POTENTIAL USES FOR WASTE VEGETABLE OIL

PREPARED FOR
ISLAND FUTURES
(GABRIOLA ISLAND)

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INTRODUCTION

Island Futures (Gabriola Island) has a source of waste vegetable oil (WVO) which was previously used to make biodiesel for the local bus operation (GERTIE). The previous bus fleet based on Sprinter minibuses could run on biodiesel, but the replacement fleet (GM) produces black smoke when fueled with the locally produced biodiesel. Island Futures is now looking for alternative use for the WVO which is local, environmentally responsible and affordable. This document explores a number of ways in which WVO has been used by others, and provides a cursory discussion of costs associated with that use.

The approach with the lowest processing is to simply have the WVO (yellow grease) removed by a renderer. Typically, restaurants pay to have their WVO removed. Rendered used oil is typically turned into feed for livestock. This report looks into higher value outcomes while keeping additional inputs low.

The research work was conducted in two main cycles. The work in the second round was guided by the client based on the work in the first pass.

FILTERED WVO

Re-use for Cooking

Cooking oil degrades with exposure to air, heating and particularly over-heating. Storing used oil for long periods can lead to the oil going rancid, and consuming rancid oil is a health risk. There is a fair bit of material about storing of used cooking oil for subsequent use. Most of that information is superficial and blurs the line between household cooking oil use and commercial (restaurant, industrial food processing).

Cooking oil which has been used once or possibly twice, has not been overheated and has been properly stored is likely fine for re-use. That's typical of household use, but not commercial or industrial use. But cleaning the used oil is important – before storing. Storage should be limited to a couple of weeks maximum in a cool, dark place (e.g. refrigerator) in an air-tight container with as little air present as possible.

Conventionally, cleaning the oil consists of warming the oil (not hot for safe handling) to help release water, and then filtering through a mesh (e.g. cheesecloth). This article provides a reasonable treatment of the topic.
Can You Reuse Frying Oil?
https://www.epicurious.com/expert-advice/you-can-reuse-frying-oil-article

Some choose to add a flocculent to the process to enhance the removal of small solids.
The Easiest Way to Clean and Reuse Frying Oil
https://www.cooksillustrated.com/how_tos/11549-the-easiest-way-to-clean-and-reuse-frying-oil

This article provides an alternate approach, which (briefly) is use gelatin as a flocculent to bind and settle out particles in used cooking oil, leaving cleaner oil to be poured off for re-use. .
A Mind-Blowing Technique for Cleaning Deep-Fry Oil Using Gelatin | The Food Lab
https://www.seriouseats.com/clean-cooking-oil-with-gelatin-technique

The restaurant industry has long established practices on how long to use cooking oil to obtain maximum value from it (typically 10 to 20 hours of cooking time, and no more than a couple of days in fryers). When a restaurant is finished with cooking oil, it is finished for cooking use. The smoking point of cooking oil decreases with the time it is hot and heating cycles, and it undergoes chemical changes. At some point, the oil is considered 'broken'. The standard for McDonalds restaurants is to change the oil daily. They are experts on squeezing resources to the limits to increase profit. (They use their waste cooking oil as a resource, turning it into biodiesel to power their trucks,) Lighter 'neutral' oils like canola, soy and sunflower degrade faster than oils with more saturated fats like olive and palm. There are health concerns related to using vegetable

oil which is heated (used) repeatedly, e.g.
Evaluation of the deleterious health effects of consumption of repeatedly heated vegetable oil
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5616019/

This article speaks to the FFA test (they say 6%, whereas 5% was the old rule of thumb I was taught) to determine when cooking oil has done its time in the deep fryer. In my opinion, when used oil reaches this state, it should not be processed for re-use for cooking; it's time to get fresh oil for cooking and use the WVO for something else.
When to Change Deep Frying Oil
https://hygienefoodsafety.org/when-to-change-deep-frying-oil/

There used to be a practice of 'defoaming' used cooking oil and mixing it with fresh oil for sale for cooking use. As best I can tell, this practice has been abandoned in North America, at least publicly.

Transportation

It has long been known that Diesel cycle engines can run on vegetable oil. It has been widely and incorrectly reported that Rudolf Diesel used peanut oil to demonstrate his engine in 1900 at the World Exhibition in Paris, France. He wasn't there. Still, in other reports, it is clear that diesel engines have run on vegetable oil. Due to the high cetane and low octane values of vegetable oil, the oil can power a compression ignition engine, but not a spark ignition engine. However, it is necessary that the engine and vegetable oil both be warmed to ensure flow through the fuel lines, fuel pump and injectors. Those temperatures are not typical of ambient conditions in Canada. Therefore, two approaches are generally employed to allow use of WVO in diesel engines here: blending the WVO with diesel, kerosene or biodiesel; or, running a two-tank system with WVO in the main tank and diesel or biodiesel in the start/stop fuel tank.

There are no ASTM or parallel standards for WVO quality. It is typically categorized as food or municipal waste. This makes it difficult to get approval from engine manufacturers to use a waste product with high variability in characteristics in their engines. In turn, that makes it harder to convince possible users to try the WVO in valuable equipment.

Blended WVO

Tickell reports that it is feasible to run a mix of WVO and commercial diesel fuel successfully in diesel engines. Mixes of up to 80% WVO have been used in warm ambient conditions, while 50% or less WVO operate in colder climates (e.g. winter on

the southern BC coast). Local reports indicate a 50-50 mix does not work on cold Ottawa winter days.

Two-tank diesel engine systems

Given the issue with burning WVO in diesel engines is the oil is not warm enough to flow when cold, people have devised a solution where the engine is started and warmed up using petro-diesel or biodiesel, then the fuel supply is switched to a second tank of WVO. This set-up requires that the WVO tank and fuel lines both have a heater, usually warmed with waste heat from the engine. It is also advised that a couple of thermostats reporting the temperature of the fuel line and the WVO tank to the operator so they will know when it is safe to switch to operating from the WVO tank. Finally, it is necessary to switch back to the petro-diesel / biodiesel tank for 5 minutes of operation before shutting off the engine. This ensures the fuel line and engine are clear of WVO before the engine cools down after shut-off. These additional parts and operating steps make this approach inappropriate for short engine run times, or where the operator finds the extra steps and need for 2 filling stops too bothersome.

A friend of mine had an Elsbett 2-tank system fitted to his VW with TDI engine some years ago. This cost about Cdn$7,000, using a licenced mechanic prepared to warranty their work. His conclusion was that in 8 years of driving before the vehicle no longer met family needs, it did not come close to breaking even financially.

This system is still available today. Cdn$2,130 does not include the second tank, additional fuel lines, shipping (from Europe), installation or taxes.
https://www.elsbett.com/epages/63102114.sf/en_CA/?ObjectPath=/Shops/63102114/Products/481009M2/SubProducts/481009M2-0004

Space Heating

Many experiments over the years have demonstrated that straight WVO cannot be used directly in a conventional furnace designed for heating oil (very similar to kerosene or diesel fuel). There have been anecdotal reports of success with blending of WVO and biodiesel with petro heating oil, ranging from 2% to 20% WVO or even higher with water-washed ASTM-compliant biodiesel. There are also reports of corrosion and pitting with straight WVO (likely due to fatty acids and particulate content) and with unwashed biodiesel, reducing furnace life.

This website advertises the ability to burn unprocessed WVO for space heating:
http://wasteoilheat.com/index.shtml

I'm skeptical about the party behind the website. The site seems poorly organized to me in terms of finding detailed information. The link to the EPA is not related to their

product(s), nor is the link to the ANSI. Other than the payments page, almost everything leads to 'call for more information'. Their toll-free number is listed as "+1(866)XXX-XXXX", which is not helpful. One of their testimonials is about the Deluxe Town Diner in Watertown, MA which does appear to burn WVO for space heating. https://greenbusinessowner.com/can-your-kitchen-grease-become-biofuel-and-earn-extra-money-for-your-restaurant/ (see last paragraph)

Based on my participation the biofuel sustainable lists forum over a decade or so, the 'holy grail' of using WVO and biodiesel for space heating for years was the Babbington burner, which was developed by a number of individuals with varying levels of success. It appears that in recent years, Tom Leue of Yellow Heat has come up with an effective and reliable version, which he has patented and made available for commercial sale. (I have met Tom a couple of times, and spent a day at his facility in Massachusetts. He's a knowledgeable, credible person committed to making use of a waste product to make cleaner fuel.)

Therefore, I would take this statement from the starting page of the operations manual to heart:

"The Yellow Heat Burner is suitable for heating greenhouses, warehouses, shops, barns, garages, certain commercial spaces and selected other larger heating spaces. Yellow Heat Burner is not appropriate for most residential applications due to insurance restrictions."

Pricing and delivery of the Yellow Heat space heater furnace can be found at: https://www.yellowheat.com/yellow-heat-burner/

In summary, I would not recommend WVO or biodiesel for residential heating within the building. It might be OK for warehouses or greenhouses with occupancy of only a few hours a day. Even then, I would not do it for my own building.

Soap Making

Soap making from WVO requires lye. You will want a really clean WVO so that it does not introduce any undesired odour. Around here, there are a number of artisanal soap makers with guarded recipes as to what else they add to their soaps to make them creamy and pleasantly fragrant. It you are hoping to sell the soap, you may find a competitive market locally as well. Allow for packaging and marketing costs, as well as materials and effort.

You may find this story inspiring: "From Grease to Soap: How One Woman is Repurposing Used Oil"
https://www.earthisland.org/journal/index.php/articles/entry/from_grease_to_soap_how

_one_woman_is_repurposing_used_oil/
Laura and FROG Soap are based in Bremerton, WA. It looks like it's been a while since their website has been updated. It does appear they have implemented some COVID-19 reality, like curbside pick-up. Perhaps they will restart soap-making workshops if COVID-19 restrictions permit in future.
https://www.frogsoap.com/

This article speaks to the process, and incorporates the minimum ingredients for soap-making from WVO.
https://beauty.onehowto.com/article/how-to-make-soap-with-used-oil-1505.html

The major operating costs for making soap are the lye (sodium or potassium hydroxide), fragrances, possibly softeners, and time. Note the caution to age the soap for a month before use to avoid skin irritation.

The less-basic recipes generally call for a blend of unused oils, possibly including beef tallow. That will be hard to control if you are using WVO unless you know exactly what original oils each source is using, and you can keep them separated and labelled until after the filtering, settling and possible other cleaning processes before using them for soap-making. Here's another starting point:
https://www.thesprucecrafts.com/create-a-basic-soap-recipe-516796

Costs will increase with the more artisanal you choose to be with the soap-making.

Lye is currently selling for $37.99 for 3 kg at the Arbutus Home Building Center, roughly enough for 20 litres of WVO, or about $2/litre of WVO.

One comment I encountered mentioned the smell of cooked food (especially fish) was hard to overcome in the resulting soap.

It is also possible to make soap from glycerine, which is a by-product from biodiesel production. Some effort is required to clean the glycerine (mostly warming, filtering and decanting) enough to use for soap-making
https://beauty.onehowto.com/article/how-to-make-glycerin-soap-1123.html

FARM USES / GARDENING– NON-POWER

Earwig Traps

Apparently WVO can kill earwigs, in much the same way that beer-traps can kill slugs. This article is about vegetable oil in general, not specifically WVO.
https://www.almanac.com/how-make-earwig-trap-your-vegetable-garden

Stable bedding

I have heard from one person that WVO mixed with straw can used for bedding material. However, because I haven't seen any reference to this in the literature and think it might attract vermin, I remain skeptical. Still, this commercial product for that application says it uses vegetable oil as a key ingredient.
https://www.strathconaventures.com/animal-bedding-freshner-organic

ULTIMATE BEDDING CONDITIONER & NATURAL DEODORIZER

Hoof oils and dressings

https://www.thefarrierguide.com/2015/02/home-remedies-for-hooves.html

"This is a pretty intuitive one, because oils and dressings basically moisturize the foot, and we're all pretty down with the concept of moisturizing. As a note, most farriers aren't convinced hoof oils actually do anything beyond superficially making the hoof look better. That said, here are some recipes people swear by:

"Just plain cooking oil – vegetable, canola, whatever. Coconut oil seems to be especially popular, and frankly, it's great for literally everything else you would ever need anything for, so why not for your horse? Application is exactly what you'd think it would be. Just smear it on."

Killing cow lice

https://animals.mom.com/organic-treatments-for-cattle-lice-12360975.html

"You can use certain forms of oils, such as vegetable or canola oil, to coat the affected areas of a cow. Oils smother adult lice, as well as kill lice eggs. Oils used on your cow will clog up the pores of the lice. The lice will lose needed oxygen for survival and die as result of lack of oxygen."

Animal feed

"Recycling used cooking oil also helps enhance animal feeds. Used oil is a common replacement for corn due to its nutrients acting as an alternative source for calories. In fact, these nutrients can contain 2.25x more energy than corn. This is particularly beneficial for pig and poultry farms located in areas with hot weather that encourages the livestock to eat less. These nutrients provide more energy and calories in a smaller amount of food, helping keep the livestock healthy despite the restrictive weather."
https://www.darpro-solutions.com/media/blog/environmental-benefits-recycling-uco

Roto-Rooter provides this advice:
"**Animal feed**. While it has traditionally been used in feed for farm animals, many people also pour waste cooking oil over their pets' food to add extra flavoring."
https://www.rotorooter.com/blog/drains/unique-uses-for-waste-cooking-oil/

The leads I have followed for using vegetable oil or cooking oil (whether WVO or not), generally refer to rendering and commercial production of feed. There appear to be lists of what are acceptable feed items for different types of livestock by province.

Per the BC SPCA, a list of supplements or additives to (dairy cattle) feed must be presented to the Validator.
Standards for the Raising and Handling of Dairy Cattle
https://spca.bc.ca/wp-content/uploads/SPCA-Certified-Dairy-Standards-2012-v.4.pdf (page 6)

For hogs, this rule applies:

Feeding
Hog rations may be prepared and supplied by local feed companies, or they may be prepared on the farm premises by using integrated feed milling and delivery systems. On-farm feeding systems require regular maintenance and monitoring to ensure that feed is stored properly and to ensure that the most efficient utilization of feed nutrients is realized.
https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/strengthening-farming/farm-practices/870218-22_pork.pdf (page 3)

I found this cautionary note regarding feed for beef cattle in my research.
"High oil content (over 7%) can impair rumen function, reducing voluntary intake"
https://www.beefresearch.ca/research-topic.cfm/alternative-feeds-100

If you plan to use WVO as a supplement for livestock feed, I recommend talking to a farm veterinarian or livestock diet specialist to find out what concerns or recommendations they may have, and what rules and regulations are in force. I have not found solid information I trust in my searching for DIY supplementing feed with WVO, and don't have such a person in my personal network.

Pet food

From: https://pets.thenest.com/vegetable-oil-dog-itching-9361.html

“Vegetable oil is great for sautéing and frying, but it can also be wonderful for your dog. If your dog is constantly scratching, vegetable oil may be the answer to that itch. The only downside is that it too much oil can lead to messy bouts of diarrhea.”

In WVO from commercial sources, contamination could be a concern. The context for the above is household WVO where the pet owner would likely know what food was cooked in the oil and how it was stored.

Why It Helps

“Vegetable oil contains omega-6 fatty acids, which help the dog's coat inside and out. Rub the oil into your dog's skin or feed it to him so that it helps internally. When rubbed onto the skin, the oil works to sooth the skin and moisturize it. When fed to the dog, the vegetable oil's omega-6 fatty acids make the dog's skin moist from the inside out. You can choose to use both methods or just one.”

How to Apply It

“Dip your forefinger and middle finger in vegetable oil and rub it into the dry area. If you want to make the experience more pleasant for the dog, heat the oil until barely warm. This will not only make the skin moist, but the motion of rubbing the oil into the skin along with the heat can serve as a gentle massage for the dog. Make sure the dog's skin absorbs the oil or you risk getting oil all over your home and furniture. Too much oil can also clog the skin's pores and prevent essential oils from being secreted.”

Feeding Vegetable Oil to Your Dog

“WebMD recommends mixing 1 teaspoon vegetable oil into a small dog's food and adding 1 tablespoon to a large dog's food. Feeding your dog too much oil could cause diarrhea. You never want to feed oil directly to your dog. Always mix it in so that you're sure your dog gets enough food with the oil, which will also cut down on the chances of diarrhea.”
https://pets.thenest.com/vegetable-oil-dog-itching-9361.html

Compost

There are a lot of references on using WVO for composting. Most warn about using too much WVO in the compost, as it can overwhelm the composting microbes. The articles also warn about potential for attracting rodents. This seems like a reasonable treatment of the subject.
https://yuzumag.com/can-you-compost/vegetable-oil/
“But throwing in the oil you used to deep fry your chips with isn’t a good idea. Always make sure oil only makes up a tiny percentage of the total waste you’re putting in.”

What's lacking is good information on how much can be used in a dose, and how long between doses.

This article recommends no more than a cup (250 ml) for a household compost pile, which I will guess is less than a ¼ of a cubic metre, or 250 litres. If my estimate is correct, that's a ratio of 1:1000.
https://rusticwise.com/can-you-compost-vegetable-oil/

City of Calgary says up to 2 litres in a green cart, which seems high to me, but they may be planning to mix with yard waste.
https://www.calgary.ca/waste/what-goes-where/cooking-oil-or-grease.html

I had one correspondent (over 15 years ago) who reported good results mixing the dark lower – likely had emulsified water content - layer of settled WVO which he did not want to use for making biodiesel, with sawdust and grass clippings (probably for nitrogen-carbon balance) in a compost pile. Said the pile got hotter, so presumably more microbe activity.

If you are looking to add WVO to compost, based on my reading, it would be worth mixing with some water and soaking them into waste paper or other compostable materials. If you are picking up from restaurants anyway, perhaps used paper napkins, used coffee grounds and filters and other compostable materials could be collected as well and mixed. Wet coffee grounds would provide the water content.

Or you could provide this information to the restaurants, if the municipality has reviewed your educational material and wants this material in their landfill diversion program for composting.

FARM USES – POWER

Stationary Power

Farms often have back-up power generators to ensure they can maintain operations when the grid power goes out. These are typically powered by natural gas, propane, gasoline or diesel. On-farm production of methane from waste biomass is not unusual, and can be directly substituted for natural gas (adding a perfume is recommended). Some propane engines can be switched to methane by changing fuel nozzles. Gasoline can be replaced by ethanol blends up to E85, depending on the engine. Biodiesel can be used as a drop-in substitute for petro-diesel. However, it is also possible in a lot of diesel generators to use a 2-tank approach with WVO as the main fuel and biodiesel / petro-diesel as the start-stop fuel. As with vehicles, the WVO and fuel lines will have to be warmed, which may be easier for stationary equipment which is sheltered. If the

generator is used infrequently, WVO may go rancid while stored. Biodiesel has a longer storage life (minimal air in sealed containers; dark, cool locations preferred).

Mobile Farming Equipment

Trucks, tractors and other implements which use diesel engines can likely operate on WVO, provided start and stop/cool down operations are done with petro-diesel or biodiesel. There are caveats. Some diesel engines (e.g. the late Duramax GM diesel truck engines) don't work well on WVO or biodiesel. For WVO, additional equipment may have to be added (e.g., second tank, valves, thermometers.) There are additional operating steps to be followed. Extra care is required to ensure there is enough fuel in the start-stop tank so that it will not run out of fuel during the cool-down running period.

I don't personally know anyone running WVO in tractors or mobile farm equipment, but this article says it has been done, at least in Arkansas.
https://www.farmprogress.com/waste-vegetable-oil-powering-tractors-trucks-arkansas

OTHER

Weed Suppression

Use it to kill weeds. Just place WVO in a spray bottle and spray those unruly nuisances away.
http://www.grease-cycle.com/blog2/cooking-oil-disposal/

Dust Suppression

Dust suppression (roads, arenas)

Enjoy Dust Free Roads and Arenas, Thanks To Soybeans
https://soynewuses.org/case-study/enjoy-dust-free-roads-and-arenas-thanks-to-soybeans/

Local regulations may prohibit – e.g. Indiana
https://www.in.gov/idem/waste/hazardous-waste/used-oil/

Spilled Petroleum Remediation

There is evidence that vegetable oil can be applied to soil contaminated with petroleum products like heating oil, diesel fuel and gasoline. This study used sunflower oil, but there's no reason to believe that other vegetable oils – including filtered WVO – would not also work.
Removal of polycyclic aromatic hydrocarbons from manufactured gas plant-

contaminated soils using sunflower oil: laboratory column experiments
https://pubmed.ncbi.nlm.nih.gov/15982705/

Mosquito control

There is a long-standing practice of spraying used motor oil onto standing water as a mosquito control measure. That puts a toxic, carcinogenic material directly into the environment. WVO could be applied instead, which would have the same benefit, but without as much unintended harm to the environment. Depending on the size of the water surface (e.g., bird bath, ornamental pond), this could be done with a hand-held spray bottle repurposed from holding laundry stain remover or similar (properly relabeled of course).

BIODIESEL

Where an application for biodiesel can be accommodated by WVO, for the most part I won't be addressing it again in this section. The differences are generally about convenience of use and cost of the additional processing.

There are applications and users which will require that any fuel they use meets an acceptable, approved standard or is permitted by the engine manufacturer without voiding the warranty or both. There are such standards for biodiesel; there are not for WVO.

Ground Transportation

Blending biodiesel with petro-diesel

Several studies, mostly in the U.S., have indicated that the biggest gain in using relatively scarce biodiesel is to blend it into petro-diesel stock over many more vehicles. This allows the engines to run smoother (lubricity of the biodiesel) and reduce engine wear, Fuel consumption (in litres or gallons) may increase with higher biodiesel ratios. With 100% biodiesel, up to 10% more fuel may be used than with petro-diesel, and some drivers report lower power. It also reduces the amount of smog precursor emissions by a higher ratio than the amount of biodiesel in the blend. A number of jurisdictions now mandate blending in as much as 5% biodiesel into the standard diesel fuel. I have used B20 blend with success. Combined with synthetic engine oil, it smoothed out the idle considerably compared to the typical diesel rumble and vibration. No difference in fuel economy or power were noticed. The exhaust did smell better (a hint of French fries).

Marine Transportation

There is a renaissance of interest in using biofuels for marine power applications again in recent months.

https://www.theglobeandmail.com/business/article-in-the-search-for-less-carbon-intensive-fuels-great-lakes-freighters/

The MV Quinsam – Nanaimo-Gabriola ferry uses 4 diesel engines. I am guessing that BC Ferries wouldn't be interested in using WVO (at least initially) for a mission critical operation. However, in general in marine operations when there are multiple engines on board, part of the reasoning is redundancy – operations can continue with a single failure. BC Ferries might be prepared to consider trying local biodiesel – especially if made to ASTM standard and they can get engine manufacturer blessing. I would propose doing the trial runs in September-October when summer traffic volumes will have subsided but the temperatures are still warm, and only as a blend, starting with a low ratio (e.g. 2% and working up). If that goes well, they might be open to trying something similar the following year with WVO, again with a ramp-up testing process.

WHAT SEEMS INTUITIVE BUT SHOULD BE AVOIDED

Bicycle chain lubricant

https://pedalchile.com/blog/bicycle-chain-lubes

Not recommended: While most vegetable oils will reduce the amount of force needed to pedal a bicycle to similar levels of those of bike specific lubricants (in laboratory settings), the main reason you wouldn't want to use them is because they will pick up dirt and grime, increasing chain wear.

Lamp Oil

In my experience, corroborated by others, WVO and biodiesel do not work in flat wick kerosene lamps (the typical type in my history). The vegetable oil does not travel up the wick the way that kerosene does. Circa 2000 I did see conversations about using biodiesel in tube wick lamps, aka centre draft lamps (e.g., Rayo, Argand). Wikipedia does suggest that vegetable oil would work in an Argand lamp. To my knowledge, neither are made anymore, though parts are advertised on eBay.

This article – read it to the end – gives a good overview (eventually) of why this is not a good idea (open flames, finicky operation, smoking combustion affecting indoor air quality…). https://www.primalsurvivor.net/vegetable-oil-lamp/

Rendering and Fish Feed

Doug Davidson of West Coast Reduction Ltd, a rendering company on Duke Pt. told me WCRL collects used cooking oil via their Redux division. They make a range of feedstock products from animal waste, used cooking oil and other materials, such as blood meal, bone meal, fish meal …
https://www.wcrl.com/finished-products

WCRL don't make the feed for livestock, pets, fish, etc. The primary customers for their products are the Big Ag companies like Cargill, ADM, Nutrien …, who make the feed which is sold to farmers and producers. As noted previously, feed for commercial livestock operations is regulated provincially, and the feed formulations are pretty rigid and have to be 'certified' as to quality and content by the feed supplier.

Feed for fish farming seems to be less structured by regulators, so far, but the fish farms are particular about feeds, looking for very high protein ratios (around 90%). Cooking oil is not high in protein, so it won't be a big part of fish feed. One of the properties of value for cooking oil in dry livestock feed is that it is a binder and helps keep the pellets intact for easier handling. That same need does not apply to feed that will be put into water.

Doug says Cargill and competitors will not talk to me (small potential player), and they guard their formulations as trade secrets. He suggested I look on the Web for 'david groves scientist fish food'. Apparently, he is (was?) based on Vancouver Island Doug provided him with sample quantities of meal products for his work on fish nutrition, I gather in the 1990s. I found this in House of Commons Committee Proceedings from 2000.
"Dr. David Groves of Sea Spring Salmon Farm was one of the pioneers of salmon farming in B.C."
https://www.ourcommons.ca/DocumentViewer/en/36-2/FOPO/meeting-39/evidence

I have not researched Dr. Groves beyond proving I had the name right, and I found the right guy. More below on why the fish feed angle may not be worth pursuing.

Doug indicated that for small fish ponds (and my extension – small poultry flocks), is that the same rigidity would not be in force, as fish in an open pond would choose what to eat from what is available to them in the water and a free-range chicken will eat what it wants from what it finds foraging. (It's been almost 60 years since I got to collect eggs from the chicken coop and dodge the hens, but I suspect chickens haven't changed much.)

For commercial fish farming, there are regulations and standards at the international level, Canadian federal government level, and in the industry.

I have not found that BC has a voice on fish feed, but they do control licensing of operations. I have seen recent media stories that BC salmon farms will start to be shut down this year (2022). That may be why fish feed producers are looking to sell in other Canadian markets.

Other things to note. Doug really doesn't like the term WVO. They don't see what they collect as waste, but as an input feedstock. WCRL pays for it. He was consistent in using the term used cooking oil (UCO).
In Doug's opinion, the highest value use of used cooking oil (UCO) is to make biodiesel.

Coming back to using WVO/UCO for feeding chickens, I think there are two distinct markets to consider: commercial scale and small scale (overlaps free range). In the commercial poultry business, regulation is pretty tight, and likely increasingly so for the next while as bird flu is an increasing threat. There might be small market for using WVO as poultry feed, but I think more research on treating the oil and the amount that should be in the feed would be valuable.

Here is a sampling of what I found on the subject.
The Use of Recovered Frying oil in Broiler Chicken Diets: Effect on Performance, Meat Quality and Blood Parameters
https://www.researchgate.net/publication/326147144_The_Use_of_Recovered_Frying_oil_in_Broiler_Chicken_Diets_Effect_on_Performance_Meat_Quality_and_Blood_Parameters
"The experimental results indicated that the use of recovered oil instead of fresh oil in the chickens' diet did not cause any significant ($P>0.05$) alteration in their body weight, weight gain as well as their feed intake and feed conversion ratios. The meat quality, carcass characteristics and blood cholesterol and triglycerides were not affected significantly ($p>0.05$) by the use of recovered oil in the diets. The use of recovered oil in replacement of the fresh oil in broilers feed was shown to be more economically." [sic]

How Used Cooking Oils and Animal Fats are Recycled
https://www.darpro-solutions.com/media/blog/second-life-for-used-cooking-oil-and-animal-fats
"We reuse virtually 100% of the material we collect from our customers. Almost all of the used cooking is used to produce biofuel, while the meat scraps, fat and bone are used to create animal food, household goods, and more biofuel."

This resource is from Iran, but pretty current and it does point out some pitfalls in the

collection and use of the WVO (EOW = Edible Oil Waste in their paper).
A mixed-method study of edible oil waste from farm to table in Iran: SWOT analysis
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8459144/
"They mentioned that there is not any specific management for recycling the discarded edible oil. The biggest buyers of discarded oil are illegally private sectors without refinements for poultry feeds.
"The use of such oils is only restricted by their chemical composition and provided that the oil's peroxide value is not higher than allowed [42]. However, a recent study in Iran showed that the peroxide content of discarded oils in restaurants was higher than the standard [34]. It seems that due to the high cost of edible oil in Iran, they are overused. Non-recovered discarded oils in broiler chicken diets could return to our bodies. Initially, EOW should filter and then be directly used in the animal feed [43]."

This piece is long, but the key item I got from it is an actual ratio for inclusion of fats and oils in feed: up to 4%.
Best Type of Chicken Feed? The result will surprise you!
https://patchtotable.com/chickens/feed-types/#t-1604874547547 (Unfortunately, this site is currently generating SSL certificate error – 2022-09-28 – so the page will not open. Use this link as an alternative:
http://web.archive.org/web/20211128090418/https://patchtotable.com/chickens/feed-types/)
Go to section 1 Chicken Feed Ingredients > Fats and oils.

Another source on feeding scraps to chickens on household scale which mentions Fats and Oils.
7 Tips on Feeding Kitchen Food Scraps to Chickens
https://www.hobbyfarms.com/kitchen-food-scraps-chickens-tips/
"4. Fats & Oils
"If you have the bad habit of pouring cooking oil down the sink, you really should see what this stuff looks like when it congeals inside a city sewer pipe. These grotesque icebergs of fat (aka "fatbergs") cause nearly half of the sewer overflows in the U.S. each year. And even when the fat doesn't congeal into a fatberg, it still has to be removed from the wastewater, and that costs taxpayer money.
"Instead of pouring cooking oil or fat from bacon, burgers, steaks and pork chops (mmm … pork chops) down the drain or even putting that stuff in the trash, we pour—and scrape—our waste oils and fat into a bowl and let it set up in the fridge overnight. We then feed it to the hens the next morning. It's like pudding for chickens, and they gobble it up fast. That's not nearly as strange as it sounds. Many cooking oil-recycling operations turn waste oils from restaurants and food processors into livestock feed anyway.

"Another tip: If you have dusty bits of pellets or grains that the chickens aren't eating, mix them with liquid waste oils into a paste that your hens will devour."

You had expressed interest in using a centrifuge to treat the collected WVO before using it in poultry feed. There isn't a lot of information on this, but here's one link. Not very informative.
Extract valuable raw material from old deep fryer fat
https://www.flottweg.com/applications/edible-fats-and-oils-biofuels/used-cooking-oil/
Centrifuges for processing used cooking oil and waste oil
"The food industry and cafeterias generate considerable quantities of used cooking oils. Used cooking oils are reprocessed by waste oil disposal companies. The recycled and processed used cooking oils serve as raw materials used in the production of biodiesel, hydrogenated vegetable oils (HVO) and technical greases. Good for the environment and the operator.
"Waste fats, such as frying fat or the contents of grease separators, sometimes contain considerable amounts of undesirable foreign materials. Vegetable and animal fats, as well as used cooking oils and fat from grease traps, are used in the production of biodiesel, HVO or technical fats. The Flottweg Tricanter® separates the unwanted solid particles from the fat in just one step." (it is a product pitch)

It's unclear to me what the centrifuge process accomplishes that settling and filtering does not. I suppose centrifuging is faster. I'll also just mention again the gelatin method for removing impurities and solids from used cooking oil (reference provided in my earlier draft report).

In summary, I suspect you will encounter issues trying to provide your WVO directly to conventional poultry producers because of regulatory barriers related to feed content and quality control. For small scale (household to small farm), there is information on how much cooking oil is acceptable as part of the feed. In your place, I would seriously investigate liability issues if poultry consuming your treated UCO became sick or died – whether or not the oil is the likely cause.

WVO space heaters

I have sorted through at least 20 trails looking for viable large space heater systems which will run on WVO, including some dead ends I'm not including here.

Assumptions

I have selected only those which are commercially available (there is a lot of home-brew) and specifically mention support for WVO / UCO. I don't think your group wants to become responsible for the construction, installation or maintenance of these units,

or potential complications from using a fuel which is not explicitly supported by the manufacturer or installer / maintainer. There are a lot of waste oil burners that are primarily or only for burning waste motor oil. (A brief list is presented later of the better-known vendors.)

In case my assumptions are wrong, I'll just point you to one item as a sample. I have chosen a page from the Journey to Forever site, as I think the material there likely aligns fairly well with your perspective. Don't stop at just Roger's heater, go further down the page for some good overview information on the workings.
https://journeytoforever.org/biofuel_library/ethanol_motherearth/me9.html

While I think it's interesting, the idea of combined heat and power units strikes me as more work than I think you want to undertake. This would involve using a stationary diesel engine to run a generator / alternator to produce electricity, and taking heat off the engine via a heat exchanger. I think this would require a very specific kind of installation with the engine outside the building, and the heat exchanger having an indoor unit. There is an additional complexity in determining which load (electricity or heat) takes precedence. The oil used in a diesel engine needs to be better filtered than in an oil burner.

This article from ASME talks about a commercial product.
Waste Not: Used Cooking Oil = Energy Source
https://www.asme.org/topics-resources/content/waste-not-used-cooking-oil-energy-source

More on the Vegawatt
Vegawatt Cogeneration System Powers Restaurants with Waste Vegetable Oil
https://www.onsetcomp.com/content/vegawatt-cogeneration-system-powers-restaurants-waste-vegetable-oil/
Sadly, I can't find references to this product after 2012, so I expect the company is defunct. The vegawatt.com domain name is available for sale.

In my reading, I have found a few cautions that burning vegetable oil in a unit designed for waste petro oil will cause some issues because the viscosity and flash point of vegetable oil is higher than waste petro oil. This will lead to increased coking and varnishing, meaning more frequent cleanings and maintenance required. Unless the petro-burner specifically addresses these issues, I think it will be a poor choice for burning vegetable oil.

So, with my overall thinking about the situation set out above, here are the commercial units I have found (searching in Canada and the U.S.) which may be of interest.

WVO Burners

Clean-Burn

Based in the U.S., Clean Burn has a Canadian authorized distributor, De-on Supply Inc (DSI), which claims to serve all of Canada. So far, I'm assuming they will contract out installation and maintenance to a local furnace or boiler installer.

Clean Burn website
https://www.cleanburn.com/

De-On Supply Inc. website
https://www.deonsupply.com/

From my reading (2005), the Clean Burn unit has to be set for either waste petro oil or waste vegetable due to different burning characteristics of the fuels. That needs to be investigated further before believing it is a good choice. I cannot find pricing online.

DSI Canadian headquarters is in Waterloo, ON.

FireLake
https://www.firelakeheaters.com/

They claim the can burn vegetable oil, but their site includes this paragraph:
"Concerns with burning used cooking oil for fuel?
"The most common concern with burning used cooking oil for fuel in a waste oil heater is an increased need to do maintenance of the burner and heat exchangers more frequently. The burner systems will need a quick cleaning of the nozzle area about every two weeks to maintain best performance when burning used cooking oil. In comparison, burners that fire used motor oils only need attention every few months."

Unless there is no better alternative, I don't think greenhouse operators will want to have to do bi-weekly cleaning and frequent maintenance.

Yellow Heat

A short treatment of the Yellow Heat burner is presented here.

https://www.yellowheat.com/yellow-heat-burner/

They have both a burner and furnace product. The burner is intended for retro-fit into an existing furnace or boiler system. The furnace system is intended for new-build installations. (Presumably retrofits will usually have an existing furnace blower and ductwork in place.)

This video provides a good introduction to the burner and context for its use and benefits.
https://youtu.be/Q35MT-1CHeU

This page gives a static description of the burner, features and specifications. Prices are in U.S. dollars.
https://www.yellowheat.com/yellow-heat-burner/

As far as I can tell, Yellow Heat does not have a distributor or service network in Canada. That presents a risk, but possibly an opportunity for someone in Canada, preferably already in the heating appliance industry, to create a market for a low-energy, high-benefit utilization of waste vegetable oil. I believe the Babbington burner is a significant technology advantage.

Note, this burner system can burn petro-waste oil or regular fuel oil, in the event the operator runs out of WVO, a flexibility which eliminates a big risk in single-fuel systems.

I have not contacted any of the suppliers listed above as yet.

If I was looking for a heating solution for an industrial space using WVO as the fuel for myself, this is the one I would pursue first. I would also connect with De-On Supply (Clean Burn rep) for context and comparison. If buying for a pilot installation, that would likely be sufficient. If contemplating a bulk-buy, I would also contact FireLake and even spend more time looking for a possible fourth candidate running a more formal evaluation.

The following units, despite some indication they can burn vegetable oil, a deeper read tells me they are really designed to burn petro waste oil only.

CleanEnergy

https://cleanenergyheatingsystems.com/

Based in the U.S. No indication of a dealer or maintenance network in U.S. or Canada.

Kroll

Kroll (based in Germany, distribution in UK, Russia and Australia, not Canada)
http://www.kroll.de/en/products/multi-fuel-oil-burner/

Lanair

https://www.lanair.com/

Based in the U.S. No indication of a dealer or maintenance network in U.S. or Canada.

METHANOL RECOVERY AND BY-PRODUCT SEPARATION

I started by working on the questions of methanol recovery and cleaning the glycerine as separate items, but in the course of my research I discovered that methanol is also present in the glycerine by-product, so there's potential for methanol recovery in two places, with one is integral to cleaning the by-product. (In the literature, the terms glycerin, glycerine and glycerol are all used. They mean the same thing. I have chosen to use glycerine. Methanol also goes by a lot of names, and I have provided a list in the Appendices.)

Working from first principles

There are a number of processes small producers use to make biodiesel, typically in batches rather than continuous process. Reactor vessels are typically cleaned out and the materials loaded in after titration of the feedstock oil to determine the acidity level and adjusting the lye and methanol mix (methoxide) accordingly. The materials are mixed to aid the reaction, intermittently or continuously. After a prescribed period of time or based on measurement or inspection of the reactor contents, the contents may be transferred to a settling container, which may be open, vented or closed.

At the end of the WVO-to-biodiesel conversion process excess methanol is present in both the biodiesel and glycerine by-product. If open to the air, the methanol liquid will eventually evaporate from the batch. (This is why methanol is stored in air-tight containers.) Unless there is a desire to recover the methanol (generally for economic or environmental reasons), evaporation with a lot of time in a warm, ventilated place combined with washing the fuel is sufficient to remove the methanol from the fuel for purity purposes. (This point has been argued many times in the material read.)

In a closed environment, the free methanol will separate into a different layer from the biodiesel and glycerine by-product paste (semi-solid), but there isn't much free methanol, most of it is chemically bound to other things in the brewed batch.

The specific gravity of methanol at room temperature and atmospheric pressure is about 0.792. The specific gravity of biodiesel ranges from 0.85 to 0.9, depending largely on the original WVO feedstock and completeness of the reaction. Water, having a specific gravity of 1.0, will increase the specific gravity of the biodiesel until it has had a chance to separate. Glycerine (pure) has a specific gravity of 1.26, while the crude by-product specific gravity is variable, but in the range of 1.05.

As a result, if a batch of freshly reacted biodiesel is emptied into a container, with time and if the mixture is allowed to sit still (minimal stirring or agitation) and kept warm, eventually the components will settle into layers based on the specific gravity values. From bottom to top these layers will be liquid glycerine, glycerine by-product (usually a

sludge or paste), water, biodiesel and free methanol. (Most of the methanol isn't free; it's bound to other elements.) A suction hose can be used to remove the top liquid layers. A bottom drain can take off the liquid glycerine. The sludge or paste can be removed with a stronger vacuum hose system, or scraped out mechanically.

There has been work done on heating the freshly reacted biodiesel so the methanol boils off, possibly assisted by use of vacuum to lower the boiling point, and using a condenser system to liquify the methanol for collection and storage. (distillation)

The following text comes from *The Biodiesel Bible* (pp 233-234):

"Some homebrewers do recover the methanol before separating the by-product (some of them use vacuum), but we'd rather not risk ending up with anything less than good process completion. It's best to recover the methanol after separating the biodiesel and the glycerine by-product. [emphasis added]

"More than 70% of the excess methanol collects in the by-product layer [emphasis added], and it's easily reclaimed.

"The methanol left in the biodiesel can also be reclaimed, but it's not cost-effective, it takes more energy than you'll recover. Best write it off as a production cost – washing the biodiesel removes the methanol, and it does no harm in the wash-water"

"The reason we call it the "glycerine by-product" is that what sinks to the bottom of the tank during the settling stage is not just glycerine, it's a mixture of glycerine, soap, most of the excess methanol, and most of the catalyst. In fact there's usually more soap than glycerine – it's more of a "soap" layer than anything else (unless you use the two-stage acid/base process, which produces less soap).

"You can separate the by-product into its components (see *Chapter 18: The glycerine byproduct, Separating the glycerine*). Adding concentrated phosphoric acid to the byproduct converts the soap back to FFAs and separates it from the glycerine, and releases the lye catalyst, in the form of potassium phosphates, which is valuable fertiliser (or sodium phosphates if you used NaOH, which makes a less valuable fertiliser, but it's valuable nonetheless).

"This leaves you with about 90% pure glycerine, which is a much more attractive product to sell to refiners – or at least they should be more willing to accept it from you. It's also a useful compost activator and accelerator, and it boosts methane production in biogas digesters.

"But the mixture won't separate without the methanol. After separation all the methanol is concentrated in the glycerine and can then be recovered.

"You can do it either way: if you're planning to separate the by-product using phosphoric acid, then do that first, and then recover the excess methanol from the glycerine portion. Or it can be recovered direct from the raw by-product cocktail.

"Methanol boils at 64.7 deg C (148.5 deg F), though it starts vaporising well before it reaches boiling point. Crude glycerine is much more viscous, with a higher boiling point, 288 deg C (550 deg F).

"In theory, you can recover the methanol by heating the by-product to 65–70 deg C (149–158 deg F) in a closed container fitted with a condenser. But, as the methanol evaporates, leaving an ever-lower proportion of methanol in the mixture, the boiling point increases, and when the temperature reaches 100 deg C (212 deg F) or a little higher, it starts to froth and you have to stop or you'll get frothy brown by-product in your methanol condensate.

"It can be done, if you monitor the temperature very carefully, keeping it just below the "frothing point": you can get it up to 130 deg C (266 deg F) with no frothing, recovering almost all the methanol, but it takes hours of careful attention."

Note: methanol is categorized as a hazardous material. It is poisonous and flammable. Methanol vapour is flammable and explosive and exposure should be mitigated by proper ventilation and personal protective equipment.

https://www.methanex.com/sites/default/files/about-methanol/safe-handling-methanol/SDS/Methanol%2867-56-1%29%20NA%20EN-final%205.3.pdf

I'm presenting the above to show methanol recovery from the biodiesel portion is not cost-effective, and that recovering methanol from the glycerine by-product is a better source. Also, working with methanol vapour is not to be undertaken lightly.

This video reinforces the information above, including the safety issues, and that doing it well is complicated, requires some special equipment for separation (e.g. distillation) and quality testing. It also requires frequent, if not continuous monitoring.

Methanol Recovery in Biodiesel Production (USDA, University of Idaho, National Biodiesel Education Program)
https://www.youtube.com/watch?v=ck1eAM7grPs

As an aside, it's essentially illegal to own a still in Canada for distilling alcohol without a federal government permit (Excise Act of 2001). Methanol is an alcohol (and so is glycerine aka glycerol), so the language is not clear enough to say this application is in the clear. I would contact the local Regional Excise Duty Office to get clarification, before proceeding with any kind of distillation process. Some fun related reading:

https://learntomoonshine.com/wp-content/uploads/2014/11/Federal-Licence-And-Laws-To-Distill-Spirits-Canada.pdf

The point about more residual methanol being in the glycerine by-product than in the biodiesel is repeated in this paper: Advanced vacuum biodiesel process https://make-biodiesel.org/images/pdffiles/Advanced_vacuum_process.pdf (page 4)

Selected text from the source above:
"6. Glycerin cocktail: The glycerin from oil is brown and may turn to a solid below about 20 deg C. Glycerin (glycerol) is the main co-product of making biodiesel. Theoretically 79 ml of glycerin per litre of oil used, 7.9% glycerin should be produced. The cocktail drained from the system is not pure glycerin. What sinks to the bottom of the biodiesel processor during the settling stage is a mixture of glycerin, methanol, soaps, water and the excess KOH catalyst. **Most of the excess methanol and most of the catalyst remains in this layer.** [Emphasis added] Once separated from the biodiesel, adding phosphoric acid to the glycerin layer precipitates the catalyst out as potassium phosphate which is useful as a fertilizer, and also converts the soaps back to free fatty acids (FFAs), which float on top. You are left with a light-colored potassium phosphate precipitate on the bottom, glycerin/methanol/water in the middle, and FFA (free fatty acid) on top. The excess methanol can be recovered similarly to the way water is removed from oil when drying. Recovered methanol must be dried for reuse in the process which is an advanced technique. Another idea for disposing of the glycerin is breaking it down, with an anaerobic digester to produce methane gas. This is mentioned here for reference but is covered in detail in the advanced process documentation."

A third source for there being more methanol in the glycerine cocktail than in the biodiesel at the end of the reaction process:
http://www.fenixchemtech.in/pdf/Recovery%20of%20Methanol%20from%20Biodiesel%20Process.pdf

From the source above:
"BIO-DIESEL Process:
"Biodiesel (methyl ester) is transesterification of vegetable oil by using methanol and KOH/ NaOH as catalyst. The reaction is carried out in 2 reactors. Esterification is carried out to about 80 – 90% level in the first reactor. Glycerin is separated which carries methanol. More methanol is mixed in second reactor to complete remaining Esterification. Glycerin phase is again separated. Consumption of methanol is about 10% of the weight of oil input but excess quantity of methanol is used for the reaction. The excess methanol goes with Bio-diesel phase as well as with glycerin phase. **Bio-diesel phase has about 10% of methanol and Glycerin phase has about 40% to**

50% of methanol. [emphasis added] Bio-diesel phase also has some quantity of soap in it and needs to be washed with water to remove soap"

In short, for a small production operation, I recommend against manual processes for methanol recovery given the hazards, and especially if the work will be done by volunteers with any degree of turnover of personnel. For safety reasons, I would not do this work myself alone.

A number of the sources I read on biodiesel production don't even touch on the subject of methanol recovery.

Because of the temperatures associated with boiling methanol or glycerine, the use of vacuum to lower the boiling point is frequently employed. This adds complexity, labour and points of failure.

I did some research on what tools might be available to automate or at least make some of the processes safer. When I was involved in small scale biodiesel production, there were no such tools available commercially, and everything was home-brew. In my current research, I see there are some entrants in the automation market, but it's not all as painless as one would hope, and prices appear to be high – possibly out of reach for small scale operations.

One cautionary story:
Why you should never buy an RSI-55 Methanol Recovery System
https://www.trianglebiofuels.com/why-you-should-never-buy-an-rsi-55-methanol-recovery-system/

I did not find much on solutions for methanol recovery from small scale biodiesel production. There are a few companies that have solutions for large plants, generally continuous operation. E.g.,

http://www.srsbiodiesel.com/technologies/methanol-recovery/
https://wintek-corp.com/flash-evaporation-systems/methanol-recovery-systems/
https://incbio.com/methanol-recovery/ (there are more).

This looks like a one-stop solution for recovering methanol from biodiesel and the glycerine by-product.

https://www.springboardbiodiesel.com/glycerin-and-biodiesel-demethylation.html

It can even process the demethylated glycerine by-product into soap.

Springboard is the only supplier I found on the Web which appears to be an appropriate commercial product for methanol recovery for small scale biodiesel production.

Drying Methanol

I have not dug into this in depth, as it appears to be a solved problem. Boiling is not a good solution, as methanol boils at a lower temperature than water, so a closed system with a condenser would be required to capture the methanol.

Some citations.

Drying Solvents
https://chem.libretexts.org/Ancillary_Materials/Demos_Techniques_and_Experiments/General_Lab_Techniques/Drying_Solvents
"**Methanol**: For most purposes, drying over 3A molecular sieves overnight followed by distillation is sufficient. Alternatively, the methanol can be dried from magnesium methoxide. Magnesium turnings (5 g) and iodine (0.5 g) are refluxed in a small (50-100 mL) quantity of dry methanol (from a previous batch) until all of the magnesium has reacted. The mixture is diluted (up to 1 L) with reagent grade methanol, refluxed for 2-3 hours then distilled under nitrogen."

Drying of Organic Solvents: Quantitative Evaluation of the Efficiency of Several Desiccants
http://ccc.chem.pitt.edu/wipf/Web/Solvent_Drying.pdf
"Methanol and Ethanol
"Lower alcohols are typically dried by heating over iodine activated magnesium with a magnesium loading of 0.5- 5.0 g/L.1 Several other desiccants, including KOH, BaO, and CaO, 1,3 have also been recommended. KOH and Mg/I 2 are found to provide methanol with a water content of 33 and 54 ppm, respectively (Table 5). Molecular sieves (3 A) were efficient at drying this solvent only when present at a loading of 10% m/v (mass/volume) or higher and when the solvent was left to stand over the sieves for a minimum period of 72 h. Optimum drying is obtained with storage of the methanol over 20% m/v 3 A molecular sieves for 5 days, by which time the water content reduces to about 10 ppm.

"Ethanol behaved similarly, requiring a minimum of 10%m/v of activated 3 A molecular sieves before efficient drying is noted, optimally also after a period of 5 days over 10% or 20% m/v of the sieves, under nitrogen (Table 6). Powdered KOH proved a rather active desiccant for methanol, and ethanol and may be used in a predrying step prior to storage over activated 3 A molecular sieves to provide ultimate drying efficiency."

Drying Alcohol Using Magnesium and Molecular Sieves
https://www.youtube.com/watch?v=NMfs3e9OdZQ

Cleaning the Glycerine By-Product

So, what is actually in the glycerine by-product (or 'cocktail') that precipitates out of the biodiesel reaction?

Obviously, glycerine (65% to 85% (w/w)) and methanol at this point. What else? Soap (FFAs), lye, salts (calcium, magnesium, phosphorus, and sulphur, in the range of 1 to 30 ppm each).

In addition to heating and separating the layers, a filter should also be used to capture any solid bits that escaped the pre-reaction filtration step or appeared as part of the reaction or post-processing. The heating to separate the material into layers which can be decanted without a condensation stage should not be considered a still.

This seems like a relatively simple approach to breaking down the glycerine product into its constituent elements:

http://journeytoforever.org/biodiesel_glycsep.html
Separating glycerine/FFAs
"Most of the lye and most of the excess methanol used in the biodiesel process collect in the glycerine layer that settles out at the bottom, along with the soap formed when Free Fatty Acids (FFAs) are neutralized by the excess lye.
"The proportions of each depend on the oil you used and your process -- the **two-stage acid-base process** will give different results to a single-stage base process.
"Adding phosphoric acid (H_3PO_4) converts the soap back to FFAs and separates it all into three distinct layers, with catalyst-phosphorus on the bottom, glycerine-methanol in the middle, and FFAs on the top.
"The methanol can then be recovered from the glycerine in the middle layer by heating to above 65 deg C (150 deg F) in a closed container fitted with an outlet into a simple condenser."

More details on the process follow at the link provided above. (This may be considered a still.)

Making soap may not be the only, or even best, by-product which can be extracted from the glycerine by-product.

The Byproducts of Biodiesel Production Are Valuable Organic Acids, Researchers Say
https://www.renewableenergyworld.com/baseload/the-byproducts-of-biodiesel-production-are-valuable-organic-acids-researchers-say-53116/

This looks like a fun topic to pursue further.
Biodiesel Glycerol Conversion to Anti-Freeze
https://www.trianglebiofuels.com/biodiesel-glycerol-conversion-to-anti-freeze/

Presumably whatever fleet is running the biodiesel fuel will also need some engine coolant, and mechanics are forever using degreasers (on parts and their hands – and this would be better than a solvent-based degreaser).

And when all else has been extracted, don't discount these end-paths for some of the small remainders:

a) The compost pile (the salts are typically soil nutrients – NaCl / sodium chloride or table salt being an exception)
b) Feeding to a (methane) biodigester

Chapter 18 of *The Biodiesel Bible* also treats the topic of the glycerine by-product and possible uses, including glycerine soap-making. It also recommends this book on soap-making: *The Soapmaker's Companion: A Comprehensive Guide With Recipes, Techniques & Know-How* by Susan Miller Cavitch.
https://www.chapters.indigo.ca/en-ca/books/the-soapmakers-companion-a-comprehensive/9780882669656-item.html

Centrifuge Research

Assuming liquids and small suspended solids with differing specific gravities, a centrifuge is a device which performs the same function as settling, but in a shorter time period by using centrifugal force to amplify what settling does by gravity. The agitation caused by the mechanical action also enhances the separation of different materials. An early and well proved centrifuge is the farm milk separator.

This article on vintage cream separators provides a readable and concise analogy: https://www.farmcollector.com/equipment/cream-separator-zmhz12mayzbea/

The gravity separation method is described, along with shallow separation and deep-settling (also known as a fractionating column), including the glass windows (sometimes a sight tube is used on current settling tanks).

This article provides a concise description of the factors of operation for a centrifuge. https://druckerdiagnostics.com/knowledge/how-a-centrifuge-works/

"Principles of Centrifugation

"At its core, centrifugation is separation through sedimentation. The denser particles sink to the bottom of the container, while the more lightweight particles remain suspended. Centrifugation will displace particles that are even slightly different in density, and is influenced by these four factors:

- The density of the samples and solution
- The temperature and viscosity
- The distance that the particles are displaced
- The speed of rotation

"Relative centrifugal force (RCF), or G-force, is the amount of acceleration that is applied to the sample. When RCF exceeds the buoyant and frictional forces in the sample, the particles will move away from the axis of rotation and result in sedimentation."

For separation of the glycerine [glycerin, glycerine and glycerol are interchangeable terms; I choose to use glycerine] by-product, there are a couple of additional factors to take into account.

1) *Will the mixture be maintained at a temperature above the melting point of the pure glycerine?* At 13.3 degrees C, it should not be difficult, and will enable separation.
   I am assuming the answer is yes for the remainder of this research.

2) *Should the remaining methanol be recovered before separating the rest of the mixture?*

The distillation process typically used with vacuum and heating is energy intensive and produces methanol vapour, which is a hazard (flammable, explosive, toxic).

Therefore, it could be advantageous to use a centrifuge to perform the separation of methanol from the rest of the glycerine by-product. Unfortunately, to date, I have not found a solid source for this being done.

This may be because methanol-water bonds are strong and may not succumb to typical centrifuges. Hence, the need for heat in the distillation process to supply the energy to break the molecular bonds between methanol and water. (but this should be the drying stage).

This discussion of the separation / purification process assumes distillation (for methanol recovery) before other steps in the process.
https://www.researchgate.net/publication/336488063_Conversion_of_Glycerol_to_Valuable_Products

The Dolphin Centrifuge, marketed specifically for the biodiesel production market (notably for separating the biodiesel from the glycerin by-product (rather than using settling), says this:
https://dolphincentrifuge.com/biodiesel-centrifuge/

"Glycerin Clarification

"**Distilling separated glycerol recovers the methanol and produces glycerin**. [emphasis added] Pure glycerin has good resale value and is in demand in the food and cosmetics industries.

"Clarification of glycerin to remove small impurities makes it usable. A disc stack centrifuge has the required g-force to remove the finest trace particles from glycerin.

"The advantages of using industrial centrifuges (listed above) are applicable for glycerin purification as well."

While centrifuges for extracting ethanol exist, a quick Web search did not find any relevant hits for a methanol centrifuge (ethanol units did come up on that search).

I have been through a few papers which satisfied the "methanol + centrifuge" Web search criteria, and none mention using the centrifuge to separate free methanol from other materials in a glycerine mixture. Several of the papers mention removing free methanol before using a centrifuge. For example:
A sustainable methanol-based solvent exchange method to produce nanocellulose-based

ecofriendly lubricants
https://www.sciencedirect.com/science/article/pii/S0959652621028730

Based on the research I have done, while I have not found a definitive 'do not use a centrifuge when free methanol is present' statement, I believe the implication is that this is not done in practice. Unhappily, in my opinion, that leaves us back at using distillation and vacuum to recover the excess methanol from the glycerine by-product before using a centrifuge to further separate / purify the glycerine.

Which brings me back to the Springboard GL 95 "demethylator". Perhaps it can be operated in such a way that the methanol is recovered from the glycerine by-product and then the remainder provided in raw form for processing (possibly in a centrifuge) rather than going directly into unpurified 'soap' bricks. This would require discussion with the vendor. Having dealt with other customers, they may be able to suggest an even better solution.

My research also led me to look into ElectroDialysis as a means of separating the components of the glycerine by-product, and while there was some interest years ago, it seems nobody is actively pursuing it now.

EET Corporation HEED technology
Company no longer operational
https://www.bluetechresearch.com/tools/innovation-tracker/eet-corporation/
http://www.eetcorp.com/heepm/heepm.htm

There does seem to be current interest in ionic treatment, physico-chemical treatment and micron sieve technologies as other means of separation, but these may also fail at the breaking the methanol chemical bonds in the glycerine by-product.

CONCLUSIONS

It is possible that biodiesel could be used in the new bus fleet (GM), but research would be required on additives, possibly modded ECU chips and consultation with the manufacturer to ensure the warranty will not be affected.

There are other uses for WVO than just making biodiesel, although the expert I interviewed feels this is the highest value use for WVO.

It is possible to use WVO for space heating, but not recommended (by vendor) for living spaces. One unit researched can run on WVO and other fuels, reducing supply risk for the property owner.

It is not worth trying to recover methanol from the produced biofuel.

It probably is worth trying to recover methanol from the glycerine by-product ('cocktail'), for both environmental and financial reasons.

Recovering the methanol via distillation could be considered to be operating a still, which has legal implications under Canadian law and regulations.

Dealing with methanol vapour is hazardous and complicated.

There are hazards associated with distillation and vacuum recovery of excess methanol from the glycerine by-product.

I would prefer that Island Futures staff and volunteers not use a distillation and vacuum system to recover methanol vapour (which would then be condensed to a liquid which needs to be dried for re-use).

There is a commercial product on the market which claims to simplify and reduce the hazards of recovering methanol from the glycerine by-product.

There are other uses for the glycerine by-product elements after methanol extraction. Some of these may be more attractive than making glycerine soap, and easier. Automotive anti-freeze (based on the glycerol content) is just one.

A centrifuge can work at separating the elements of the glycerine by-product mixture. However, it appears that separation of the methanol is typically done as a pre-treatment step before using the centrifuge to separate the salts and other impurities from the liquid glycerine (acid process). Otherwise, the energy costs of methanol recovery are high.

RECOMMENDATIONS

1. Make biodiesel from the WVO for fueling diesel vehicles and equipment.
2. Connect with Yellow Heat (Tom Leue) to investigate the potential for using their system to burn WVO for heating a warehouse or greenhouse or other structure that is not occupied continuously. I don't recommend WVO or biodiesel for residential heating within the building, per the information from Yellow Heat.
3. With the expectation of purchase, investigate using some of the Springboard technology as a way towards methanol recovery and processing of other material from the by-product. In particular, the GL95 which recovers methanol from the glycerine by-product and also produces soap.

APPENDIX - DIFFERENT NAMES FOR METHANOL:

This can be useful information when sourcing product for biodiesel production. When I was making small amounts of biodiesel, methyl hydrated (marketed as a paint thinner / cleaner) was less expensive than 'methanol', which was sold in bulk by car performance outlets.

- Bieleski's solution
- Carbinol
- CH_3OH
- Methylol
- Methyl alcohol
- Methyl hydrate
- Methyl hydroxide
- Monohydroxymethane
- Pyroxylic spirit
- Wood alcohol
- Wood naptha
- Wood spirit
- White spirit

REFERENCES

Websites used to obtain specific information are not listed here, but are inserted in the document as appropriate

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Applications of Waste Cooking Oil Other Than Biodiesel: A Review D.C. Panadare & V.K. Rathod 2015 Iranian Journal of Chemical Engineering http://www.ijche.com/article_11253_54b41ee620eb7a8972ee3e37776dad5f.pdf

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From the Fryer to the Fuel Tank Joshua Tickell published 2000 ISBN 0-9707227-0-2 (author's personal collection)

Market Warms to Bioheat Joanna R. Turpin 2014 ACH News https://www.achrnews.com/articles/128196-market-warms-to-bioheat

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The author's personal files and correspondence
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(glycerine used as fire starter and soap product)

https://www.methanol.org/wp-content/uploads/2016/06/Methanol-Technical-Data-Sheet.pdf

https://www.researchgate.net/publication/228589856_The_specific_gravity_of_biodiesel_fuels_and_their_blend_with_diesel_fuel

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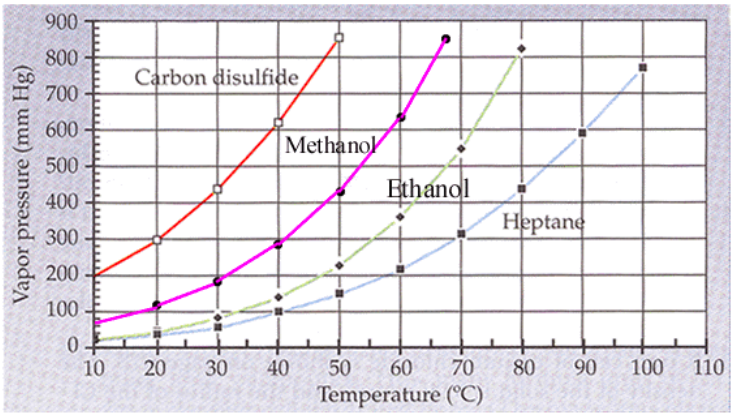
PURIFICATION OF CRUDE GLYCEROL BY A COMBINATION OF PHYSICO-CHEMICAL TREATMENT AND SEMI-CONTINUOUS MEMBRANE FILTRATIONPROCESSES
Masters Thesis by Chol Ghai Chol 2018
https://harvest.usask.ca/bitstream/handle/10388/11230/CHOL-THESIS-2018.pdfl
(methyl alcohol, wood alcohol): 66°C or 151°F at STP



The vapor pressure of **chloroform** is 400 mm Hg at **42.0** °C. From the plot of vapor pressures vs temperature above, estimate the temperature at which the vapor pressure of **carbon disulfide** is 400 mm Hg. ____ °C

The heat of vaporization of **chloroform** would be expected to be ____ than the heat of vaporization of **carbon disulfide**.

If using vacuum for lowering the boiling point of methanol, these might be useful information:

STP is 20 C and 760 mmHg

350 mm Hg at 25 C as a boiling point

110 mm Hg at 20 C