acknowledged, however, that "anything indoors is more expensive to operate". The compost is formulated to the correct application rate by crop scientists and used in nearby farming operations.

Guelph-Wellington, ON

Population	210,000 (combined)
Technology	Multiple strategies
Capacity	N/A
Key Partners	Our Food Future, Circular Opportunity Innovation Launchpad, City of Guelph
Implementation	January 2020
Cost Range	Unknown
Financing Model	Government of Canada, Smart Cities Challenge

The City of Guelph and Wellington County have taken a unique approach among Canadian municipalities, benefitting from their location at the nexus of cutting-edge research on food and agriculture. While most of the region's organic food and yard waste is still directed to composting facilities, the city has established Our Food Future, Canada's first circular food economy. The

[9] As the General Supervisor for Edmonton stated, yard waste compost is a clean product with few contaminants, and is therefore sought after in bulk by nurseries and soil amendment companies. While the City's concern is lost revenue, "sometimes that's ok if we use the free compost to drive some positive waste behaviour changes, like having residents sign up for waste reduction newsletters or bring their yard waste and recycle at one of our eco-stations in order to qualify for free compost".

organization is an arms-length office attached to the City of Guelph but funded by Infrastructure Canada. As such, they benefit from their location near the University of Guelph and several other institutions devoted to food research and initiatives, but they set their own priorities apart from the city. As an officer there said, the organization is essentially a well-equipped food lab designed to experiment as a township and export proven solutions.

Established only in the last five years, several initiatives have grown from the early days of their efforts. One is the Circular Opportunity Innovation Launchpad (COIL), an “innovation platform and activation network” that works with local organizations to design and trial creative solutions that address waste, including food waste. Essentially, it is an incubator for circular business models and technologies. As their website describes, they have accelerated dozens of businesses, launched several flagship projects and innovation challenges, facilitated dialogue among diverse stakeholders, and set up a “matchmaking” site where businesses can sell their waste output to another that might use it as a resource input. Although participants have so far mainly been confined to the geographic region, the aspiration is to grow and replicate successful models across Ontario and other provinces.

The PDF link provides a case study published by the Ellen MacArthur Foundation on Guelph-Wellington’s initiatives. Though many focus on ways to reduce food waste, some diversion strategies and private companies in the WTE space are profiled. In addition to launching the Food Future Data Hub to better study food waste, their Resource Exchange Marketplace launched in May 2021; meanwhile, the City has contracted with a private firm to use biosolids from wastewater treatment as liquid organic fertilizer to support regenerative farming, reducing reliance on synthetic alternatives. Because the commercial sector accounts for almost half of all food waste in Ontario, still-edible food is diverted to The Seed, a non-profit organization that works to address food insecurity in the area. Finally, private companies have made circularity a philosophy – for example, local Oreka Solutions uses black soldier flies to help convert pre-consumer food waste into livestock feed and liquid biofertilizer, and Rothsay converts fats, oils and greases (FOG) from local establishments into feed and fuel.

Kamloops, BC

Population	90,000
Technology	Not yet chosen
Capacity	N/A
Key Partners	N/A
Implementation	Once OMRR is updated
Cost Range	N/A
Financing Model	Dependent on chosen technology

The City of Kamloops deserves brief mention for an intentional strategy not detailed elsewhere: do nothing for the moment. The City’s website contains several options evaluations for processing biosolids and organics – including liquid fertilizer, pyrolysis, thermal drying and windrow composting, among others. As their Environmental Services Supervisor explained, because the Organic Matter Recycling Regulation (OMRR) is being updated by the BC Ministry of Environmental and Climate Change Strategy, the City is uncertain how to move forward with a long-term strategy. The OMRR is the primary driving document and piece of legislation for waste management in BC, offering guidance on siting, permitting, maximum waste capacity, leachate collection, environmental protection measures, and more. Unfortunately, it has been in flux for several years; several aspects of the regulation are being updated, including the language around the management of biosolids. Explaining that Kamloops is by far the largest municipality in the region, the Supervisor said, “we want to know that what we develop can be scaled to bring in other districts, but we’re not comfortable moving forward with any investment given the uncertainties, so we reach out to the Ministry once a quarter to check in where they’re at so we can assertively move forward with it when the time comes.” In the meantime, the district is currently designing a residential curbside organics collection program, with the first phase of public consultation ongoing.

Surrey, BC

Population	580,000
Technology	Anaerobic Digestion
Capacity	115,000 mt/year
Key Partners	Convertus (formerly Renewi and Orgaworld), Greenlane Biogas, Smith Bros & Wilson, FortisBC
Implementation	2018
Cost Range	$68 million
Financing Model	75% private finance, 25% Government of Canada grant

The City of Surrey is home to the Surrey Biofuel Facility, which uses dry anaerobic digestion to convert organic waste into biogas and compost. The organic waste is about 65% kitchen scraps and 35% yard waste; even though the latter does not generate much gas, the operator says it is a “helpful gesture to the community that we take it all”. Waste material is loaded into tunnels and irrigated with liquid from side valves to accelerate the digestion process and reduce the timeframe for gas collection. The resulting biogas is put through an upgrader to extract the carbon dioxide and most of the impurities, leaving RNG that is then fed into the grid run by Fortis BC, which offers substantial premiums to its partners for supplying gas from renewable sources. While the partnership is profitable, “the major challenge is that you have to meet your commitments to the grid – in other words, supply a minimum level consistently,” which requires reliable volumes of feedstock, said an operator.[10] The facility currently produces 120,000 GJ of RNG per year from its annual waste volume of 115,000 tonnes.

The Surrey Biofuel Facility is an integral part of the city’s Rethink Waste Program. Billing itself as the “first closed-loop organic waste facility in North America”, the facility is maintained and operated by Convertus Group, which collects revenues from tipping fees and the annual sale of 45,000 mt of certified compost and 3,500 mt of fertilizer. Even though the private firm designed and built the facility, capitalizing 75% of upfront costs, the facility is technically owned by the City of Surrey, with whom Convertus has a 25-year lease to take waste at an agreed upon tipping fee. Surrey has ownership rights to the gas produced on site, and receives credits that municipal employees use to fuel their fleet vehicles. In the case of garbage collection vehicles, this represents a closed loop system.

[10] The facility’s average weekly supply of ~2,300 GJ meets their commitments, but the operator did stress that a watchful eye is necessary in the summer when the ratio of yard waste to kitchen scraps increases, as AD will produce less biomethane (and therefore RNG) for every tonne of combined waste.

Figure 5: Surrey Biofuel Facility

Note. Copied from Ryan Lauzon, in Canadian City Ready to Launch AD and Composting Facility, by BioCycle, 1 May 2017 (https://www.biocycle.net/canadian-city-ready-launch-ad-composting-facility/)

Toronto, ON

Population	2.9 million
Technology	Anaerobic Digestion
Capacity	130,000 mt/year (combined)
Key Partners	Anaergia, Enbridge, AECOM, CCI Bioenergy, E.S.Fox, Veolia, Xebec
Implementation	2018 (Dufferin) and 2021 (Disco)
Cost Range	$77 million (Dufferin) and $75 million (Disco)
Financing Model	Public-Private Partnership

As part of its *TransformTO Climate Action Plan*, the City of Toronto has embarked on several ambitious projects over the past decade to divert its massive volumes of organic waste and implement principles of circular economy in practice. The city has two AD facilities, Dufferin and Disco, that are able to process up to 55,000 and 75,000 tonnes, respectively, using technology developed by the private firm Anaergia. The biogas is upgraded into renewable RNG and injected into the natural gas grid through a contract with Enbridge, where it can be used to heat city buildings and fuel collection trucks that are NG-compatible. The solid digestate by-product is sold to private contractors, where it is processed into fertilizer for use in city parks and gardens.[11]

[11] This closed-loop system is detailed on their website: https://www.toronto.ca/services-payments/recycling-organics-garbage/solid-waste-facilities/renewable-natural-gas/

While city officials did not cite any intractable issues with the current operations, they emphasized two points for any municipalities thinking of implementing similar solutions. First, contamination is a major issue. While organics end up in regular garbage despite landfill bans, garbage also ends up in green bins due to “negligence or confusion” in separation, and despite transparent guidelines. As a result, expensive pre-processing (ie, sorting) facilities are required, and anywhere from 22% - 30% of what is collected must be turned away. (Light and heavy plastics and diapers are the most common issue, but batteries, broken glass and even bicycles have been found in source-separated green bins.) This wasted capacity could instead be utilized to process (at least some of) the approximately 45,000 tonnes that is handled externally by a third party due to capacity constraints.

The second issue is cost. As a Senior Project Leader in the City’s Circular Economy & Innovation department said, these facilities represent “a hefty upfront cost unless a funding source is secured (Enbridge is front-financing Toronto’s entire project) so unless you have enough material to process and therefore produce enough gas to net out or make profit it might be hard to justify to Council or senior management (which is something we have seen or heard from smaller municipalities in Ontario)”. This cautionary note notwithstanding, neighbouring Durham Region (population: ~650,000) is currently planning to build an AD facility to produce RNG.[12]

Vancouver, BC

Population	2.5 million
Technology	Co-digestion
Capacity	300,000 mt/year
Key Partners	ABR consultants, AECON, NAC Constructors, FortisBC
Implementation	1998 (Annacis), 2012 (Iona and Lulu)
Cost Range	Difficult to estimate due to ongoing upgrades
Financing Model	Publicly owned and operated

Metro Vancouver uses AD facilities to create biogas as part of its Integrated Solid Waste and Resource Management Plan. Specifically, Vancouver uses co-digestion, which feeds controlled volumes of fats, oils, greases (FOG) and other organic waste into wastewater anaerobic digesters. In simple terms, says a city engineer, the process enlarges the feedstock and lets the entire slurry decompose anaerobically. This accelerates the process and produces larger volumes of methane gas while achieving diversion of waste from landfills. Co-digestion is a common approach being employed by municipalities because it utilizes existing infrastructure and surplus digester capacity. The City of Vancouver has treatment plants on Iona Island, Lulu Island and Annacis Island. Revenue is earned through co-generation of heat and electricity, selling RNG to FortisBC, and tipping fees.[13]

[12] See the City of Toronto’s Report for Action and Strategy Financials for further resources.
[13] Should Central Saanich ever decide to pursue similar technologies, it may be worth contacting government officials at Metro Vancouver to learn about their experience. As someone in Surrey remarked, Metro Vancouver is currently in litigation to get out of their contract due to issues with the technology provider, but no further details could be uncovered by city officials.

It bears mentioning that Vancouver has embarked on these massive capital projects while pushing a concerted campaign to reduce waste. The nationwide "Love Food Hate Waste" campaign is led by the Zero Waste Council and has 140 partners across Canada. Metro Vancouver became a partner and launched their own campaign in 2015. Largely focused on consumer and retailer education, the campaign offers practical tips on how to reduce food waste, extend freshness, buy appropriate portions, and understand "best before" dates all while highlighting the cost of avoidable waste for the average family and business.

Victoria and Saanich, BC

Population	92,000 (Victoria) and 119,000 (Saanich)
Technology	Source-Separated Organics followed by composting
Capacity	N/A
Key Partners	CRD
Implementation	2015
Cost Range	No capital expenditures
Financing Model	N/A

With neighbouring locations and similar populations, the District of Saanich and City of Victoria share similar approaches to organic waste management, and supervisors at both municipalities expressed similar views on the cost and regulatory environment that constrains further action. Currently, both districts run their own internal residential collection service with in-house staff and fleet, with Saanich collecting co-mingled waste and Victoria requiring separation of kitchen scraps from yard and garden waste.[14] Meanwhile, private haulers collect from MF and commercial units. Ultimately, both districts deliver the organic waste to processing facilities on Keating Cross Road (Central Saanich) and Fisher Road (Cobble Hill), respectively, both of which are owned by the same company. Representatives both cited the CRD's recent study that concluded an on-site composting facility or anaerobic digester at Hartland Landfill was not economically feasible. Moreover, while the CRD is attempting to coordinate action among the municipalities of southern Vancouver Island, ultimately it cannot mandate that haulers send waste to Hartland Landfill, further stymying progress. As Saanich's Manager of Fleet and Solid Waste Services stated, "the higher volumes really do make the business case."

After essentially re-running CRD's analysis on a district level, the Director of Public Works released a recommendation to the City of Victoria Council on June 17, 2021, that the City maintain the status quo of directing waste to composting facilities on the lower island, while continuing to work with the CRD on potential future opportunities. Saanich, meanwhile, investigated using RNG to fuel the district's dump trucks. Their analysis indicated that the breakeven point (in number of vehicles converted) was 50% higher than current capacity due to large upfront investments. Working within the status quo, both

[14] The Manager at City of Victoria stated that their decision to collect kitchen scraps and yard waste separately was in part due to the design of their trucks: when the kitchen scraps collection program was rolled out in 2013, it was unclear whether yard waste could be accommodated in a normal schedule, so its collection was separated. The City also benefits from a lower tipping fee of $50/mt to process yard waste, versus $135/mt for kitchen scraps. The City collects approximately 2,000mt of kitchen scraps and 1,100mt of yard waste per year. At the time of writing, the District of Saanich had not yet responded to similar inquiries.

supervisors suggested two changes: first, that the organics ban be enforced more stringently (currently, haulers are not subject to fines because contamination goes unnoticed); and second, to explore ways to fine the generator rather than the hauler. In other words, strata properties and other MF buildings that do not properly separate their waste would be fined, not the haulers. The bottom line, as Victoria's Manager of Sustainability said, is that "regulation should seek to directly impact behaviour."

6.2 International

There are far too many international examples of innovative organic waste management to thoroughly cite, but a select few case studies may briefly highlight the contrast in strategies and approaches taken by cities around the world, both big and small.

It is generally acknowledged that the most comprehensive progressive strategies have been undertaken by city governments within the European Union, where the European Commission has made the transition to a circular economy one of its primary goals through the adoption of its Circular Economy Action Plan (CEAP), updated in March 2020. Unfortunately, Eurozone statistics gloss over the stark differences in national strategies: in some countries, almost no food waste is source-separated, while others have taken aggressive steps to reduce and repurpose it (Zero Waste Europe, 2020). All told, about half of organic waste is still either landfilled or incinerated, and the two primary strategies used to treat the other half are composting and AD (European Environment Agency, 2020). While "composting dominates treatment capacity…the use of anaerobic digestion with biogas production is increasing" because it can recover both materials and energy, and therefore promises greater environmental benefits (Alvarez et al, 2010). Often, the two are used in tandem: AD for kitchen scraps, composting for yard waste.

Europe currently produces about half of the world's biogas, a volume that represents about two-thirds of the continent's renewable energy production (Folk, 2018). The organization REGATRACE has established a harmonized biomethane market for trading renewable gases across Europe. Germany, Italy, Denmark and several other countries currently use AD technology to simultaneously reduce their reliance on fossil fuels and to power public transport and municipal buildings. Sweden has set the bar high, combining national guidance and funding with local implementation to turn half of the country's household waste into energy – primarily biomethane used to fuel public transport (Government of Sweden, 2021). Overall, the European Biogas Association predicts that by 2050 Europe will enjoy a fully renewable energy system using biomethane and other biofuels. As a profile on Oslo's efforts notes, however, "it only makes economic sense to invest in a biogas plant to treat the municipal biowaste if there is enough waste available. The solution may only be suitable for relatively densely populated areas and requires co-operation between neighbouring municipalities" (Sitra, 2019).

Federal, state and municipal authorities in the United States take a multi-pronged approach that covers the full gamut of solutions, from low to state-of-the-art technology, and in the smallest towns to the largest metropolitan areas. For example, according to the United States Environmental Protection Agency (EPA), San Francisco "implemented the first and largest urban food scraps composting collection program in the U.S., covering both commercial and residential sectors" by collecting over 2 million tonnes of organic waste and converting it into compost for use on state farms and vineyards (EPA Zero Waste Case Study). Meanwhile, about 4 hours south, San Luis Obispo County (population: ~280,000) processes about 35,000 tonnes of organic waste per year in a dry AD facility designed, financed, built, owned and operated by the Zurich-based company Hitachi Zosen Inova. The facility generates 20,000 tonnes of compost, 1,500 tonnes of liquid digestate, and 6.2 million kWh of electricity per year.[15]

6.3 Biodiesel-Specific Case Studies

As a low-carbon, widely available advanced liquid fuel, biodiesel has made inroads over the last few decades as several countries have sought strategies to address their greenhouse gas emissions, divert FOG waste, and reduce their reliance on foreign energy imports. Federal governments have adopted guidelines or mandates for the use of biofuels, including biodiesel, while offering incentives for adoption such as tax credits and grants. Combined with state/provincial incentives or requirements, municipal governments over time have incorporated biofuels into their vehicles and equipment. Beginning with Brampton, Ontario, in July 2002, several Canadian municipalities have committed to using biodiesel in their fleet, including Vancouver, Richmond, Burnaby, Delta, Saskatoon, Toronto, York, Guelph, Kingston, Halifax and more. Numerous American success stories are available, and it is now common for many cities to mandate a minimum blend in their fleets.[16]

Other institutions are joining as well. For example, various institutions of higher education across North American have been using waste oil from dining services to create biodiesel, integrating the activity into relevant curricula for students (for example, in chemistry or engineering) or exposing them to the process within a club or lab overseen by a professor. In Canada, Engineers for a Sustainable World (ESW) at the University of British Columbia, under the supervision of Professor Naoko Ellis, have a dedicated Biodiesel Lab for converting UCO obtained from Food Services into biodiesel, which is then sold for use within the campus community. Some institutions have built customized equipment within their labs, while others have purchased production machinery from a manufacturer. One such company, discussed in depth later, has sold production units to 100 universities.[17]

A key point, however, is that almost all of the municipal examples involve the wholesale purchase of biodiesel from a certified distributor. These success stories act as evidence of biodiesel's proven record as a safe, clean-burning alternative to conventional diesel, but to find examples of internal production one must turn to the hundreds of small-scale institutions – mainly businesses and universities, as noted, but also some local governments – that have sought, not to purchase biodiesel, but to produce their own from local waste oils. Three such case studies are profiled.

[15] 20% of the electricity is used to power the plant, and the remaining 80% is sold to Pacific Gas & Electric Co to power approximately 600 homes.
[16] One such collection, covering a diverse range of actors, can be found here: https://www.biodiesel.org/docs/default-source/fact-sheets/biodiesel-success-stories.pdf?sfvrsn=f8688d12_11.
[17] A full list can be found here: http://www.springboardbiodiesel.com/colleges-using-springboard-technology.

Daphne, Alabama

Population	26,000
Technology	Biodiesel via transesterification
Capacity	15,000 gallons/year
Key Partners	Daphne Utilities, Utah Biodiesel
Implementation	2006
Cost Range	$10,000 USD (in 2006 dollars)
Financing Model	Purchase

Daphne, Alabama, did not embark on biodiesel production for environmental reasons. Rather, the water and sewer utility for the city, Daphne Utilities, was facing increasing costs and liabilities in the early 2000s due to fats, oils and grease (FOG) clogging up the sewer system. A successful campaign called “Cease the Grease” was launched to raise awareness of the issue and encourage residents and businesses to bring their used FOG to recycling stations across the city, and the program is still running today. Their compliance supervisor stated that they collect about 300 gallons a week from 12 drop-off points (and a few nursing homes, as a courtesy), all of which is donated, and that the savings from avoided sewer clogs more than justifies any collection costs. The number of participating businesses and residents is hard to estimate due to centralized collection, but a good fraction of the town’s 120 restaurants is happy to get rid of their waste oil.

Daphne Utilities uses a Springboard BioPro 380 and has a proven method for making their biodiesel, described more in the call log. Production costs (not including initial capital and labour) is around $0.79/gallon USD ($0.26/L CAD). All biodiesel is for internal use in vehicles and equipment, except for emergency equipment such as a generator. While the gelling is not a problem in their warmer climate, the supervisor acknowledged that it can be prudent to switch to a lower blend during colder months. Like the sales representative at Springboard, he also reiterated that biodiesel is a solvent: it will clean the engines it is used in, which is generally positive except for the effect on used fuel filters, where prior buildup will dissolve; therefore, it is recommended to replace fuel filters if using older vehicles that have run largely on diesel. Lastly, their glycerin by-product is taken to a wastewater treatment facility.

Alachua County, Florida

Population	269,000
Technology	Biodiesel via transesterification
Capacity	21,000 gallons/year
Key Partners	Utah Biodiesel, Springboard Biodiesel
Implementation	2010
Cost Range	$10,000
Financing Model	Purchase (with grant from State of Florida)

Alachua County, Florida, is a case study with similar origins. The county’s Hazardous Waste Department began collecting UCO out of concern for the sewer and pipe systems, and then began converting the product to biodiesel. The program was briefly suspended when changes in state reporting requirements made the administration too costly, but the law was amended and production resumed after 6 months. According to a Hazardous Waste Coordinator, the county currently processes about 50 - 100 gallons (190 - 380L) per week. The UCO is donated directly by homes or dropped off at one of 5 pick-up locations serviced by their department on weekly rounds. Workers will also pick up one or two large 55-gallon drums once a quarter from a small number of restaurants. The biodiesel is blended for use in fleet vehicles (approximately B10 - B20), and a pure B100 blend is used to power a 20 KVA Caterpillar generator. No issues have been noticed or reported so far; as the coordinator noted, “if anything, our biodiesel acts as a good fuel line cleaner like all biodiesels”. The glycerin by-product is disposed of in a wastewater treatment plant.

The county currently uses a Springboard BioPro 380 and, over the years, has purchased various equipment from Utah Biodiesel, such as a transfer pump, filter, and kit to test for quality. The county’s production cost currently sits around $2.36 USD per gallon, or $0.78/L CAD (at an exchange rate of 1.25). The coordinator stated that all oil is donated and that collection costs are close to zero because the 5 pick-up locations must be serviced weekly as part of their hazardous waste rounds; therefore, their largest cost is methanol, which the employee confirmed was true even before current high costs. The program has been tweaked and improved since its inception in 2010. Employees apply heat in order to lower FFA and remove impurities before conversion; the heat (and keeping the machine indoors) also helps on cold days where some used oils, like peanut oil, may be more likely to gel and cause problems. Total cost savings are hard to estimate because they are referenced against fluctuating diesel prices, but have certainly been positive. Moreover, “the intangible savings we have had in our area is the local utility has fewer clogged pipes,” noted the coordinator.

Hoover, Alabama

Hoover, Alabama, initiated a UCO recycling program in 2007 when rising fuel prices and ongoing sewer maintenance issues prompted it to take action. The program ran until 2015 and allowed any residents and small restaurants to donate their vegetable waste oil or cooking grease at several public locations throughout the city. While the city collected approximately 1,250 gallons (4,730L) each month in its heyday, which was used to fuel its fleet and heavy construction equipment, the program was ended in 2015. Production costs were low (well under $1/gallon) but the fleet manager reported that rising maintenance costs on their vehicles due to biodiesel issues began to outweigh any gains in fuel savings. As the manager noted, “We started losing injectors, seeing fuel line and fuel tank corrosion, and other issues. It seemed like every week we were making repairs. One truck had to have 17 fuel filters and 3 injector pumps changed in a single year. And on top of that, in the winter the biodiesel we made would sometimes freeze up.” He also noted that the labour associated with collection pushed their costs further into negative territory. At the same time, he did clarify that they used an old machine assembled with parts from a company no longer in business. As he acknowledged, “I’ve heard the technology has come a long way since we ended the program”.

7. Discussion

The overarching message from these government officials, and the overarching theme of municipal waste management in general (encompassing even those districts that still landfill organic waste and were not contacted), is that the most cost-effective option will prevail in the absence of market incentives, whether provided by the private sector or government. Environmental conservation and GHG reduction are worthy goals, and genuinely espoused by municipal governments who have taken grassroots action within their communities to aggressively address climate change, but ultimately these actions will not pay the current annual bills. As a result, both private haulers who must stay in business, and local government officials under pressure to justify expenditures funded by taxpaying constituents, will naturally gravitate toward the cheapest option that is legally permissible. This was an oft-repeated fact during interviews.[18]

Size matters because it can change what the cheapest option available is. The importance of scale cannot be overemphasized: as virtually all government and industry reps emphasized during interviews, scale is absolutely critical to managing fixed costs – like overhead, bookkeeping, and to a degree labour – that will be present regardless of waste volumes. The larger the operation, the lower the operating costs per tonne. As the founder of a Halifax-based firm said, 6,000 tonnes of waste per year is "nowhere near enough to justify a standalone facility. You need 50,000-60,000 tonnes a year to make it work". Unless a district is large enough to generate sufficient waste, or can marshal regional efforts to achieve equivalent volumes, it will naturally gravitate toward landfilling or (if a ban is in place) allow the private market to signal the next best use.

Given its low capital costs, composting often fills this role. As noted, however, composting facilities require larger areas of land and higher labour costs, while operations are easily affected by weather and have well-documented odour problems (Mayer et al, 2019).[19] Forced aeration can make operations energy-intensive, while contamination issues (for example, the presence of metals and plastics) can affect the final quality (Alibardi et al, 2020). The total process is a "regulatory headache" according to one professional and, overall, the market value of compost remains low. Meanwhile, AD facilities "tend to have a smaller footprint than centralized composting facilities relative to their processing capabilities and thus may be more suited for urban areas where available land is limited" (Mugica & Rose, 2019). In other words, AD's volumes and siting requirements benefit from denser settings and lower labour costs, helping to achieve the economies of scale that can justify such large capital expenditures.

Even when districts or regions are large enough to consider biofuels, solutions that rely on waste feedstocks must be able to compete on price with conventional fuels. The feedstock mix and cost of fuel, therefore, are pivotal variables in any sensitivity analysis. Over the long run, proven crude oil

---

[18] As an employee at a large Vancouver-based bio-engineering firm said, "We hear time and time again that municipalities want to invest in these technologies, but it just doesn't work because they don't have the volume of waste or the capital to underwrite the investment. These facilities are very expensive, which is why they're designed to service an entire region. Letting the private sector (like us) take care of it provides a practical alternative, doesn't use any taxpayer money, and is sustainable."

[19] The owner of a composting facility on Vancouver Island said that his 9-acre plot of permitted to process up to 39,000 mt per year, which is in line with the 10 acres recommended for medium-sized facilities. He did, as an aside, say "I don't think the District's scale would support the cost of a small facility", citing the multiple CCME (federal) and OMRR (provincial) regulations that any site must meet in order to operate.

reserves are expected to grow scarcer and more expensive, making alternative fuels increasingly attractive. In the short run, however, it is unclear what price path conventional fossil fuels will take, as the last decade alone has displayed volatile price swings owing to a range of macroeconomic conditions. Meanwhile, the mix of feedstock determines the volume of biogas generated, and while yard and garden waste can be treated by AD, “it often reduces the energy yield of the process because of the presence of lignin”, the rigid fibrous material in plants (European Environment Agency, 2020). Overall, with cost savings from biofuels so difficult to forecast within this context, private firms and governments may be reticent to make large capital investments even in the presence of compelling environmental arguments.

Next, because of the cost, scale and uncertainty of these large investments, technology providers in today’s waste-to energy environment are inextricably linked with the clients whom they serve. Providers serve four primary functions – design, build, own, operate – and they contract with municipal governments to guarantee a consistent volume and type of feedstock. The facilities are not only complex in their own right, but are designed and built by engineering firms to serve the unique requirements of the region so that no two projects are built exactly alike: design depends on volume, siting, provincial regulations, contamination rates, desired outputs and, crucially, the mix of feedstock (without which, as one engineer said, “we’re in the dark”). And while a small number of districts that were interviewed own their facilities, such as Vancouver and Surrey, no examples could be found of any that operated them with in-house staff.[20] The technology is sufficiently complex that the district must hire either the contractor or a third-party operator to manage daily operations. Unsurprisingly, these facilities are found almost exclusively in larger, denser jurisdictions.

Some options avoid these pitfalls while introducing other potential problems. Bioethanol, as noted, is a lower carbon option than conventional gasoline, but it does not involve diverting organic waste; moreover, its use of virgin crops intensifies competition for land and food. At-home composters are just beginning to see consumer uptake, and they may prove to be a popular appliance in the future; however, given their current price, they represent a substantial investment for districts offering to subsidize cost to ensure widespread use among residents in an attempt to minimize the volume of collected waste. As noted, other treatment options remain promising but are not yet commercially viable. Lastly, several city officials even argued that landfilling can be preferable to composting if the methane can be captured, unlike composting where it is released due to aeration, but landfills will fill up more quickly, to say nothing of the landfill bans currently in place to induce behavioural changes in residents.

Biodiesel sidesteps the issues highlighted above, which plague the application of any treatment technology on a small-scale. Of all processes surveyed, only biodiesel production:

1) uses turnkey technology that is relatively uncomplicated;
2) can be done on a small scale, and is relatively affordable at that scale;
3) does not need to be operated by trained third-party technicians and/or engineers;
4) avoids regulatory clearances, permitting, siting, feasibility studies, resident consultations and other matters of due diligence that attend large capital investment projects;

[20] Even in cases where the district owns the facility, the firm will capitalize the project up front and arrange repayment by the district over the useful life of the plant, much like a homeowner pays down a mortgage underwritten by a bank.

5) can be scaled up or discarded at little additional cost if the district pivots strategy.

Biodiesel production meets the objectives of Central Saanich: it re-purposes food waste, creates a value-added product, and reduces reliance on fossil fuels, thereby lowering GHG emissions and particulate matter. It can potentially earn carbon credits, generating additional revenue. Of all options, it is the sole turnkey technology that can be operated by municipal staff. Importantly, while several colleges and companies utilize small-scale biodiesel technology, along with a few municipalities in the United States, research for this project has uncovered no other municipality in Canada taking this approach to diverting food waste. As such, the district's utilization could act as a showcase or example for other municipalities of what is possible.

There are two major drawbacks, however. Industry consultations revealed that several private firms are eager to enter the WTE space on lower Vancouver Island (as one engineer said, "we will take anything that stinks"), so it appears possible and even likely that several new solutions to divert organic waste will become available to the District in the next five years. As such, it may be unwise to make district-level investments when regional solutions lie around the corner (unless, as a few representatives pointed out, the purpose were to act boldly as a "first mover" on some capital-intensive technology that can pull other neighbouring districts into the effort – a risky move). Second, in terms of scope, biodiesel generation will help divert only a fraction of organic waste – namely, the waste oils generated from the service industry, and possibly from local residents if collection can be organized. And given the existence of Cowichan Biodiesel Co-op (CBC) a biodiesel provider in Duncan, there could be potential duplication of effort, or at least the perception of it, although direct purchase from the Co-op would not divert local waste and therefore lacks the circular approach that motivated this project.

There is no definitive response that can address these drawbacks. The timeline for private AD facilities is uncertain, as is whether the restaurant industry would even choose to include UCO among its organic waste rather than give or sell it to the District. A response to future investment in the region is risk-minimizing in origin: the technology is estimated to pay for itself within a few years, during which point a multimillion facility is unlikely to be built, and biodiesel machinery represents an inexpensive "gamble" to trial in the interim. In other words, there is potential upside and limited downside. The presence of a biodiesel supplier one hour's drive from the District brings into sharp focus the question of whether an in-house project can yield additional cost savings and environmental benefits to the District. Although ultimately a political decision, addressing that question is largely an empirical matter – to be analyzed in the next section.

8. Introduction to Cost-Benefit Analysis

Biodiesel is a liquid fuel made of mono-alkyl esters of long chain fatty acids from a chemical process called transesterification. It is produced mainly from vegetable oils but can also be made from animal fats. Biodiesel is recognized as one of the lowest carbon fuels available, and in fact was recognized by California Air Resources Board as the lowest of all liquid fuels (National Biodiesel Board, 2015).[21] With

[21] While the grams of CO_2 per megajoule of fuel depend somewhat on the source of biodiesel (for example, 19.9g in UCO versus 51.8g in soy or 52.3g in canola oil), all sources had lower scores than corn ethanol or CNG. The scores also indicate that UCO is the cleanest source within the biodiesel grouping.

major infrastructure around the world, including 125 plants in the US alone, biodiesel is now widely commercially available as a readymade substitute for conventional diesel. Although electric and hybrid vehicles continue to gain popularity with consumers, conventional diesel itself has extensive infrastructure networks and is still widely used in a wide range of vehicles and equipment that focus on commercial, industrial and agricultural applications. In other words, production of biodiesel is unlikely to become obsolete in the next 15 – 20 years.

As previously noted, a blend of BXX denotes that XX percent of the fuel is biodiesel, with the remaining fraction conventional diesel. The District of Central Saanich currently uses approximately 40,000L of B5 biodiesel per year in a wide variety of equipment.[22] The fuel is obtained through a municipal joint purchasing group; approximately 46% is used by fire, road and parks vehicles. If the District were to use B20 biodiesel, it would need to produce around 8,000L of pure B100 biodiesel, which would then be mixed with 32,000L of low-sulfur diesel to produce enough B20 blend for the District's needs. Overall, this would entail sourcing approximately 160L of UCO per week (theoretically feasible given the number of restaurants) and processing through a biodiesel machine along with several chemical inputs.

Compared to other biodiesel equipment suppliers, Springboard Biodiesel's machines are small enough to meet the District's needs but large enough to come pre-assembled and ready to use, with automated features and a 1-year manufacturer's warranty. Its machines produce ASTM D6571-grade biodiesel from a wide range of oils. The company has been in business for 13 years with sales to 100 universities, dozens of municipalities and other organizations during that time. Springboard's equipment has CE certification, an internationally recognized standard that establishes equipment as safe for consumers to use, and a full list of safety features can be found on their website. Specifically, the BioPro 190EX machine at $20,357 CAD appears to be the most appropriate investment choice: its size fits the District's likely volumes of UCO and it does not need to be monitored during use, thereby greatly reducing labour costs. The machine occupies a small footprint with dimensions of approximately 1m x 1m x 1.7m.

The Cost-Benefit Analysis (CBA) spreadsheet tool provides all key details and assumptions that affect the net benefits and therefore the viability of the entire project. The spreadsheet lists private and economic (or social) returns, where private returns refer to the gain or loss accruing to the stakeholder underwriting the investment, in this case the District of Central Saanich; meanwhile, economic returns capture these private returns and also include positive or negative externalities borne by members of society who did not fund the project. In this case, economic returns include the positive externalities of cleaner air. As is conventional in project evaluation, all annual cash flows are discounted and summed to yield a single Net Present Value (NPV), which succinctly expresses in a single value, in current dollars, the gains or losses associated with the project over its entire duration, in this case 10 years. An internal rate of return (IRR) expresses this value relative to all costs – essentially, a return on investment.

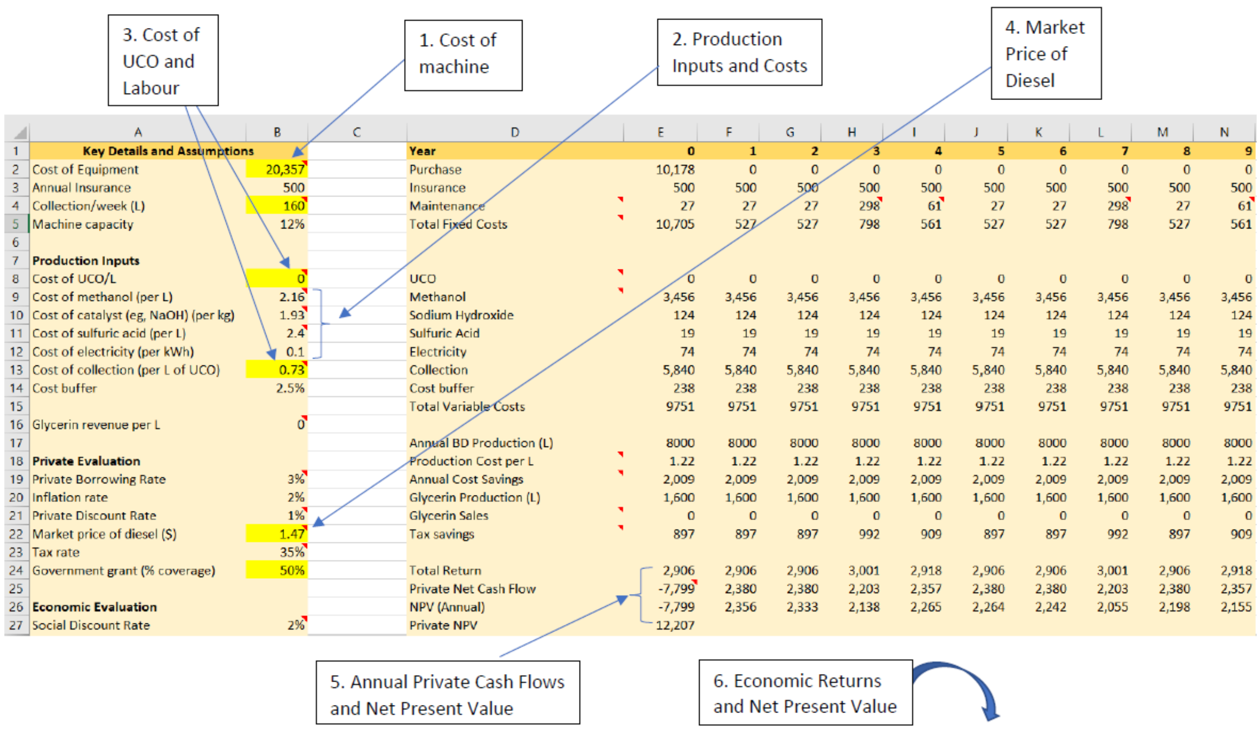
To supplement the spreadsheet, an explanation of all assumptions is provided below, along with a "guided tour", interpretation of private and economic results, sensitivity analysis, and concluding discussion.

---

[22] As noted by Ali Rivers via email correspondence on July 14, "The vehicle types are extremely varied and include: backhoe, loader, flush truck, asphalt roller, brush chipper, skid-steer, weed steamer, F550, single axle truck, loader, Sprinter Van, F750, mower, single axle and tandem axle dump trucks, ladder truck, pumper, rescue vehicle, tractor/mower, street sweeper and pumper apparatus." The District used 40,090L in 2019 and 39,897L in 2020.

8.1 CBA Excel Tool: A Guided Tour

The CBA tool in Excel is designed to calculate the private and economic returns to the District of Central Saanich of purchasing a biodiesel machine and obtaining used cooking oil to produce biodiesel with that machine (often simply referred to as “the project” for brevity). Because there are several key details and assumptions listed in column A, a step-by-step explanation for future users will help illuminate which variables can be adjusted, and how they interact with each other to estimate final returns. All values are expressed in real 2021 dollars that have been adjusted for expected inflation.[23]



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Key Details and Assumptions**			**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2	Cost of Equipment	20,357		Purchase	10,178	0	0	0	0	0	0	0	0	0
3	Annual Insurance	500		Insurance	500	500	500	500	500	500	500	500	500	500
4	Collection/week (L)	160		Maintenance	27	27	27	298	61	27	27	298	27	61
5	Machine capacity	12%		Total Fixed Costs	10,705	527	527	798	561	527	527	798	527	561
6														
7	**Production Inputs**													
8	Cost of UCO/L	0		UCO	0	0	0	0	0	0	0	0	0	0
9	Cost of methanol (per L)	2.16		Methanol	3,456	3,456	3,456	3,456	3,456	3,456	3,456	3,456	3,456	3,456
10	Cost of catalyst (eg, NaOH) (per kg)	1.93		Sodium Hydroxide	124	124	124	124	124	124	124	124	124	124
11	Cost of sulfuric acid (per L)	2.4		Sulfuric Acid	19	19	19	19	19	19	19	19	19	19
12	Cost of electricity (per kWh)	0.1		Electricity	74	74	74	74	74	74	74	74	74	74
13	Cost of collection (per L of UCO)	0.73		Collection	5,840	5,840	5,840	5,840	5,840	5,840	5,840	5,840	5,840	5,840
14	Cost buffer	2.5%		Cost buffer	238	238	238	238	238	238	238	238	238	238
15				Total Variable Costs	9751	9751	9751	9751	9751	9751	9751	9751	9751	9751
16	Glycerin revenue per L	0												
17				Annual BD Production (L)	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
18	**Private Evaluation**			Production Cost per L	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
19	Private Borrowing Rate	3%		Annual Cost Savings	2,009	2,009	2,009	2,009	2,009	2,009	2,009	2,009	2,009	2,009
20	Inflation rate	2%		Glycerin Production (L)	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
21	Private Discount Rate	1%		Glycerin Sales	0	0	0	0	0	0	0	0	0	0
22	Market price of diesel ($)	1.47		Tax savings	897	897	897	992	909	897	897	992	897	909
23	Tax rate	35%												
24	Government grant (% coverage)	50%		Total Return	2,906	2,906	2,906	3,001	2,918	2,906	2,906	3,001	2,906	2,918
25				Private Net Cash Flow	-7,799	2,380	2,380	2,203	2,357	2,380	2,380	2,203	2,380	2,357
26	**Economic Evaluation**			NPV (Annual)	-7,799	2,356	2,333	2,138	2,265	2,264	2,242	2,055	2,198	2,155
27	Social Discount Rate	2%		Private NPV	12,207									

1. Capital Cost of Machine – Biodiesel manufacturers offer a range of machines. The price in CAD can be entered in cell B2.[24] At the same time, the District can determine what amount may be covered by provincial or federal grants, and enter this percentage in cell B22. Enter an estimate of annual insurance in B3, and alter the denominator in cell B5’s formula to reflect maximum capacity of whichever machine is purchased. Note that the entry and formula for maximum capacity in no way determines NPV or IRR – it is simply to track usage.

2. Production Inputs and Costs – In cell B4, enter how much used cooking oil will be collected and processed each week. It is important to emphasize that all production inputs (methanol, catalyst, sulfuric acid, and electricity) from cells B9:B12 will follow in lockstep based on the prescribed “recipe” for biodiesel production.[25] These ratios are built into the formulas from E9:N12. For example, the

[23] This final note is important, as the District will want to incorporate expected inflation if calculating future outlays, which would typically be expressed in nominal terms (e.g., in 2026 dollars for the 2026 fiscal year).
[24] Sales taxes and any customs fees have not been included.
[25] As noted in the spreadsheet, NaOH (sodium hydroxide) has been chosen as the most cost-effective catalyst, but potash (a.k.a. potassium hydroxide) can also be used. In terms of safety, both are identical, but extreme care must

coefficient of 0.2 in B9 reflects the fact that 1 part methanol will always be used for every 5 parts UCO. While these coefficients will not change, the prices of these production inputs may fluctuate, and can be updated in cells B9:B12 to reflect current market rates.

3. Cost of UCO and Labour – The cost paid to participating establishments for used cooking oil is entered in cell B8. This number is an estimated average that masks what could potentially be a range of values paid for UCO – anywhere from zero to over a dollar per liter based on local supply and demand. The default value is zero. Meanwhile, the collection cost – or the cost in labour to take the UCO from source to machine – is expressed in relation to volume of UCO, and is entered in cell B13. As will be discussed later, these two numbers will to a large extent determine the production cost and therefore the viability of the project from a financial perspective.

4. Market Price of Diesel – The current price of B5 biodiesel used by the District is entered in cell B20, which at the time of writing was $1.47/L. Without considering capital costs, the private gain or loss from the project is simply the difference between the market price of diesel (B20) and the annual production cost of biodiesel (E18:N18), multiplied by the annual volume of biodiesel produced (E17:N17). When the market price of diesel is higher than the production cost of biodiesel, there is a private gain – equivalent to the savings from foregoing the purchase of (more expensive) diesel – and the opposite scenario yields a private loss. This gain or loss is given in E19:N19.

5. Annual Private Cash Flows and Net Present Value – Total return (E25:N25) adds glycerin sales and tax savings to the total gain/loss described above. Fixed costs (machine, insurance, and maintenance) are subtracted from this number to give the private net cash flows in cells E26:N26. These private net cash flows are all expressed in current inflation-adjusted (real) dollars, as noted, but a dollar today can be invested to yield real returns. Therefore, to discount the future into current dollars, as is conventional in any project evaluation, we must divide annual net flows by a private discount rate, given in cell B21. These discounted values are found in cells E27:N27, and cell E28 represents their sum.

6. Economic Returns and Net Present Value – All cell entries thus far describe the private returns accruing to the District of Central Saanich if it pursues this project; however, as mentioned, there are broader societal impacts that must be measured and incorporated into the full economic analysis – namely, the positive gains associated with cleaner air. The social cost of emitting one tonne of carbon or methane is equivalent to the social value of abating the same tonne. These values are expressed in E34:N34 and E36:N36 for carbon dioxide equivalent (CO_2e) and methane (CH_4), respectively.[26] Adding these benefits to private net cash flows yields the economic net benefit, which is discounted and summed in the same way as described above.

Values chosen for some of the cells described above represent assumptions that are explained below, along with other fixed values that require explanation.

---

be taken when mixing either catalyst with methanol, given the highly exothermic nature of the reaction. This process is assisted by machine settings.

[26] Carbon dioxide equivalent, or CO_2e, is a measure that compares the emissions from all GHG, such as methane and nitrous oxides, by benchmarking their global warming potential (GWP) against that of carbon. Diesel releases a range of GHG, not just carbon, but altogether its combustion produces the *equivalent* of 2.748kg of CO_2 per liter. Methane emissions are calculated separately for food waste, as it is the only GHG released in that context.

8.2 Assumptions

Depending on the parameter in question, all default values in the CBA spreadsheet tool have been chosen based on educated estimates, convention, or in some cases scientific consensus. Explanations are provided below. All values can be adjusted in the model as circumstances dictate or as academic/policy opinion evolves.

1) The volume of UCO was originally set at 300L/week based on the assumption that 30 local establishments (e.g., pubs, restaurants, schools) could contribute 10L per week.[27] Ultimately, a lower value of 160L/week was chosen because this meets the District's fuel needs, and because of the assumption that any surplus production could not be distributed, discussed further below.
2) Following the example of other municipalities described above, it is assumed that all UCO will be donated by residents and establishments. Otherwise, the cost of UCO will follow market prices, which, as a Cowichan Biodiesel Co-op (CBC) employee described, depends on the purity of the oil (yellow versus brown). Therefore, the price can change over time and across establishments. The employee was unable to disclose exactly how much they pay for UCO, but did state the cost "can be anywhere from a few cents per liter up to a dollar, depending on how much you buy and whether it's first been processed".
3) The collection cost is essentially the cost of labour – in many ways, the most difficult element in the whole project to determine. While proprietors and residents may be willing to drop off UCO at predetermined depots, to be conservative it is assumed that collection would be necessary. If it took one worker 6 hours of driving around the District biweekly to pick up UCO, and the wage rate were $39/hour, this can be rounded up to approximately $0.73/L.
4) For all chemical inputs (methanol, catalyst, sulfuric acid) and electricity, as well as for the cost of B5 diesel, the current market price has been used, rather than a long-run average.
5) A cost buffer of 2.5% has been added to total variable costs.[28]
6) Given the relatively small size of the capital investment (<$50,000) and the likelihood that the District will pursue a cost-sharing grant, it is assumed that the District will not borrow funds to finance the project. Borrowing costs are therefore zero.
7) It is assumed that all glycerin is given away or disposed of costlessly.
8) A private discount rate of 1% was chosen based on the 25-year long-term lending rate of 3% provided by the Municipal Financial Authority. Because the lending rate is nominal, and inflation is equivalent to 2% in Canada, it can be assumed that the real opportunity cost of capital is 1%.
9) A straight-line method of depreciation is applied to the physical asset over a useful life of 10 years. A tax rate of 35% is assumed (cell B23), which determines the amount of reduction in District taxes due to asset depreciation.
10) A government grant covering 50% of upfront costs is assumed. See cell B24.

[27] While collecting from North Saanich establishments (Stonehouse, Rumrunner, Dickens, Roost, etc) would not divert the District's own food waste, it nonetheless represents a source of UCO and a concomitant reduction in methane emissions.

[28] It is highly recommended that the District contact the relevant parties for updated price quotes before making any final decision, as market prices will likely have changed.

11) The social discount rate, like its private equivalent, is an attempt to calculate a present value for costs and benefits realized at future dates. Technically, it is the real rate of return that any public investment must earn in order to justify a project. Within the context of climate change, the SDR reflects current society's estimation of the harm to future generations, with a lower rate valuing the harm more greatly. In essence, it reflects a trade-off between the current cost of action to us (today), and the benefit of that action to future generations. Though it is the topic of great academic debate, a wide consensus of scientists and economists support a real SDR of 2% (Drupp et al, 2018), which has been adopted in this analysis (cell B27).[29]
12) Emissions rates for carbon dioxide equivalent (CO_2e) from diesel, and for methane (CH_4) from food waste, are both based on Canada's National Inventory Report (2020), which aligns with the CRD Inventory, EPA and other scientific estimates.
13) While the true social cost of carbon (SCC) is hotly contested, in part due to differences of opinion over the SDR, as noted above, the lower bound of $50/tonne has been chosen to align with current BC government policy, which will rise by $15 per year until 2030 (a carbon tax being the "revealed" SCC). Currently, the District pays a BC carbon tax of 11.71 cents for every liter of B5 biodiesel it purchases, an amount that will rise annually in line with the increasing carbon tax.[30]

8.3 Results

The default setting on the CBA spreadsheet assumes an average collection of 160L per week, with a collection (labour) cost of $0.73/L for labour. Costs for all other production inputs follow from the strict ratios needed to process the assumed volumes. All other assumptions are listed in columns A and B, and are described above. Over a duration of 10 years, the project has a private NPV of $12,207 and a private IRR of 25%. The economic evaluation incorporates the benefit of clean air due to reductions in carbon and methane emissions. CCM credits can be factored in if pursued in the future; for now, they are assumed to be zero. Over 10 years, the project has an economic NPV of $26,812 and an economic IRR of 50%. Table 1 summarizes private and economic calculations at several points throughout project duration, including the breakeven point, when the project returns have covered all costs to that point.

Table 1: Net Present Value Intervals and Breakeven Points (B20 Biodiesel Production Solution)

Project Length	**1 year**	**3 years**	**4.4 years**	**7 years**	**10 years**
Private NPV	-$7,799	-$3,110	0	$5,799	$12,207
Economic NPV	-$6,965	0	$4,999	$14,927	$26,813

[29] The Biden administration, meanwhile, adopted a SDR of 3% in February, part of its methodology for valuing carbon at $50/tonne. While many scientists' and economists' opinions fall in the 2-3% range, Biden's choice was at least partly a desire to reverse the previous administration's use of a 7% SDR and still stay within the bounds of what Americans would find politically realistic. A 2.5% SDR, for example, would have pushed the SCC to $62/tonne.
[30] This tax translates into around $4,100 paid in carbon taxes to the BC government each year for diesel. While the District has managed to recoup this cost for the last 10 years due to the province's conditional grant program under CARIP, which reimbursed municipalities for taxes paid on fuels used for government services, this arrangement ended on August 6, 2021.

Two critical points emerge from these results. First, while the private and economic NPV are positive, it must be stressed that this result is largely due to three variables. Two of them – cost of UCO and cost of labour – are highly uncertain and will depend on whether proprietors can be persuaded to drop off their UCO at the Public Works yard or other collection spots, and/or are willing to receive less than a competitive market price for their UCO. Donation is the norm from other municipal case studies, and is assumed here, but paying even $0.15 per liter will push the private NPV into negative territory. The third variable, market price of methanol, is currently very high due to the ongoing capacity constraints resulting from February's Texas freeze. Indeed, it is about 3x higher than biodiesel manufacturers assume in their analysis. Managing the first two costs, and letting the third return to normal levels, will help the private NPV sustain net gains year on year.

Second, it is important to emphasize that the environmental gains associated with BD production derive predominantly from the switch away from fossil fuels, and not from diverted food waste. In other words, the environmental benefit from not burning 1L of diesel is far greater than the benefit of keeping 1kg of food waste out of landfills.[31] Of course, any true circular solution will aim to tackle both, but this comparison illustrates the reality presented in the economic evaluation of the model, specifically E34-N34 and E36-N36: abatement from fuel substitution, not waste diversion, is primarily responsible for environmental gains. In this case, the District may wish to consider the benefit of simply purchasing B20 biodiesel outright from nearby CBC. This scenario is considered in the "Alternative Solutions" section below.

8.4 Sensitivity Analysis

Sensitivity analysis assesses how the change in a particular variable affects the overall NPV. A variable can be sensitive for two reasons: there is either a large confidence interval around the value owing to uncertainty in estimation, or because small changes in that variable translate to large changes in NPV (even when the variable can be estimated with a high degree of confidence). When both considerations are present, a single variable can swing the overall NPV and IRR between adoption and non-adoption. The "BD Sensitivity" tab in the CBA spreadsheet interacts two variables at a time to show how changes in values affect overall NPV. The most sensitive variables in this analysis include the market price of diesel, cost of UCO or labour (and, correspondingly, combined cost of UCO and labour), market price of methanol, and the social cost of carbon.

A summary is given by stating the change in NPV for every incremental change in one of the sensitive variables (holding all other variables constant). The relationship is either positive or inverse; in other words, a rise in a particular variable will translate into either a rise or fall in NPV. All NPV values are private – that is, they express changes to the District's bottom line – except for the last, the social cost of carbon, where change in economic NPV is expressed.

---

[31] As a thought experiment, imagine that 5,000 mt of organic waste is produced annually in Central Saanich (likely a high estimate) and that this amount simply disappeared or was repurposed before any methane could be generated. 5,000 mt produces about 5 mt of methane, or 125 mt of carbon based on a global warming potential (GWP) of 25. While encouraging, this is only 3 times the amount that would be saved by simply substituting 300L per week of diesel for biodiesel.

Table 2: Sensitivity of Net Present Value to Incremental Increases in Select Variables

Variable	Δ Value	Δ NPV
Market price of diesel	$0.10	$7,653
Cost of UCO or collection cost	$0.10	–$7,844
Combined cost (UCO + collection)	$0.10	–$7,844
Market price of methanol	$0.10	–$1,569
Social cost of carbon	$50.00	$7,637

It was deemed unnecessary to interact the collection volume with any other variables. The price differential between diesel purchased externally and biodiesel produced internally represents the District's profit per unit. If positive, greater volumes will increase total profit and, if negative, will decrease total profit, so volume simply serves to amplify the loss or gain. If volume has any effect on profit per unit then it is through the mechanism of collection cost, as economies of scale may exist when volumes increase (in other words, the average cost of collecting 1L falls). Therefore, the proper variable for sensitivity analysis is the collection cost or, as has been done in some tables, the combined cost of UCO and collection.[32]

The market price of diesel and the cost of either UCO or collection are the most sensitive variables. In the last 10 years, according to StatsCan data, the price of diesel in Victoria has fluctuated from $0.92 to $1.42 per liter, in one instance moving $0.44/L in only 6 months (November 2019 – May 2020). Typically, however, it will fluctuate within a band of around $0.25.[33] By contrast, the cost of UCO and especially collection are not as firmly tied to market forces to the extent that the District can induce participants to donate their UCO (a default assumption in this analysis) and/or drop it off at select locations.[34] As shown, a reduction in the cost of either will have an identical impact on NPV. Given the large band of uncertainty around collection costs – unlike UCO, for which a market exists – and its impact on NPV, it remains the most sensitive variable in the analysis.

The current biodiesel equipment was chosen based on the District's fuel needs. Different machines are available, with faster processing speeds and higher volume capacities being more expensive. The table listing the impact of the machine's cost on NPV is provided in the relevant tab; as one can see, this fixed cost is not very sensitive compared to the numerous variable costs described above. Finally, the social cost of carbon can be considered sensitive; however, if default values are to remain aligned with government policy, will take four years before a carbon tax of $100/tonne is instituted. Meanwhile, as mentioned above, any changes to NPV will not impact the District's private returns, which may make the project unsustainable despite solid environmental benefits. That said, as key carbon reduction targets approach in the coming 25 years, federal and/or provincial policies may alter the NPV calculus by

---

[32] Besides the reason outlined here, it should be repeated that collection volume was also held constant due to the underlying assumption that the District is interested only in collecting as much used oil as they would need to run their fleet, or 160 liters per week. Sale and distribution of any surplus product would entail additional regulations.
[33] The nominal market price of diesel in Victoria has swung from $1.00/L to upwards of $1.40/L during every 5-year period from 2005 to present. With a 5-year (2016-21) average in Victoria of $1.23/L masking great fluctuations, it is impossible to discern any long-run trends in the market price of diesel to incorporate within the spreadsheet.
[34] A determination of cross-price elasticity for diesel and UCO is beyond the scope of this project, and is therefore ignored in the analysis; however, it remains plausible that any gains from rising diesel prices will be partially erased by a concomitant rise in UCO prices, given their nature as substitutes.

changing the revealed social cost of carbon. Given the direction of current policy, any changes would only raise the economic NPV.

8.5 Caveats and Considerations

The project's current private and economic NPV are positive under the assumed default values, but the results are fragile due to the number of sensitive variables, as described above, and the nature of the variables. Some are highly volatile – such as the price of diesel and methanol – and all but guaranteed to make large swings over a 10- to 15-year time span that will make revenue streams positive in some years and negative in others. The inherent limitation is that key details and assumptions are fixed for the entire duration of the project and, unfortunately, setting different values for each year based on the expected value of certain variables is an exercise in forecasting that would likely do nothing more than introduce even greater uncertainty into the analysis. Experimenting with different values (even though these values will be set for project duration) will help District staff determine the interaction effect of all parameters, in order to help make an informed decision.

Even still, there are challenges not captured by numbers that deserve discussion. These include collection, glycerin disposal, and surplus production. First, the challenge of collection goes beyond a precise estimation of cost. It involves coordination, logistics and community engagement to be successful, and controlling this cost will be pivotal to any long-term operation. While UCO itself will to a large extent reflect market conditions, the execution of collection services will be shaped by constraints on municipal employees' time and by community engagement and participation. The Daphne and Alachua case studies illustrated that collection costs can be driven to (close to) zero when a public-spirited campaign motivates residents and proprietors to contribute to a larger effort – in this case, by depositing UCO *for free* at select locations in pre-made collection bottles that can be exchanged for clean ones. Realizing this scenario involves an upfront effort by the District to liaise actively with stakeholders and encourage them to drop off their oil. As a CBC employee said of their operation, "collection is a big hurdle, and it comes with customer service". Therefore, challenges may arise where proprietors wish to sell their UCO and/or prefer to have their UCO collected at their site, adding not just to costs but to overall coordination efforts and payment tracking that may divert time and energy away from Public Works employees. Like the cost of UCO itself, collection cost is a highly sensitive variable, and may be controlled through smart logistics and community engagement.

Second, Springboard employees and multiple biodiesel case studies emphasized that any organization producing biodiesel needs to have an active strategy for how to deal with the large volumes of glycerin by-product (cells E20:N20). For every 5L of biodiesel produced, 1L of glycerin will also be produced. Glycerin has some uses – such as for soapmaking or as livestock feed – or can be disposed of in a sewage treatment plant. Given the prevalence and importance of agriculture within Central Saanich, where around two-thirds of all land is zoned as A-1 and forms part of the ALR, glycerin by-product presents a potentially unique and useful opportunity. The District could sell it to local livestock farms, or offer it to them (or artisan soap makers) for free as a friendly gesture or form of community engagement. Either way, the important point is that an active plan is necessary before embarking on any project.

Finally, surplus production may present an intractable challenge. If production is greater than District demand, which is assumed to stay roughly constant, then the only three options are to distribute to outsiders, use a higher blend, or dump the excess product. Unfortunately, while surplus product can hypothetically be sold at market rates, distribution entails blending and testing to ensure the product meets ASTM D6751 standards for sale to the general public. Instead, the District may choose to use a higher blend, such as B50. The City of Toronto, for example, is cited in the BC Climate Action Toolkit as reporting "positive results from some early testing of B50 biodiesel". While case studies and testimonials revealed that many individuals have no issue with using higher blends, such usage may void the vehicle manufacturers' warranties, a risk that the District may not wish to take. Most manufacturers' will support only up to B20.[35] For these reasons, it is assumed that the District would source only as much UCO as needed to fuel its fleet with B20 – approximately 160L/week. A quick snapshot of the private and economic NPV of using B40 is presented in Table 2 below, which would entail collection of 320L/week.

Table 3: Net Present Value Intervals and Breakeven Points (B40 Biodiesel Production Solution)

Project Length	1.6 years	2.3 years	5 years	7 years	10 years
Private NPV	-$3,209	0	$11,059	$19,337	$31,264
Economic NPV	0	$5,244	$24,769	$40,835	$65,767

At the same time, there are benefits not captured by the numbers that are equally important to consider. A positive externality cited by all three biodiesel case studies was the steep reduction in sewer maintenance and repair costs due to diverted FOG, which at least one coordinator cited as far greater than any costs associated with collection. Of equal importance, the project is an example of circular economy that uses local resources to create a closed loop by converting one waste product into something of value. This smart usage and conservation or resources has clear financial and environmental benefits. Lastly, the model's circularity and positive impact on local sewer systems may act as an example to other municipalities of an initiative that can engage community members in a common purpose on a small scale.

8.6 Alternative solutions and future directions

Finally, there are two alternative solutions (subsidizing at-home composters and switching to B20) as well as two future directions (an equipment rental and a local partnership). These scenarios are not mutually exclusive.

Countertop Composters

Retailing at around $500 each, at-home countertop composters are easy-to-use appliances designed to allow consumers to produce soil amendments from their household organic waste.[36] Subsidizing these composters for District residents represents a wholesale shift away from biofuel production, toward

[35] A full list of manufacturers' positions can be found here: https://www.biodiesel.org/docs/default-source/fact-sheets/oem-support-summary.pdf?sfvrsn=4e0b4862_12

[36] Aside from candy, cooking oil, and beef and pork bones, the composters can handle virtually all organic waste.

investment intended to divert food waste away from Hartland Landfill, lowering methane production and saving the District collection costs in the process. Simple calculations are provided in the "Composter Alternative" tab of the spreadsheet. The 10-year CBA analyzes the NPV of investing in at-home composters in order to reduce the District's collection costs. This is similar to the pilot program trialed in Nelson, BC, as described in the literature review. Private costs are primarily the subsidy, along with some minor costs associated with marketing and administration, while economic costs include the co-pay by residents. Private benefits are the reduction in collection costs due to the diversion of organic waste, while public benefits include the savings from making at-home compost, a reduction in property tax bills (which are assumed here to be zero), and the reduction in methane emissions due to organic waste diversion.

The cost-benefit analysis is straightforward. The retail price of a FoodCycler is given in cell B2. The District can choose its subsidy in B3; the default value of $125 is based on the Nelson case study. With approximately 18,089 residents in Central Saanich, it is assumed that there are 6,890 households (cell B4), as per the District's 2021 Financial Plan. Cell B5 expresses the average collection cost per household. The default value of $230 is based on City of Victoria data, which the Manager of Sustainability and Asset Management said would be very similar to costs in Saanich and Oak Bay, both of which currently offer residential collection. The majority of costs, however, are fixed and will not vary based on tonnage. Altogether, fixed costs such as administration, labour and equipment represent about 75% of the per household cost, with the remaining 25% being the variable cost that will fluctuate with tonnage, as expressed in B6. If residents convert food waste to compost, only the organic fraction of all waste (about 28.6%) will change, as expressed in B7. The savings to the District, therefore, is equal to the change in variable costs that result from collecting a lower volume of kitchen scraps.

The economic NPV incorporates gains to residents and the environment. While residents' initial cash flow is negative due to the co-pay, they eventually realize a net gain after just less than 3 years by saving on compost. (It is highly unlikely that all households would have spent $150 on compost per year, so this number can be adjusted by changing the value of compost in B11 to better reflect real preferences for compost.) The net gain to all District residents is simply the gain per household multiplied by the number of households. To this is added the benefit of cleaner air, calculated by taking the methane abated (E17:I17) and multiplying it by the social cost of methane. As noted in the spreadsheet, there are two major assumptions at play: 1) kitchen scraps would not have otherwise been composted in the household's backyard – all scraps would have been destined for Hartland to generate methane, and 2) the value of this compost to each household is equivalent to its market cost.

Table 4: Net Present Value Intervals and Breakeven Points (Countertop Composter Solution)

Project Length	**1 year**	**2.9 years**	**5 years**	**7.9 years**	**10 years**
Private NPV	-$748,057	-$536,119	-$306,383	0	$221,555
Economic NPV	-$2,123,043	0	$2,254,730	$5,217,763	$7,261,140

B20 wholesale purchase

A second solution is to switch to purchasing B20 biodiesel from CBC. As explained above, the environmental gains from the biodiesel project are primarily the result of using B20 instead of conventional diesel. The clean air benefits from keeping UCO out of landfills is minimal. In this case, a simple solution is to switch fuels. Currently, the District pays $1.47/L for B5, and the cost of B20 from CBC is $1.40/L, as noted on their website, so there will already be financial savings realized from the switch. The tab labeled “BD Alternative” calculates the private and economic gains over 10 years from such a switch. It is assumed that there is no cost to switching.[37] Though simplistic, the numbers demonstrate that unless the average cost of producing biodiesel in-house is appreciably lower than $1.40/L, the District may wish to forego the effort of investment, planning and rallying community participation to produce an identical product; however, in this approach, the District also foregoes the opportunity to create a local circular economy, divert waste from landfill (a key action of the CLP), and involve more community members in local waste-to-energy programs. The main tab shows the projected production cost per L as $1.22 (see cell E18:N18) but, as emphasized, this cost is likely to swing greatly depending on several key cost variables. By contrast, whether produced in-house or purchased externally, the positive impact on the District’s carbon footprint of switching to B20 will be identical.[38]

Table 5: Net Present Value Intervals and Breakeven Points (B20 Biodiesel Purchase Solution)

Project Length	**1 year**	**3 years**	**5 years**	**7 years**	**10 years**
Private NPV	$2,800	$8,317	$13,726	$19,027	$26,785
Economic NPV	$3,624	$11,229	$19,215	$27,481	$40,045

Other Directions

A possible future direction that is not analyzed in technical detail here is for the District to rent a BioCube and/or partner with a local entrepreneur who currently uses a BioCube and is eager to expand capacity. BioCube is an Australian company with a manufacturing base in BC that produces “cubes” – about the size of a shipping container – that house all equipment for producing biodiesel. It was not chosen for this analysis because, even though its flow rate of 250L/hour is considered “small” within the industry, its capacity is still well beyond what the District would need and would also require a full-time operator, thus adding to labour costs.

[37] A costless switch explains why the table below has no breakeven points: there is no initial investment, and so no point at which costs are recouped. The assumption of costlessness also implies that this solution can be pursued alongside other solutions that may require investment, like subsidizing countertop composters.

[38] It should be noted that, if CBC is at or near capacity, there is the potential for total carbon reduction to be less than a simple switch would imply. If the District’s actions raise the price and push marginal buyers away from biodiesel, then the District’s carbon footprint will fall while society’s will rise. Quantifying the probability or extent of this “leakage” is beyond the scope of this project, and depends upon the District’s power to move market prices.

The owner and founder, Laurence Baum, has offered to rent the equipment to the District of Central Saanich on a minimum lease contract of 3 years.[39] Again, because the District is unlikely to collect any volume close to the amount needed to fully utilize the equipment, a preferable scenario – one that Mr. Baum in fact mentioned – is to partner with Brian Roberts, the owner and founder of Ergo Eco Solutions, which supplies the CBC with their biodiesel. By email and in phone conversations, Mr. Roberts has stated he is looking to expand capacity and needs a location for another BioCube unit. The exact details of any arrangement could take multiple forms, but a partnership would essentially aim to share capacity and therefore costs.

9. Conclusion

As the global population approaches 8 billion and food production per capita remains at historically record highs, governments at all levels will be forced to wrestle with organic waste management, an issue that touches on food security, land usage and climate change. Meanwhile, greenhouse gas emissions from the use of fossil fuels in transportation continue to contribute to climate change, despite progress in federal and international policy and the growing popularity of EV and hybrid cars. For both of these intractable issues, broad social behavioural changes will continue to be part of any long-term solution, nudged by federal policy and supported by local government, but technological ingenuity will provide a supporting role by continuing to imagine new ways to convert waste into energy. Specifically, the ability to convert organic waste into biofuels is a prime example of circular economy able to address these two pressing issues at the same time.

The waste-to-energy industry has demonstrated remarkable growth over the past several decades, aided by growing public consciousness, federal initiatives, and an influx of private capital to fund innovation and underwrite large investments. Meanwhile, local governments have, even without the latest technology, shown awareness and commitment to educating their residents, implementing organics separation to keep waste out of landfills, and reconfiguring townscapes to promote alternative modes of transportation. To synergize the efforts of these two primary stakeholders, however, many issues continue to stand in the way: the logistics and economics of waste collection, the enormous start-up costs of some technologies, a strategy for utilizing by-products, and consumer education around sorting and contamination. These roadblocks will be all the more difficult to address for small municipalities, where scale can easily make upfront capital investment costs prohibitive. But more than half of Canadians live in small municipalities (Statistics Canada, 2017), and unless they are able to join larger regional efforts, then food waste – and, with it, landfill space and climate change – will continue to present tough trade-offs to the full implementation of a circular economy model.

---

[39] Details were discussed over Zoom on June 28. As is a common public-private arrangement, Mr. Baum offered to provide the capital in return for revenue derived from operating revenues. In other words, the District would pay for their rental through the sales of biodiesel. Whatever the arrangement, his primary goal is to cover his costs, which would be approximately USD $5400/month (USD $325,000 spread over 60 months). There could be a written option to buy BioCube out of the long-term lease and any point should the District wish to own the equipment outright. There would be no duties except for GST.

To the extent that food waste concerns are borne of climate change concerns, biodiesel represents a tangible solution for smaller municipalities to save money, support a cleaner environment, and showcase the circular economy in practice to its residents and to other municipalities. Though biodiesel uses only a fraction of all food waste (specifically, used oils), its substitution for conventional diesel has large environmental impacts that make it a more efficient way to mitigate global warming than landfill diversion alone. Moreover, biodiesel is the only liquid fuel that can be produced on a small scale. With the growth of the biodiesel industry over the past three decades, and rising interest in small-scale applications by various institutions like universities and small businesses, processing equipment has improved to the point that everyday consumers can safely and easily engage in micro-production.

This analysis has aimed to demonstrate the case for biodiesel production within the District of Central Saanich, and the conditions under which such a project would yield private returns to the municipal government and broader returns to society. Though the District is small, its various establishments theoretically contain enough used cooking oil to produce 160L of pure biodiesel per week, which, when blended as B20, would sufficiently meet the needs of its various departments. At the same time, low population density and an established competitive market for used oil in the region will require smart collection strategy and community outreach to control costs. If the Department of Public Works can integrate collection into their regular routine, and if local residents can be inspired to contribute to a larger effort – one that promotes waste diversion from landfills, clean sewers and cleaner air – then the project may act as a sustainable example within Canada of how local communities can independently contribute to broader climate change efforts. Meanwhile, even secondary alternatives offer Central Saanich the opportunity to reduce its carbon footprint, in pursuit of reaching its 2050 GHG reduction goals.

Political decisions must invariably take into account considerations that extend well beyond numbers. Ultimately, the decision must fit within a framework that balances the culture of Central Saanich – its "way of doing things" – with its own stated goals, some of which might require nudges away from the usual "way of doing things". These political calculations go beyond the scope of this report to account for the probability and magnitude of risk, an important complement to any quantitative model. When such intangibles are discussed and weighed, it is hoped that the District can also consider carefully the risk of inaction, not just for the perceived misalignment of its goals with any efforts, but for the missed chance to guide residents toward a slightly different way of living. Conversely, aside from any private returns, the District has an opportunity to model the way for its own residents of what conservation looks like in practice, and to offer lessons to similar municipalities looking for ways to marry progressive goals with bold action.

10. References

Alibardi, L., Astrup, T. F., Asunis, F., Clarke, W. P., De Gioannis, G., Dessì, P., ... & Spiga, D. (2020). Organic waste biorefineries: looking towards implementation. *Waste Management*, *114*, 274-286.

Alternative Fuels Data Center. (n.d.). *Renewable Hydrocarbon Biofuels*. https://afdc.energy.gov/fuels/emerging_hydrocarbon.html.

Álvarez, P., Burken, J. G., Coan, J. D., De Oliveira, M. E., Dominguez-Faus, R., Gomez, D. E., et al. (2010). *Fundamentals of a Sustainable US Biofuels Policy*. Houston, TX: James A. Baker III Institute for Public Policy, Rice University Civil and Environmental Engineering. 134.

Barik, S., Paul, K. K., & Priyadarshi, D. (2018, June). Utilization of kitchen food waste for biodiesel production. In *IOP Conference Series: Earth and Environmental Science* (Vol. 167, No. 1, p. 012036). IOP Publishing.

Biodiesel Basics. (n.d.). Biodiesel.org. http://www.biodiesel.org/what-is-biodiesel/biodiesel-basics.

Biomass Explained. U.S. Energy Information Administration. (8 June 2021). https://www.eia.gov/energyexplained/biomass/.

Biodiesel Magazine. (2015, September 25). *CARB affirms biodiesel as lowest carbon fuel in revised LCFS*. The National Biodiesel Board. http://www.biodieselmagazine.com/articles/534034/carb-affirms-biodiesel-as-lowest-carbon-fuel-in-revised-lcfs.

Capital Regional District. (2021, March 31). *CRD Solid Waste Management Plan*. MWA Environmental Consultants Ltd. Retrieved from https://www.crd.bc.ca/service/waste-recycling/solid-waste-management.

City of Surrey. (2021, April 16). *Biofuel Products*. https://www.surrey.ca/services-payments/waste-collection/surrey-biofuel-facility/biofuel-products.

Church, M. (2020, May 22). *Garbage gold: Sustane converts curbside waste into high-value biomass products*. Canadian Biomass Magazine. https://www.canadianbiomassmagazine.ca/garbage-gold-sustane-converts-curbside-waste-into-high-value-biomass-products/.

City of Toronto. (2021, April 29). *Turning Waste into Renewable Natural Gas*. City of Toronto. https://www.toronto.ca/services-payments/recycling-organics-garbage/solid-waste-facilities/renewable-natural-gas/.

Cools, E. (2020, May 26). *Toronto organics processing facility to convert food waste to RNG*. Canadian Biomass Magazine. https://www.canadianbiomassmagazine.ca/toronto-organics-processing-facility-to-convert-food-waste-to-rng/.

Dahlgren, S. (2020). Biogas-based fuels as renewable energy in the transport sector: an overview of the potential of using CBG, LBG and other vehicle fuels produced from biogas. *Biofuels*, 1-13.

District of Central Saanich. (2021, July 13). *Financial Plan 2021*. https://www.centralsaanich.ca/municipal-hall/resource-library/financial-plan-2021.

District of Central Saanich. (2021, March 19). *Climate Leadership Plan (2020)*. https://www.centralsaanich.ca/municipal-hall/resource-library/climate-leadership-plan-2020.

Drupp, M. A., Freeman, M. C., Groom, B., & Nesje, F. (2018). Discounting disentangled. *American Economic Journal: Economic Policy*, *10*(4), 109-34.

Ellen MacArthur Foundation. (2017, June 21). *Urban Biocycles*. https://www.ellenmacarthurfoundation.org/assets/downloads/Urban-Biocycles_EllenMacArthurFoundation_21-06-2017.pdf

Engineers for a Sustainable World UBC. (2013). *Biodiesel Project: Transesterification* [Image]. http://blogs.ubc.ca/sustainabilityclub/biodiesel-project/.

Environmental Protection Agency. (2019, June 14). *Zero Waste Case Study: San Francisco*. EPA. https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-francisco.

Environmental Protection Agency. (2020, July 27). *Basic Information about Anaerobic Digestion (AD)*. EPA. https://www.epa.gov/anaerobic-digestion/basic-information-about-anaerobic-digestion-ad.

European Commission. (n.d.). *Circular Economy Action Plan*. Environment. https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en.

European Commission: Environment. (2014, March 5). *Oslo introduces buses powered by a by-product of food waste*. European Green Capital. https://ec.europa.eu/environment/europeangreencapital/oslo-buses-powered-by-food-waste/.

EverGen Infrastructure Corp. (2021). *Renewable Natural Gas Capture* [Image]. Retrieved from https://www.evergeninfra.com.

The Finnish Innovation Fund Sitra. (2019, November 18). *Biogas from food waste, Oslo*. Sitra. https://www.sitra.fi/en/cases/biogas-from-food-waste-oslo/.

Folk, E. (2018, August 10). *Europe Converting Waste to Biogas for Biofuel*. Renewable Energy Magazine. https://www.renewableenergymagazine.com/emily-folk/europe-converting-waste-to-biogas-for-biofuel-20180810.

Giavini, M., & Favoino, E. (2020). Bio-Waste Generation in the EU: Current Capture Levels and Future Potential. *Bio-Based Industries Consortium (BIC): Brussels, Belgium*.

Gore. (2021). *GORE® cover for organic waste treatment* [Image]. https://www.gore.com/products/gore-cover-for-organic-waste-treatment.

Government of Canada, Statistics Canada (2019, April 3). *Census in Brief: municipalities in Canada with the largest and fastest-growing populations between 2011 and 2016.* Retrieved from:

https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016001/98-200-x2016001-eng.cfm.

Government of Sweden. (2021, June 1). *The Swedish recycling revolution*. sweden.se. https://sweden.se/climate/sustainability/recycling-and-beyond.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). Global Food Losses and Food Waste-FAO Report. *Food and Agriculture Organization (FAO) of the United Nations*, 1-37.

Hancock, John. "Future Fuel: Meet The Company Turning Food Waste Into Power." *Forbes*, Forbes Magazine, 27 Mar. 2018, www.forbes.com/sites/johnhancock/2016/10/13/future-fuel-meet-the-company-turning-food-waste-into-power/?sh=1f78932321ed.

Hayman, A. (2021, March 11). *Webinar Presents FoodCycler Municipal Solutions to BC Municipalities*. FoodCycler. https://www.foodcycler.com/post/webinar-presents-foodcycler-municipal-solutions-to-bc-municipalities.

IMF (2008a). *World Economic Outlook*. Washington, DC. April.

Kutney, Gerald. (2017, July 4). *Celebrating Canada's 150th: A Short History of the Biofuel Industry in Canada*. Biofuels Digest. https://www.biofuelsdigest.com/bdigest/2017/07/04/celebrating-canadas-150th-a-short-history-of-the-biofuel-industry-in-canada/

Lam, N. A. (2020, September 18). *Municipal waste management in Sweden*. Swedish Environmental Protection Agency. https://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Work-areas/Waste/Municipal-waste-management/.

Lauzon, R. (2017, May 1). *Canadian City Ready to Launch AD and Composting Facility* [Image]. BioCycle. https://www.biocycle.net/canadian-city-ready-launch-ad-composting-facility/.

Lilwall, S. (2020, July 30). *Trash is biofuel treasure; Enerkem uses Alberta as a launching pad for expansion*. Alberta Innovates. https://albertainnovates.ca/impact/newsroom/trash-is-biofuel-treasure/.

Malmir, T., Ranjbar, S., & Eicker, U. (2020). Improving Municipal Solid Waste Management Strategies of Montréal (Canada) Using Life Cycle Assessment and Optimization of Technology Options. *Energies*, *13*(21), 5701.

Mayer, F., Bhandari, R., & Gäth, S. (2019). Critical review on life cycle assessment of conventional and innovative waste-to-energy technologies. *Science of the Total Environment*, *672*, 708-721.

McHanon, J. (2018, June 5). *Dry Anaerobic Digestion*. Kompogas Organic Recycling Plant. https://www.sanluisgarbage.com/organics/dry-anaerobic-digestion/.

Media Release. "Love Food Hate Waste." *Metro Vancouver*, 7 May 2015, www.metrovancouver.org/media-room/media-releases/solid-waste/394/Love%20Food%20Hate%20Waste.

Messenger, B. (2018, June 1). *Closing the Loop on Organic Waste in British Columbia*. Waste Management World. https://waste-management-world.com/a/in-depth-closing-the-loop-on-organic-waste-in-british-columbia.

Mihai, F., & Taherzadeh, M. (2017). Rural waste management issues at global level (Introductory chapter). *Mihai FC. and Taherzadeh M J*, 1-10.

Mitchell D (2008). *A Note on Rising Food Prices*. Policy Research Working Paper 4682. World Bank, Washington, DC.

Mittal, A. (2009). *The 2008 food price crisis: rethinking food security policies* (pp. 1-40). UN.

Mugica, Y., & Rose, T. (2019, February). *Tackling Food Waste in Cities: A Policy and Program Toolkit*. Natural Resources Defense Coucil. https://www.nrdc.org/sites/default/files/food-waste-cities-policy-toolkit-report.pdf.

National Zero Waste Council. (2018, May). *A Food Loss and Waste Strategy for Canada*. NZWC.

Net Zero Waste Abbotsford. (n.d.). http://www.netzerowasteabbotsford.com/.

Nunez, Christina. "Biofuels, from Ethanol to Biodiesel, Facts and Information." *Environment*, National Geographic, 15 July 2019, nationalgeographic.com/environment/article/biofuel.

Recycle Track Systems. (2020). *Windrow Composting* [Image]. Retrieved from: https://www.rts.com/blog/what-is-commercial-composting-and-how-can-cities-manage-organic-waste.

Reisch, M. S. (2019, October 27). *The race is on to repurpose garbage*. C&EN. https://cen.acs.org/business/biobased-chemicals/race-repurpose-garbage/97/i42.

Region of Durham. *Mixed Waste Pre-sort and Anaerobic Digestion Facility*. https://www.durham.ca/en/living-here/anaerobic-digestion.aspx.

Staff, Budget Dumpster. "5 Companies Turning Trash into Fuel." *The Fill*, Budget Dumpster, 9 Jan. 2019, www.budgetdumpster.com/blog/5-companies-turning-trash-fuel/.

Toussaint, K. (2021, June 2). *This Styrofoam-like packaging is made of popcorn-not plastic*. Fast Company. https://www.fastcompany.com/90641461/this-styofoam-like-packaging-is-made-of-popcorn-not-plastic.

Treacy, M. (2018, October 11). *New Technology Quickly Turns Food Waste Into Fuel*. Treehugger. https://www.treehugger.com/new-technology-quickly-turns-food-waste-fuel-4858129.

United Nations Environment Programme (2021, March 4). *Food Waste Index Report 2021*. Nairobi.

United States Environment Protection Agency. (2021). *Food Recovery Hierarchy* [Image]. Retrieved from https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy.

van der Werf, P., & Cant, M. (2006, December 1). *State of Composting in Canada - Part 2*. Waste & Recycling. https://www.wasterecyclingmag.ca/feature/state-of-composting-in-canada-part-2/.

Wise, T. A., & Murphy, S. (2012). *Resolving the food crisis: assessing global policy reforms since 2007*. Global Development and Environment Institute (GDAI).