

The World Bank

Asia Sustainable and
Alternative Energy Program



Pacific Islands

COCONUT OIL POWER GENERATION:
A how-to guide for
small stationary engines

December 2009

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Acknowledgments

This guide was written by Matt Carr, World Bank Consultant, and was funded by ASTAE as part of the World Bank Sustainable Energy Financing Program. The author would like to acknowledge the support of the PNG Sustainable Development Program and the assistance of Peter Lynch (of Pelena Energy), Jan Cloin (formerly of SOPAC), Matthias Horn, and Daniel Fürstenwerth in researching, preparing, and peer-reviewing this manual.

Introduction

This “how-to” guide will assist anyone interested in running small, stationary diesel-powered engines on coconut oil. It provides you with relevant information on every aspect of fueling an engine with coconut oil.

The guide specifically describes small (less than about 50 kilovolt-amperes [kVA]) diesel generators in a stationary position. Although the information and principles given in this guide can be applied to all diesel engines, it is intended only for stationary applications—ones that typically involve few stop/starts, long running times, and consistent loads. You must consider additional complicating factors when applying the information and principles to a vehicle, for example. Diesel engines that stop/start regularly and unpredictably (for example, a car engine or a backup generator) are outside the scope of this guide.

The technical considerations for running a diesel engine on coconut oil—or any vegetable oil, for that matter—are not particularly complex. The concept of powering a diesel engine with vegetable oil is, after all, as old as the diesel engine itself. To do it successfully, however—particularly with today’s modern diesel engines—several key elements of the fuel delivery and combustion system must be “just right” or made so. If they are not suitable, the engine will be damaged, ultimately leading to premature engine failure.

A significant amount of material about running vegetable oils in diesel engines is available. Recommendations about how to go about this are as varied as the types of oils and engines themselves, ranging from the “pour-it-in-and-go” method to sophisticated conversion systems.

Most standard diesel engines will run on vegetable oil, but the key issue for the engine here is: for how long will it run? A good diesel engine that is well maintained can provide tens of thousands of hours of operation, but the “pour-it-in-and-go” method has the potential to reduce that to just tens of hours. Conversely, an overly sophisticated system may not be appropriate if there is no way to source spare parts or technical assistance.

In this guide, we will try to strike a balance between these two approaches (“pour-it-in” and sophisticated), the goal being to develop a practical solution. We want a system that:

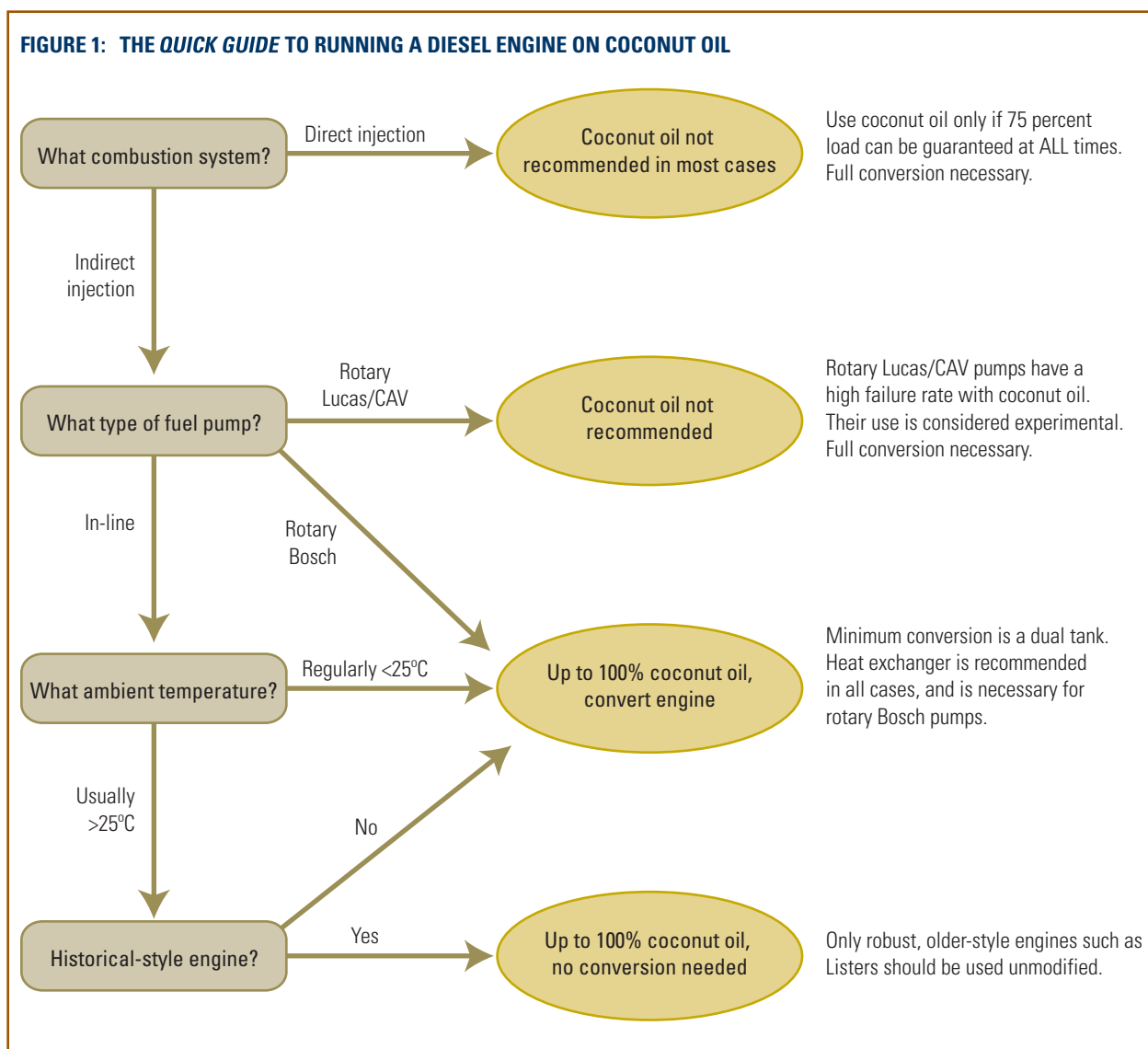
- Will work,
- Will not adversely damage the engine,
- Is manageable,
- Is suitable for the specific situation, and
- Is as simple as possible.

To fuel an engine with coconut oil, we need to consider a number of interdependent factors. These mostly relate to the type of engine being used, but also include how it is used and such local conditions as temperature. To develop a solution for any given situation, it is important to understand the impact of these variables. The following sections and chapters will provide some necessary background, including the relevant aspects of the diesel engine system and the theory of running an engine on coconut oil.

The Quick Guide

Whether a diesel engine requires conversion to be successfully operated on coconut oil is typically determined by a few key factors relating to the engine. This *Quick Guide* aims to give you a quick snapshot of the key factors that influence running a diesel engine on coconut oil. It steps you through the four main considerations when assessing the suitability of an engine for coconut oil and what adaptation measures are required to successfully operate an engine on coconut oil.

FIGURE 1: THE QUICK GUIDE TO RUNNING A DIESEL ENGINE ON COCONUT OIL



The Diesel Engine

History: It Started with Peanut Oil

The diesel engine is named after Rudolf Diesel, who presented his prototype engine—running on peanut oil—at the 1900 World Exhibition in Paris. Following this, Diesel proved that his engine could run on a range of liquid fuels, including vegetable oils, animal fats, and gasoline.

It was about this time also that new drilling technologies enabled the exploitation of cheap and plentiful petroleum fuels. Initially, these were being produced predominantly for the lighter distillates such as gasoline. When the petroleum industry realized that the low-value by-product of this refining process could power Diesel's new engine, they capitalized on it by labeling it diesel fuel. The abundance of cheap diesel fuel ultimately caused the decline of using biomass-based fuels, which since then have been used only during periods of instability in the petroleum market.

Over time, diesel engines have evolved to efficiently burn the fossil fuel powering them. In the early days, they were built strong and robust to handle the broad range of crude distillates being produced at that time. As fuel quality and standards have improved, particularly in

the past 20 years or so, engines have been optimized to run on a specific grade of diesel fuel.

Fueling the Engine: Diesel Fuel versus Coconut Oil

If you physically compare diesel fuel with coconut oil or, say, the vegetable oil you cook with at home, it is easy to understand that the two have different properties. The most obvious one of these is that coconut oil is much thicker, or viscous, than diesel fuel. This factor of viscosity accounts for many of the main problems associated with using coconut oil as fuel. The other important difference between the two relates more specifically to combustion properties, in that coconut oil has a much higher ignition temperature than diesel fuel. The key physical properties are listed in table 1 (data for rapeseed oil, a very popular vegetable-oil fuel used in Europe, is included for comparison).

In its simplest form, the diesel-fuel molecule comprises hydrogen and carbon atoms that are linked together to form a single solid chain known as a *paraffin*, comprising an average of 12 links and with a typical range of 10–16 links. In reality, the diesel-fuel molecule can come in a

TABLE 1: CHARACTERISTICS OF DIESEL FUEL, COCONUT OIL, AND RAPESEED (MULTIPLE REFEREES)

Fuel	Specific Energy (MJ/kg)	Density (kg/m ³)	Cetane Number	Kinematic Viscosity (cSt 40°C)	Solidification Temp. (°C)	Flash Point (°C)	Iodine Value
Diesel fuel	42.6	828	40–55	2–4	–9	>62	—
Coconut oil	35.8	915	60–70	27	22–25	200–285	6–12
Rapeseed	35.0	915	38–42	38	–5 to 0	290–330	100–120

Sources: See References section, table 1.

Note: **Specific Energy**—the energy released when burned
Density—the weight of fuel per unit volume
Cetane Number—the ability to ignite when compressed (the higher, the better)
Kinematic Viscosity—the ability of the fuel to flow and also atomize (the lower, the better)
Solidification Temp.—the temperature at which the fuel will become solid

Flash Point—the autoignition temperature (at which fuel will start to ignite)
Iodine Value—the fuel's chemical stability and tendency to polymerize (the lower, the better)
MJ/kg—millions of Joules per kilogram
kg/m³—kilograms per cubic meter
cSt—centistokes
°C—degrees centigrade

FIGURE 2: DIESEL MOLECULE

Schematic (left) and 3D (right) representation of the diesel fuel molecule

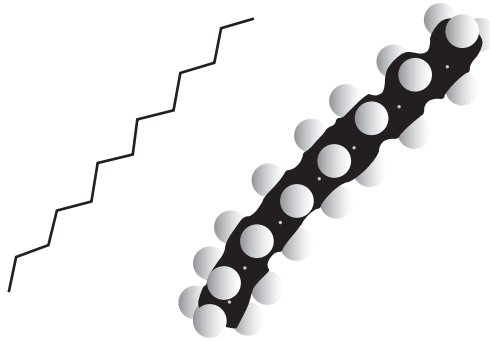
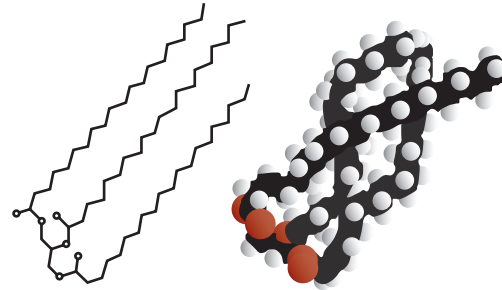


FIGURE 3: VEGETABLE OIL MOLECULE

Schematic (left) and 3D (right) representation of a triglyceride molecule



number of molecular orientations, displaying a range of chemical bondings, substitutions, and inclusions that will not be discussed here in more detail.

Coconut oil, like all vegetable oils, predominantly comprises hydrogen and carbon atoms that are linked together. They differ from diesel fuel, however, in that instead of forming a single chain, three chains are all linked together at one end to form something like a tripod, which is referred to as a *triglyceride*.

All vegetable oils will burn and therefore have the ability to be used as a diesel-fuel alternative. Different types of vegetable oil, however, display very different properties, which makes some vegetable oils more suited to replacing diesel fuel than others. In this sense, coconut oil can be considered one of the best vegetable oils for use as a diesel-fuel alternative because it is made up of medium-length, saturated hydrogen and carbon chains, making it chemically stable and less likely to react or polymerize. It also has better combustion properties than any other vegetable oil.

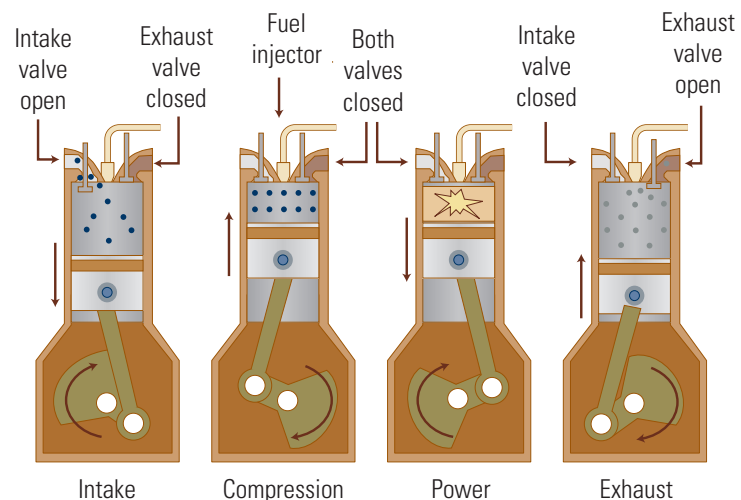
Diesel Engine Basics

The diesel engine is an internal combustion engine that uses compression ignition to ignite the fuel injected into the combustion chamber. It does this by first compressing air in the combustion chamber with a piston, causing the air to become very hot. Fuel is injected into this hot pressurized air and spontaneously combusts, increasing

the pressure in the chamber and forcing the piston or power stroke. In contrast, gasoline engines operate by spark ignition, in which fuel and air are mixed before entering the combustion chamber and ignited by a spark. Diesel engines contain no spark plugs, ignition coil, distributor, or carburetor; their overall simplicity makes them more reliable and durable than a gasoline engine.

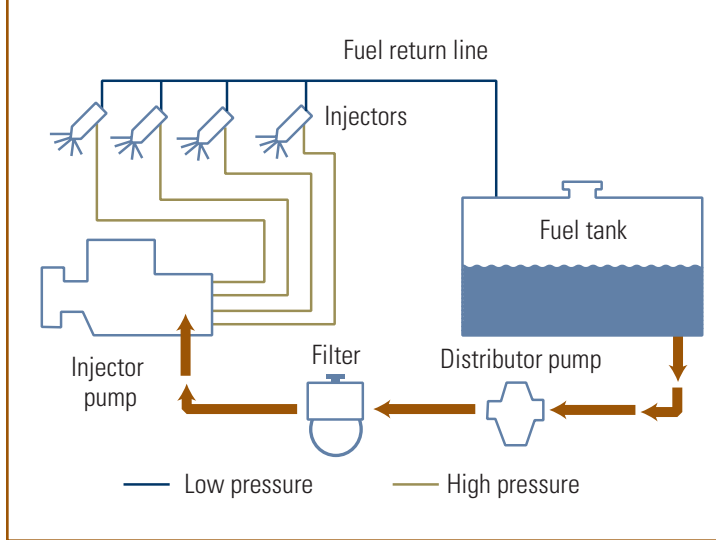
Most diesel engines operate on a four-stroke cycle, consisting of two up and two down strokes of the piston and two revolutions of the crank shaft per cycle. Typically only very large engines, such as those in large ships, operate on a two-stroke cycle.

FIGURE 4: DIESEL FOUR-STROKE CYCLE



Most diesel engines operate on the four-stroke cycle.

FIGURE 5: FUEL DELIVERY SYSTEM OF A DIESEL ENGINE



Fuel is delivered from the tank to the combustion chamber via low-pressure and high-pressure systems. The low-pressure system is made up of the fuel tank, the fuel-distribution pump, and one or more filters. On some small engines where the fuel tank sits above the engine there is no distribution pump and fuel is fed by gravity and the suction created by the injection pump. The primary purpose of the low-pressure system is to deliver fuel from the tank to the injection pump.

The main components of the high-pressure system include the injection pump and the injectors. The injection pump builds up the necessary pressure to spray a dosed amount of fuel into the combustion chamber via the injector nozzles. The pump always delivers an excess of fuel to the injectors, which is returned to the fuel tank via the return line.

Although all diesel engines are alike in that they use the principle of combustion ignition described above, they

can come in all shapes and sizes and with many refinements. Some of these variants are critical when running a diesel engine on coconut oil. The two most critical factors are the type of combustion system and the type of injection pump.

Combustion System

Fuel can be injected and combusted in two different ways in a diesel engine: one method is to inject the fuel directly into the cylinder chamber while the other injects fuel into a precombustion chamber that is offset, but attached to the cylinder chamber. These methods are called *direct injection* and *indirect injection*.

Direct injection. The prevailing type of injection system in small, modern diesel engines is direct injection. It is preferred to indirect injection because of the greater efficiency (approximately 10 percent), resulting from reduced heat loss. The piston has a hollow in the top that contains most of the compressed air when the piston is at the top of the cylinder during the compression cycle. Fuel is injected through a multiport injector nozzle into the piston hollow, mixes with the compressed air, and combusts. In direct-injection engines, the ability of the injector to deliver a finely atomized mist of fuel is responsible for good fuel-air mixing and complete combustion.

Small direct-injection engines have become common only in the past 10 years or so. If they were run on the diesel fuel common 20 or more years ago, most direct-injection engines would not have lasted very long. The variable grade of diesel fuel back then would have impacted (over time) the spray pattern required to achieve complete combustion and started creating problems with carbon deposits. In addition, the cooler combustion temperatures

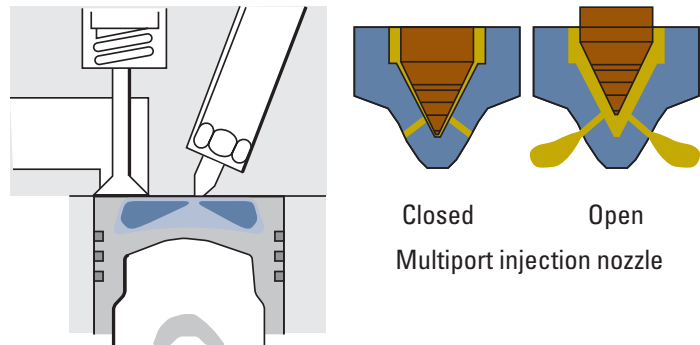
Q Which combustion system is best for coconut oil?

A multitude of studies on using vegetable oils in unmodified direct-injection engines have indicated that it leads to premature engine failure. This is typically attributed to incomplete combustion of the fuel, which creates carbon deposits throughout the combustion system.

However, in several cases in the Pacific, coconut oil has been successfully used in adapted direct-injection engines. Although this has been considered experimental and a risk to engine life, many reports indicate no detrimental effects in practice if certain procedures and conditions are consistently met. These include starting and stopping the engine on diesel fuel, preheating the fuel, and maintaining a consistently high load on the engine at all times.

A Indirect injection is best. Direct injection is feasible only if certain adaptations to the engine are made.

FIGURE 6: DIRECT INJECTION

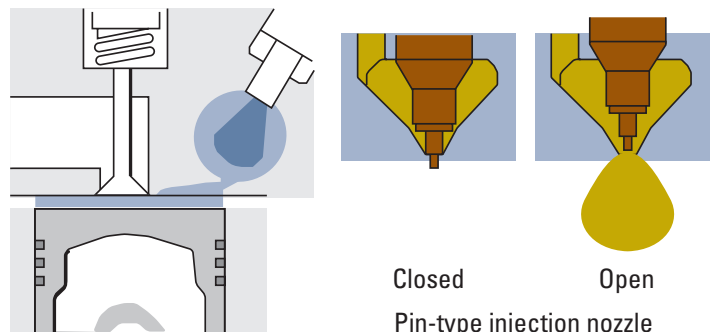


The single orifice of the pin-type injector nozzle is larger than that of the multiport nozzle in direct-injection engines, making the former more suitable for crude fuels. The pin-type nozzle also has a self-cleaning effect, unlike the multiport nozzle.

Injection Pump

The injection pump is responsible for delivering high-pressure fuel to the injector nozzle. In some engines, particularly small ones that have the fuel tank raised up above the engine, the injection pump is the only pumping mechanism used to deliver fuel from the tank to the injector. In most engines, a distribution or "lifter" pump first draws the fuel from the tank to the injection pump.

FIGURE 7: INDIRECT INJECTION



Injection pumps in small generator engines typically fall into one of three categories: *jerk* or *single-cylinder pumps*, *in-line pumps*, and *rotary pumps*. Electronically controlled and high-pressure pumps such as *common rail* or *unit injection pumps* are uncommon in small generator engines; however, common rail is becoming increasingly common in automotive and large industrial diesel engines, so this trend may change. Today's common rail injection systems are not suitable for using with

in direct-injection engines would not always have been high enough to completely burn all fractions of a crude diesel fuel, leading to further problems with deposits.

Indirect injection. Most older diesel engines use indirect injection. This combustion system was designed in an era when fuels were crude, and as such, these engines are generally more durable and reliable compared with their direct-injection counterparts. The piston head does not have a hollow, and the air in the precombustion chamber gets compressed and heated.

Fuel is sprayed by a single-port, pin-type injection nozzle into a precombustion chamber adjoining the top of the cylinder (hence the name *indirect injection*). In indirect-injection engines, the turbulent air flow created in the precombustion chamber is responsible for fuel-air mixing, leading to complete combustion. Most of the fuel combustion takes place inside the precombustion chamber, and then the expanding gases flow into the main cylinder chamber to drive the power stroke. The chamber is also referred to as a *prechamber*, *swirl chamber*, or *turbulence chamber*.

coconut oil, but their electronic management systems could, in the future, allow for the use of variable fuels.

Jerk pumps are the simplest type of injection pump and are found only in single-cylinder engines. They use a piston-and-barrel-style mechanism to deliver fuel to the injector via a high-pressure pipe. The piston inside a jerk pump uses a timing mechanism running from the engine camshaft.



In-line pumps operate on the same principle as jerk pumps, but are for multi-cylinder engines. A number of jerk pumps are combined "in-line" to form a single component. The pistons operating

each injector use a timing mechanism running from the engine camshaft.

TIP: In-line pumps and rotary pumps can be distinguished from each other by the location of the pipes exiting the pump. With rotary pumps, the outlets are arranged in a square or circular configuration and come out of the side of the pump. The outlets on an in-line pump come out in a row across the top of the pump.



Bosch-style rotary pump



Lucas/CAV-style rotary pump

Rotary pumps are found on modern multicylinder engines and use a single pumping mechanism rotating at high speed to distribute fuel to as many as six cylinders. They typically operate at higher pressures than in-line pumps; to achieve this, they operate at very high speeds.

Rotary injection pumps are produced by a large number of manufacturers, yet most models are licensed copies of either Bosch or Lucas/CAV. Bosch-style

rotary pumps are also produced by Denso, Zexel, and Diesel-Kiki. Lucas/CAV-style pumps also appear under the brand names Stanadyne, Roto-Diesel, Condiessel, and Delphi.

Q Which injection pump is best for coconut oil?

Jerk and in-line pumps are more robust than rotary pumps and are suitable to use with coconut oil. Lucas/CAV injection pumps are susceptible to malfunctions when running on coconut oil because of their less rugged construction. Successful use of these pumps is reported, but it should be attempted only if you have a high degree of mechanical resources available. Great care should be taken to ensure that the coconut oil is thoroughly filtered, heated, and/or blended before use. Bosch rotary pumps use a more robust mechanism and can be safely run on heated or blended coconut oil.

A Jerk and in-line injection pumps are best. Bosch rotary pumps can be used with coconut oil, but Lucas/CAV pumps have high failure rates.

Coconut Oil as Fuel

Most diesel engines can run on 100 percent coconut oil, at least for a short while. Tempting as it may be to simply pour coconut oil into the fuel tank of your engine, this approach will probably have you shopping for a new generator in a very short space of time. However, if you have a sound understanding of the issues of using coconut oil and effectively manage those issues, then your coconut-powered generator can run as long as a generator using diesel fuel—or even outlive it. Some of the key points regarding the type of engine were touched on in the previous section. Here we will discuss the key problems with using coconut oil and provide the necessary information about how to avoid them.

The Main Issues

There are two fundamental issues with using coconut oil in a diesel engine:

- Incomplete combustion
- Viscosity

Incomplete Combustion

For coconut oil to burn completely, a minimum combustion chamber temperature of 500°C is required, compared with about 250°C for diesel fuel. If this minimum is not reached, partially burned fuel will form carbon deposits (coking) on injector nozzles, cylinder walls, and elsewhere throughout the combustion system. Coked injector nozzles have a strong, self-enforcing negative effect. This is particularly the case for multiport injector nozzles found in direct-injection engines, where a finely atomized fuel-spray pattern is more critical. Deposits around the injector ports create an uneven spray pattern,



This multiport injector tip shows significant carbon buildup, which has a self-enforcing effect.



Partially burned fuel on the cylinder walls has caused the top piston ring to stick and completely malfunction.

producing larger fuel droplets that do not burn completely, leading to more carbon buildup and escalating the problem that will eventually lead to engine failure if left unchecked.

If partially burned fuel makes contact with the cylinder walls, it will get picked up by the piston rings and can cause them to stick and malfunction. Also, very low combustion temperatures will leave unburned fuel on the cylinder walls that can be transferred to the engine sump (oil pan) either by the sweeping nature of the piston or blown through as “blowby” because of malfunctioning piston rings and lost compression.

To achieve complete combustion using coconut oil, it is critical that the engine is regularly and consistently loaded—a typical rule of thumb being about a 75 percent load. This will ensure that complete combustion is achieved. This factor is critical if attempting to use coconut oil in direct-injection engines: a load of 75 percent or more **MUST** be placed on the engine at all or nearly all times. In contrast, indirect-injection engines are more tolerant of underloading and have proven that they can

TIP: White smoke coming out of your exhaust pipe indicates that the fuel is not combusting completely and is usually caused by the engine being underloaded. Hold a piece of white paper or cloth over the exhaust airstream while the engine is running, and check for deposits of unburned coconut oil.

successfully run on loads down to 50 percent. There are three reasons for this: the precombustion chamber retains heat, assisting combustion; any partially burned fuel lines the precombustion chamber, rather than the walls of the cylinder chamber, and gets blown out with the exhaust gases; and the single larger port of the pintail injector nozzle has a self-cleaning effect and is less susceptible to coking. (Direct-injection engines are more susceptible to problems for the opposite of these reasons.)

Higher Viscosity

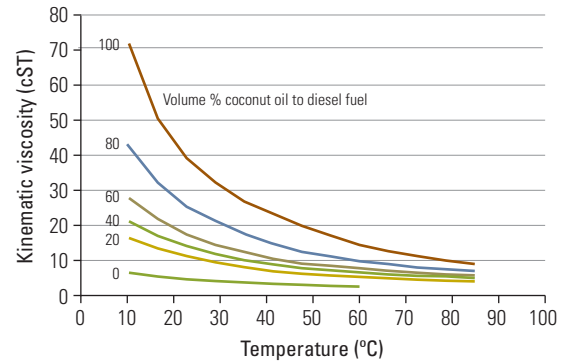
At 25°C, coconut oil is about 10 times more viscous than diesel fuel. This can have two detrimental effects on the engine: it produces an altered spray pattern of injected fuel, and it creates additional stresses on both the injection pump and the distribution pump.

The more viscous coconut oil will not produce as fine a fuel mist as with diesel fuel, and the larger droplets do not burn as effectively. This leads to the problems of incomplete combustion and deposits of carbon throughout the combustion system, introduced above. Multi-port injector nozzles in direct-injection engines are more prone to this problem because they have smaller holes than pin-type injectors. This problem is even worse in very small (about 5kVA) direct-injection engines.

Experience has shown that jerk and in-line injection pumps are better able to tolerate the more viscous coconut oil than rotary pumps, particularly those of the Lucas/CAV variety.

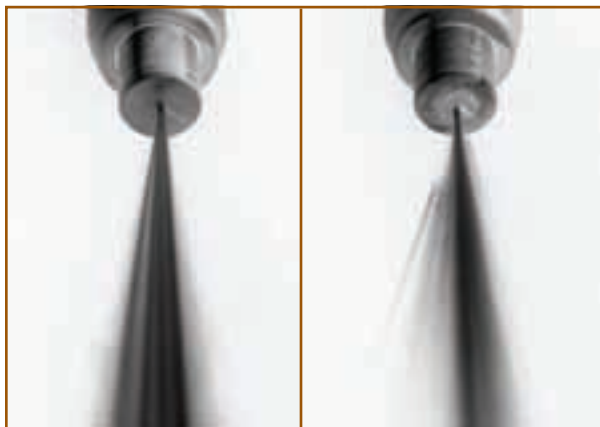
The viscosity of coconut oil can be reduced by two methods: heating and blending. The adjacent graph

FIGURE 8: VISCOSITY OF COCONUT OIL AND DIESEL BLENDS OVER A RANGE OF TEMPERATURES



indicates the overall effect on viscosity as different blends of coconut oil and diesel fuel are heated. The graph shows that at temperatures around 80°C, coconut oil has a viscosity of about 10 centistokes (cSt)—the measurement for kinematic viscosity—which is only twice the viscosity of diesel fuel at normal operational temperatures. Most diesel-engine makers specify a maximum fuel viscosity of 10–15 cSt, so coconut oil at 80°C is within the design parameters of most diesel engines at this temperature.

TIP: You can test the comparative viscosity of coconut oil against diesel fuel yourself by timing how long it takes for a marble or ball bearing to fall through a fixed vertical column of each liquid (using a tall glass tube is best).



The fuel spray pattern of a single-port pin-type fuel injector is detrimentally affected on the right by using more viscous fuel.

Coconut oil can be safely blended with diesel fuel in any ratio to thin the fuel. This approach is used by many practitioners during times of cooler weather as a safety measure. Others blend with a small percentage (less than 10–15 percent) of kerosene to achieve the same result, but because the cetane number of kerosene is substantially different from that of diesel fuel, it results in two separate ignitions during the ignition cycle, which is believed to stress the engine.

NOTE: Cetane is a 16-carbon-chain paraffin that is used as a reference material to measure the combustibility of fuels: the higher the cetane number, the better the combustion quality of the fuel during compression ignition.

Other Issues

A number of other issues can arise from using coconut oil. These can be broken down into the following categories:

- Solidification temperature
- Filter blockage
- Carbon deposits
- Lubrication oil deterioration
- Distribution pump problems

Solidification Temperature

Coconut oil solidifies within the temperature range of 22–25°C. At temperatures within or below this range, the semisolidified to solidified oil can have a catastrophic impact on the injection pump and the distribution pump.

Heating or blending is the solution to this problem. In climates where temperatures commonly drop to 25°C, you can install a dual-tank system, so the engine can be started and heated up on diesel fuel, or you can blend with diesel fuel or kerosene to lower the solidification temperature.

Filter Blockage

Using coconut oil as fuel can cause filter blockage for a variety of reasons, putting stress on the injection pump and distribution pump and potentially leading to failure of either pump. When using coconut oil, it is important to use a quality filter rated to 5 microns; because these can be expensive, you do not want to have to change them regularly.

The first step is to ensure that the oil used is of sufficient quality (that is, prefiltered to 5 microns or less, dewatered, and without an excessively high free-fatty-acid content [free fatty acids are discussed in more detail in the section on Oil Quality in the chapter on Oil Production]). Poorly filtered oil will quickly block your engine filter with coconut particulate matter. If the oil has been prefiltered, then the engine fuel filter merely acts as a final safety step and should not block for this reason.

If there is water in the oil or in the fuel tank, it can emulsify with free fatty acids and form a white sticky or gummy residue that will block your filter. High free fatty acids can also react with some metals and rubber components in the fuel system to produce globular residues, but this only occurs when they are in very high concentrations, indicative of very low-grade oil. (More will be discussed about water and free fatty acids under Oil Quality.)

Another common cause of filter blockage follows the introduction of coconut oil into an engine that has previously been operated on diesel fuel. Fuel tanks get dirty over time, particularly if the diesel fuel used has been handled multiple times and passed through dirty fuel drums or containers. Much of this dirt will settle out in the base of the fuel tank. Coconut oil is about 10 percent denser by volume than diesel fuel, which means that some particles that settle out in diesel fuel will, when in coconut oil, float or become neutrally buoyant. This newly mobilized dirt will block the fuel filter following changeover from diesel fuel to coconut oil. To avoid this problem, the fuel tank should be removed and thoroughly washed before switching over to coconut oil.

TIP: Remove and thoroughly clean the fuel tank before switching to coconut oil.

The final common cause of filter blockage is the result of the buildup of solid oil on the filter medium. Although coconut oil solidifies between 22°C and 25°C, a tiny percentage of oil can precipitate out as a solid fat at temperatures above this. If you allow well-filtered coconut oil to stand in a glass jar for a period of two weeks or more, you can see this solid fat accumulate on the base of the jar, and if rubbed between two fingers, it readily melts. The problems caused by this fat can be solved by either heating the fuel or settling the oil for a period of two weeks.



Carbon deposits on head of exhaust valve and inside exhaust manifold indicate incomplete combustion.

Carbon Deposits

Earlier in this chapter, we discussed how incomplete combustion can lead to the formation of carbon deposits on injector nozzles and piston rings and how this can lead to engine failure. Carbon deposits can also form in other areas of the combustion system, causing problems with airflow and compression and a reduction in power and further worsening the well-known problems. The areas where this can occur include the exhaust valves and inside the exhaust manifold itself. Deposits can form on the valve heads so that they do not seal properly, causing compression loss, and also on the valve stems, which can lead to the valve sticking. A buildup of deposits inside the exhaust system affects the required back pressure and also leads to power loss.

Deterioration of Lubrication Oil

Deterioration of lubrication oil can occur when unburned coconut oil gets into the engine sump by being swept off the cylinder walls by the pistons or blown through as blowby because of malfunctioning piston rings. Whereas diesel fuel evaporates out of the hot lubrication oil, coconut oil accumulates. This in turn reduces the overall viscosity and lubricity (the “antiwear” property)

TIP: Monitor lubrication oil levels regularly, and if you see them increasing, you know that coconut oil is entering the engine sump.

of the lubrication oil, increasing the wear on bearings and other moving engine parts. This problem is usually symptomatic of an underloaded engine, although issues with compression loss or injection timing can create the same outcome.

Distribution Pump Issues

Most distribution pumps use a diaphragm-pumping mechanism to deliver fuel from the tank to the injection pump at low pressure. These pumps are typically quite robust, but can suffer a reduced design life because of the higher viscosity of coconut oil. In most cases, the failure rate is very low, and you can expect to get many years of trouble-free operation before any issues arise. Apart from ensuring that the coconut oil is completely liquid, little can be done to negate this hazard; just accept it as one of the elevated operational risks of using coconut oil.

Options for Using Coconut Oil

To operate a diesel engine on coconut oil, there are four options:

- Use an unmodified engine with 100 percent coconut oil
- Adapt the engine and use 100 percent coconut oil
- Blend coconut oil and use in either unmodified or modified engine
- Modify coconut oil chemically to produce biodiesel fuel and use in unmodified engine

This manual will address the first three options mentioned above, but will not discuss further the modification of coconut oil to form biodiesel fuel. The chemical process called *transesterification* used to produce biodiesel fuel requires the use of a specially built reactor vessel and chemicals that can be difficult and expensive to source and potentially unsafe to use. In any case, the extra effort, expense, and potential for producing poor-quality biodiesel fuel are not warranted in most cases in relation to small stationary power systems.

Unmodified Engine Using 100 Percent Coconut Oil

Using an unmodified engine on 100 percent coconut oil is viable in the long term only if both the engine and the climate are suitable. This approach is only recommended with “historical-style” engines using design principles that are a few or more decades old. Modern-day production of such engines is all but limited to China and India. Compared with their modern-day counterparts, these engines are slower, have a long bore stroke, and are fitted with a heavy flywheel.

Possibly the best-recognized engines to fall into this category are those of the Lister CS series. True Lister engines have not been made since 1987, but since then, a range of copies, commonly called *Listeroids*, have been produced in India under a host of different names. Most

historical-style engines produced in China are based on the design of Changfa engines and are produced by many manufacturers. These engines have often run successfully—unmodified—on coconut oil throughout the Pacific and in Asia. The key point in choosing an engine of this style—or any other engine, for that matter—is whether spare parts are easily available.

Adapt Engine and Use 100 Percent Coconut Oil

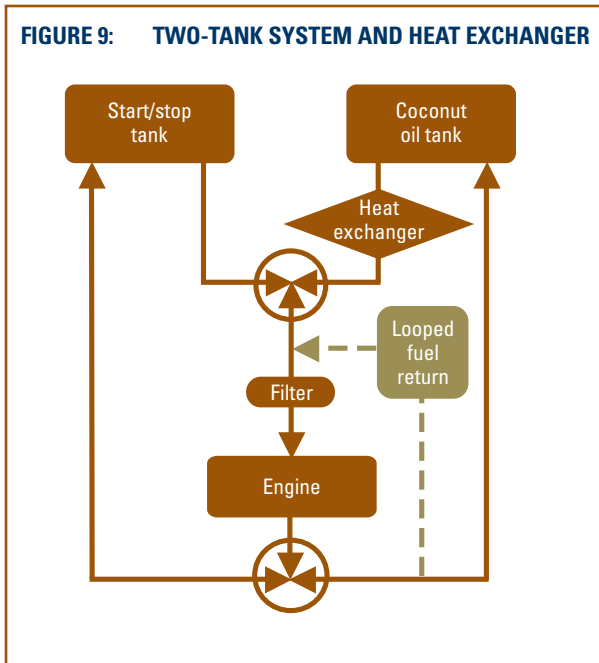
In most situations, some form of engine modification is recommended. Many adaptation technologies are available, and several companies now make conversion kits that can be bought off the shelf or ordered through the Internet. These commercial kits are typically designed for the conversion of diesel vehicles. Although these kits (or at least parts of them) can be used on a generator engine, most components either are unnecessary or can be easily sourced locally and more cheaply. Because vehicle engines regularly stop and start and have varying loads, they require a more complicated conversion system than do stationary engines.

Adaptation technologies recommended in this manual consist of modifications to the fuel delivery system only and include the *two-tank system*, the *two-tank system and heat exchanger*, and *looping the fuel return*. Although it is possible to make changes to the cylinder, injectors, pistons, and injection pump (for example) and to alter combustion timing, these measures are considered too costly and impractical for small diesel engines.



Lister (left) and Changfa (right) engines are typical of “historical-style” diesel engines.

FIGURE 9: TWO-TANK SYSTEM AND HEAT EXCHANGER



Two-Tank System

A diesel engine is particularly susceptible to damage on start-up when the engine is cold. The simplest and minimum adaptation method to counter many of these issues is the inclusion of a second fuel tank. The dual-tank system with a manual switching device allows the engine to be started and stopped on diesel fuel, while being dominantly powered by coconut oil. This approach means that the engine is sufficiently hot before introducing coconut oil and that the fuel lines and filter are flushed with diesel fuel before the engine is turned off. The amount of time required for the engine to reach operating temperature is dependent on the engine, but five minutes is usually sufficient. To determine the time required to flush the system, you can measure the time it takes from switchover for diesel fuel to come out of the fuel return line.

Two-Tank System and Heat Exchanger

Adding a heat exchanger to the coconut-oil line represents an added safety measure and is recommended in all instances. A heat exchanger uses a heat source from the engine to pre-heat the coconut oil before it is

injected, reducing its viscosity so it behaves more like diesel fuel.

The heat exchanger should be placed on the coconut-oil fuel line before the junction with the diesel line so that diesel fuel from the start/stop tank does not pass through the heat exchanger. With the heat exchanger located in this position, the coconut oil is heated before passing through the filter, reducing stress placed on the pumping system and stopping the accumulation of any solid oil in the filter.

The most convenient heat source to use is the coolant fluid (that is, radiator water), which typically maintains a temperature above or around 80°C once the engine is up to operating temperature.

A suitable heat exchanger should raise the temperature of the coconut oil close to this temperature so that the viscosity of the coconut oil is approaching that of diesel fuel. The idea here is to start the engine on diesel fuel to allow the engine and coolant water heat up and then to switch across to coconut oil once everything is hot.

A number of heat exchanger varieties are appropriate for this job. Commercially built varieties can be bought or ordered at marine, truck, or general engineering-supply stores and generally fall into two categories: plate heat exchangers and shell-and-tube heat exchangers. Alternatively, you can make one yourself or have one made up for you. Homemade exchangers or workshop varieties can be built from stainless-steel pipe (preferred), steel pipe, or copper pipe and threaded pipe fittings (for example, BSP, BSPT, NPT, and others) to suit connection to the engine. Copper is less preferred because it can react with the free fatty acids in the oil. The reaction, however, is very slow, and there are many cases where copper has been used successfully for many years without trouble.



Commercially made heat exchangers include plate (left) and shell-and-tube (right).



The simplest approach for small engines is to run coolant through a length of copper pipe adjacent to another section of metal pipe for the fuel and insulate the two pipes together. This is referred to as the *hose-on-hose method*. The amount of heat transfer will depend on the length that the two pieces of pipe are in contact, which may not be effective in raising the coconut-oil temperature to the target 75–80°C.

A more complicated and more effective option is to run the fuel-line pipe inside a pipe carrying coolant fluid; this is called the *hose-in-hose method*. There are many variations of the hose-in-hose method, including coiling the pipe inside the coolant hose to increase the surface area. The longer the contact between the fuel line and the coolant fluid, the greater the heat exchange will be.

If your engine is not water cooled, the alternative is to loop a section of copper pipe carrying the coconut oil around the engine exhaust pipe. This approach, however,

should be attempted only on single-tank systems and as such is limited to historic-style engines or engines using indirect injection and a jerk or in-line injection pump.

Using the exhaust heat is a considerably more risky option compared with using the coolant fluid. Whereas coolant fluid will maintain a consistent temperature of about 80°C, the exhaust temperature can range between 250°C and 500°C, depending on the type of engine and how much load is on the engine.

TIP: When bending copper or other metal pipe, fill the pipe with fine sand before attempting to bend. This will stop the pipe from pinching and breaking. Clear the pipe using compressed air afterwards.

If the coconut oil is heated above 100°C, it can cause residual water to boil off, which can damage the engine and potentially rupture the fuel line, causing a fuel hose to blow off. For these reasons, it should be attempted only if there are no other options available. It should not be used in conjunction with a dual-tank system because the coconut oil will overheat when running from the diesel-fuel start/stop tank. If attempting this method, start with about five coils and check the temperature of the pipe as it leaves the exhaust. If it is not hot enough, you can try another winding and so on.

The final option for preheating coconut oil is electric heating. Commercially made fuel heaters typically use a 12 volt (V) input and have a built-in upper limit of about 70°C. Heated fuel filters are made by a number of filter



Copper tubing coiled around the exhaust of this Lister heats the fuel to 80–90°C before it is injected.

manufacturers and work very well, but in the Pacific they will usually need to be ordered from overseas. In-line fuel heaters can also be ordered through overseas suppliers.

Electric heaters can sometimes draw many amperes of current, sometimes close to the maximum output of the alternator, thereby reducing the usable power available for other items. Care should also be taken to ensure that any electric heater does not operate at excessively high temperatures that will char the coconut oil. Given that most engines have an unused waste-heat source in the form of coolant water that can be used to preheat the fuel, electric heating is not the preferred method of preheating fuel.

Fuel Blends

Coconut oil can be blended with diesel fuel in any ratio to reduce the overall viscosity of the fuel. Kerosene can also be used, but no more than a 15 percent blend is recommended because of the different combustion properties. Blending is most suited to situations in which an unmodified engine is being used to reduce the solidification temperature in times of cool weather. The use of alcohols, petrol, surfactants, cetane improvers, solvents, and other fluids should be avoided.

In most Pacific island countries, the hot tropical weather means that blending is usually unnecessary (and besides, the concept of using coconut oil is primarily about not using diesel fuel). Although blending has been popular with those using coconut oil in unmodified vehicles, in stationary engines, with their predictable and consistent usage patterns, heating coconut oil is considered a more practical option to reduce viscosity.

Adapting an Engine for Coconut Oil

In the previous section, we looked at the options for using coconut oil in a diesel engine. Of the few available, adapting your engine is recommended in most cases. Three adaptation options are recommended:

- Dual-tank, so the engine starts and stops on diesel fuel
- Dual-tank with heat exchanger, so the coconut oil is preheated before it is injected
- Looping the fuel return to reduce stresses on the injection pump

The method you choose will depend on the type of engine you have, the ambient temperatures, and the level of precaution you wish to take.

The most common and practical method of preheating the coconut oil is to use a coolant-heated heat exchanger (the steps required to install this system are discussed below). Exhaust heating is not discussed further because it applies only to single-tank systems and simply involves coiling a section of copper pipe around the exhaust. Electric-heated filters and in-line heaters are not discussed further because these methods involve merely installing the system in-line with the fuel-supply line, in accordance with supplier instructions.

Essentials

Before switching to coconut oil, it is essential that the following two measures are met:

- A quality fuel filter rated to 5 microns is installed.
- The fuel tank is free of dirt and/or water.

In most situations, the fuel filter should be upgraded to one rated to 5 microns and of larger capacity (about double) than the factory-supplied filter. Some manufacturers make 12V or coolant-heated fuel filters, which are ideal for using with coconut oil. In tropical Pacific countries, however, these are invariably difficult to obtain, and it is usually easier to use a standard filter and a heat exchanger to achieve the same result. Quality filter manufacturers include, but are not limited to, Racor, Baldwin, Fleetguard, DAVCO, Lucas/CAV, Delphi, and Bosch.

If you are heating your coconut oil before it passes through the filter, you need to ensure that the filter is rated for heated fuel. This should be indicated either on the filter itself or on the packaging that comes with it. The brands mentioned above typically use the same filter medium for their fuel filters as they do for their oil filters and, as such, do not have problems with heat. Low-quality paper filters have been known to disintegrate with heated fuel, causing blockage and failure of the injection pump.

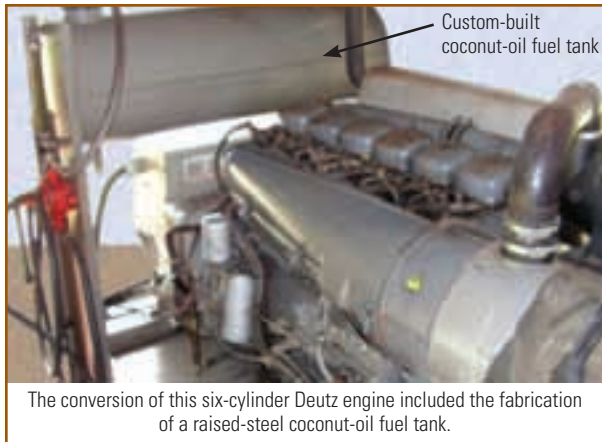
TIP: Before using an unknown filter type on coconut oil, you should fully immerse the filter cartridge in heated coconut oil for 24 hours to check that it does not degrade the filter material or the glues used.

Fuel tanks get dirty over time, particularly if the diesel fuel used has been handled multiple times and passed through dirty fuel drums or containers. Much of this dirt will settle out in the base of the fuel tank, except with some small generators, where the tank sits above the engine and the fuel drains from the base of the tank.

As we saw in the section on Filter Blockage in the previous chapter, coconut oil is about 10 percent denser by volume than diesel fuel, which means that some particles that settle out in diesel fuel will float or become neutrally buoyant in coconut oil. This mobilized dirt will block the fuel filter following changeover from diesel fuel to coconut oil. To avoid this problem, the fuel tank should be removed and thoroughly washed before switching to coconut oil. This can be done using soapy water and successive thorough rinses of water and then diesel fuel or coconut oil before being reinstalled.

Dual-Tank System

In most cases when installing a dual-tank system, the simplest option is to use the original fuel tank as the coconut-oil tank and then install a small, auxiliary start/stop diesel tank. Ideally, the coconut-oil tank should be positioned above the engine, to reduce stress on the fuel pumps, and close to the engine, to receive heat from the



engine. In places where temperatures drop below 25°C, the radiant heat of the engine can be sufficient to ensure that the coconut oil is fully liquid before the engine is switched across from diesel fuel. If you do not think that radiant heat is sufficient, a small U-bend of metal pipe (preferably stainless-steel) connected to the coolant fluid can be fitted and used to heat the fuel tank. Taking these factors into consideration, you might decide that the original tank is not suitable for coconut oil and buy or construct a new one.

TIP: If you decide to make a fuel tank, do not use galvanized steel because the coconut oil will react with the zinc coating.

Any sealed and vented container suitable for diesel fuel or chemical storage can be used as the start/stop diesel tank. The easiest option is to use a small tank designed for fuel (such as an old tank from a small diesel generator or lawn mower). Other examples include outboard motor-fuel tanks or high-density polyethylene (HDPE) plastic containers.

The start/stop tank should be bolted or braced to the engine or chassis or located in a suitable and secure position. Additional fuel lines will need to be purchased or acquired, along with some valves to allow the switching from one fuel to another. These items should be sized to match the original fuel lines.

The switching mechanism can be fitted using either two three-way valves or four ball valves and two T-pieces. Three-way valves are more convenient to use, but are more expensive and sometimes difficult to source. The junction where two fuel lines meet should be located above the fuel filter.

Dual-Tank and Heat Exchanger System

There are usually a number of options for tapping into the coolant-water system of your engine. You will need to decide what option is best or easiest for you, based on the engine you have.

If your engine has a factory-designed coolant circuit that you can tap into, this is the simplest and most common option. In vehicles, this circuit supplies hot water to the adjustable cabin-heater unit. Most diesel engines in generators larger than about 10kVA will have such a circuit, but it will be plugged off. In this case, it is simply a matter of removing the plugs and plumbing into the ports.

The location of these ports varies from one engine to another, and you may have to consult the operator's manual to find them. Typically, they are $\frac{3}{8}$ inch (9.525 mm) in size, and one will be located somewhere around the engine head, near the outlet of the water pump, and close to the junction for the radiator hose or somewhere along the manifold. You can recognize it because the plug will usually have a square nib on the end, rather than a hexagonal one like most nuts. A port in this position will act as the hot-feed inlet for your heat exchanger.

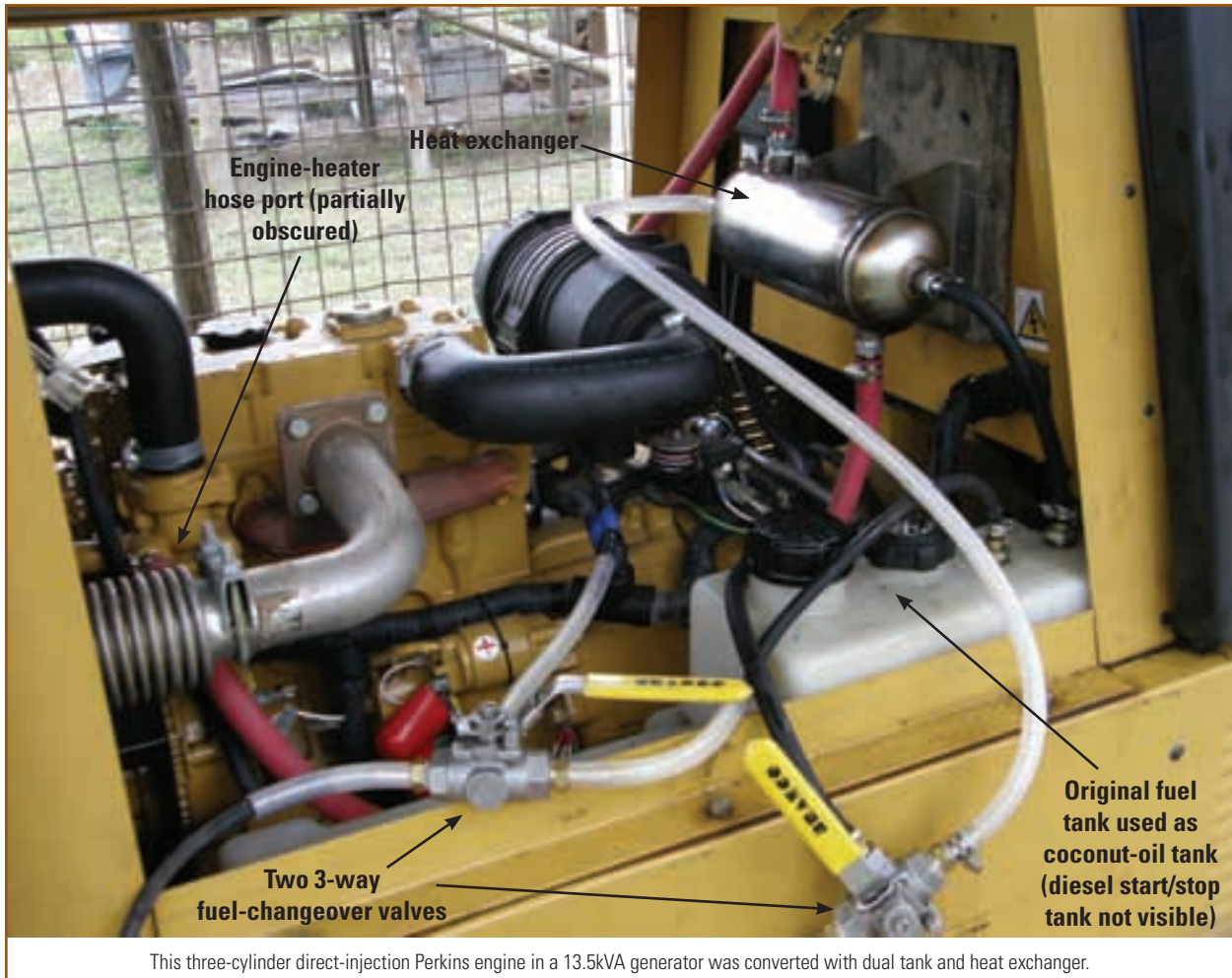
The outlet from your heat exchanger will then need to feed back into the coolant system. In most cases, this should connect directly into the radiator, using a purpose-built port (if there is one) or using the drainage port at the base of the radiator.

Another option is to tap into the water line designed to cool the lubrication oil. In many engines, an external pipe comes out of the engine block and runs into the junction where the oil filter screws on. Your heat exchanger can be installed in-line with this pipe. It is usually a fixed metal pipe, and you will need to cut away a section so you can attach the heater hoses onto it.

If none of the above options are available, another one is to install your heat exchanger into the main radiator hose. If choosing this option, the most important consideration is that you do not restrict the flow of water because this will put stress on the water pump and cause the engine to overheat.

Looped Fuel Return

Looping the fuel-return line back into the supply line adds another level of complication to the conversion, but helps reduce the stress on the injection pump. In most cases, it is considered unnecessary, but if you are attempting to



convert an engine with a Lucas/CAV injection pump, it is highly recommended. These pumps are less rugged than others, and a looped return is one method of reducing the stresses on the pump.

All diesel engines draw more fuel to the injector than what is actually required by the engine. The surplus fuel exits a port in the injector housing and returns back to the fuel tank via the return line. Looping the return line refers to splicing the return fuel back into the supply line, using a "tee" piece. The junction should be located just before the filter.

This system has two beneficial effects: it reduces the stress on the injection pump because less fuel is drawn from the tank, and it helps boost the temperature of the coconut oil. The downside of looping the return is that any air that gets into the system is not given the opportunity to escape. It is critical when installing a looped return that you thoroughly bleed the fuel system and ensure that all connections are airtight. If you notice reduced

power from your engine and other possible causes such as a blocked filter or fuel line are not at fault, then it is likely that you have air in your line, and you will need to bleed the system again.

Bleeding the Fuel Line

When you adapt your engine to run on coconut oil, you will invariably introduce air into the fuel-distribution system that must be bled out. The easiest way to remove air is to manually pump fuel from the tank toward the engine and vent air at all available points along the fuel system. Most diesel engines will have a built-in primer pump for this purpose, but if not, a squeeze-bulb pump for an outboard motor can be fitted to the supply line coming out of the fuel tank.

Bleeding begins downstream from where air leaked in and must be done in order, starting at the filter (or filters), and moving toward the injectors. In the case of

a two-tank modification, bleeding begins at the primary filter (if there is one) and moves on to the secondary filter. In most cases, the primary or coalescing filter will not accumulate air, and you can move directly to the secondary filter. Either way, air can be removed from the filters using the bleed screw located somewhere on the top of the filter body. To do this, loosen the bleed screw and pump fuel through, using the primer until a steady flow of fuel, without bubbles or air, exits from under the screw. While fuel is still pumping out, close and tighten the screw.

When bleeding the fuel filters, you need to be aware that air can get trapped in high spots along the fuel line. By bending the fuel hose and progressively moving the high spot toward the filter while you are pumping, you can move these air pockets into the filter where they can be vented.

With a two-tank system, air will need to be bled out on both the diesel-fuel start/stop line and the coconut-oil line. If you first bleed air out of the coconut-oil line, you will then need to switch to the diesel-fuel line and repeat the above steps.

If air did not enter the system downstream of the secondary filter—it usually does not with a two-tank modification—then your work is done. Start the engine on diesel fuel, check for leaks, run it for 10 minutes, load the engine, switch to coconut oil, and run it for another 10 minutes or so, checking for leaks.

If you changed over the secondary filter or suspect that air has entered the lines downstream of the secondary filter, you will also need to purge the injector pump and the injectors. Your operator's manual should indicate where the injection pump's bleed screws are located and in which order you should bleed them. After bleeding the injection pump by using the same technique as you used for the filters, move on to the injectors.

To bleed the injectors, you need to start the engine and loosen the high-pressure fuel-line fittings (not the return-line fittings) attached to each injector. These fittings are

located at the top of each injector where the high-pressure line connects, can be loosened with a spanner or shifter, and need to be only slightly opened with a quarter to a half turn. Fuel will dribble out of the fitting, removing any air with it. Once the fuel is exiting consistently and free of air bubbles, you can tighten the fitting and move on to the next injector until all have been done in the same manner.

Now that you have finished bleeding the fuel system, you should make a final and thorough check of all hoses and fittings along the delivery system. The most common place where air enters the system is between the distribution pump and the tank, because this is where suction is taking place. Downstream from the distribution pump, the fuel is under pressure; therefore, any leaks will cause fuel to leak out rather than air to leak in.

Once the engine has been operating for an hour or so, you should check that there is no air accumulating in the secondary fuel filter by slightly opening the bleed screw on top and checking for bubbles.

Hoses and Fittings

When converting an engine using any of the above methods, purchase extra hoses and fittings. Normal fuel hoses work fine, and brass, stainless-steel, or high-pressure PVC fittings can be sourced from auto- or engineering-supply stores. Try to avoid copper fittings because the free fatty acids in coconut oil can cause them to corrode. This will also happen to a lesser extent with brass, but will occur only if using low-grade oil (and even then, the corrosion will take a very long time before it becomes a problem).

A commonly encountered problem following conversion is air getting into the fuel line. Rubber hoses expand and contract with changes in temperature, and installing a heat exchanger increases this occurrence. It is very important to make sure that all hoses and fittings are fixed off properly, using hose clamps; it may be necessary to coat joins with silicone to ensure airtight seals.

Engine Operation and Maintenance

Experience has shown that, on the whole, using coconut oil in engines leads to a higher incidence of adverse technical effects than occur with diesel fuel. These can be reduced to an acceptable level (that is, comparable to that of diesel fuel) only if certain conditions are fulfilled. These refer not only to the fuel and the engine used, but also to the usage and maintenance of the engine.

Adapted Usage Pattern: The Right Load

Using coconut oil successfully requires extra work and a strong commitment to adapt how the engine is used and monitored. In an adapted usage pattern, you will be aware of the specific requirements and issues that can arise from using coconut oil, and you will be on the lookout for the telltale signs of any problems arising. If a problem is identified, it should be addressed immediately. This will primarily involve ensuring that the engine is sufficiently loaded at all times, but will also include other factors to do with the operation and maintenance of the engine, such as always having spare filter cartridges and fresh lubrication oil available.

The most important factor in keeping a suitably high load on your engine is to first ensure that the generator is appropriately sized for the application. To do this, you need to add up the watt or kilowatt ratings of all the appliances and machines that you wish to run at the same time from the generator. This total should represent about 75 percent of the kilowatt (kW) rating of your generator, which is on average about 60 percent of the kilovolt-ampere (kVA) rating of the alternator.

The difference between the kW and kVA ratings is the result of the power factor of certain appliances and machines. The power factor is the ratio of real power (in watts) to apparent power (in volt-amperes). Purely resistive loads, such as heating elements and incandescent lights, have a power factor closer to 1.0, whereas inductive loads, such as electric motors and fluorescent lights, might have a power factor of 0.6. The power factor typically averages out at 0.8 (or 80 percent) across a mixed load.

If, for example, the maximum power requirement is 10kW of a mixed inductive and resistive load, then a generator with a capacity of 13kW would be the most suitable size. Using an average power factor of 0.8, the ideal capacity of the alternator would be about 16kVA ($16 \times 0.8 \times 0.75 = 10$).

There will usually be occasions when an appliance or machine drawing power from the generator is turned off, reducing the total load and causing incomplete combustion that may damage the engine. Continuing with our example, if an appliance drawing 4kW is turned off, the load on the engine will drop to 6kW, which represents less than 50 percent load. There are three options in this type of scenario: first, the 4kW appliance is simply left on even if it is not required; second, the engine is switched back to run on diesel fuel during times of low load, or third, a *dummy load* is used to substitute for the appliance.

A *dummy load* refers to any electrical load used to bring the total power use up to the target load. In most cases, the dummy load has no functional purpose except to raise the load. The most suitable type of dummy load is one that offers a resistive load. This includes any appliance that has a heating element using electrical resistance, such as a heater, a kettle, or an incandescent lamp.

If we consider our example from above again, a suitable dummy load might comprise two 2kW bar heaters or four 1kW electric-stove elements. Alternatively, a 4kW water-heating unit might represent a more beneficial option because it could also provide hot water for washing or other purposes. Other beneficial options might include a pump to irrigate or fill a header tank or a freezer unit to make ice. The main point here is that if part of the load is removed from the generator, then an equal and alternative load must be used to replace it.

With most stationary power applications, there is usually a repeated pattern in power usage over the course of a day or in general operation. When you are using coconut oil as fuel, you need to become aware of these patterns and develop necessary systems and habits as part of your adapted usage pattern, whether it be switching on dummy loads or switching back to diesel fuel as necessary.

Maintenance Program

The operator's service manual that comes with your engine should be the primary source of information regarding the engine maintenance program. It is important, however, to understand the added complications that can arise from using coconut oil as fuel and to adopt a more stringent maintenance program. Engine service periods should be halved compared with those recommended in the service manual, so that the engine is serviced every 150 or fewer hours of operation. Particular care should be taken and inspection made during the period following conversion. The maintenance and inspection program should include the following:

- **Fuel filter.** The fuel filter needs to be monitored more closely for clogging, and filter cartridges will usually need to be replaced more regularly than if using diesel fuel. Replacement cartridges should always be available so if clogging is identified, the filter can be changed immediately.
- **Lubrication oil.** Oil levels should be checked before running the engine each time. If oil levels rise, then coconut oil is entering the sump because of incomplete combustion or faulty piston rings. Oil-change

periods should be halved compared with those for diesel fuel, implying an oil and oil-filter change every 150 hours or fewer.

- **Injector nozzles.** Injectors should be removed, inspected for carbon deposits, and cleaned (if necessary). This should be done during the 150-hour service.
- **Valves and exhaust.** Intake and exhaust valves and the exhaust manifold should be inspected for carbon deposits during the engine service.
- **Piston rings.** If engine-oil levels rise or any noticeable carbon deposits are noted on the injectors, valves, or exhaust, the pistons should be removed so the piston rings can be examined and cleaned (if necessary).
- **Coolant fluid.** Radiator levels should be checked regularly to check for leaks in the heat-exchanger system.

In addition to the above measures, one long-term user of coconut oil recommends running the engine for several hours on diesel fuel and a diesel additive between service periods. A number of commercially available diesel additives clean the fuel-delivery system and injector nozzles.

Oil Production, Processing, and Quality

Coconut oil has been produced around the Pacific for more than a century, using copra (dried coconut meat) and large centralized mills located in urban centers. However, for coconut oil to be used cost-effectively as a fuel in rural areas, it must be produced locally. There are two practical and economical options for small- and medium-scale decentralized oil production: mechanized *minimills* (using oil expellers) and *hand presses*.

Minimills

Minimills operate on the same working principle common to large commercial mills. This consists of a three-step process: feedstock preparation, oil extraction, and filtration. They use copra as the feedstock and are powered by electric motors or diesel engines, which themselves can be run on coconut oil.

Feedstock Preparation

Copra is produced by cutting fresh nuts in half and drying the coconut kernel. Drying can be carried out by various means. The most common methods include direct-heat smoke drying, direct-heat smokeless drying (hot-air drying), and solar drying. Ideally, the copra produced should have a moisture content within the range of 4–6 percent. This small amount of water assists with oil-expelling

efficiency, is boiled off as steam from the heat generated during pressing, and produces water-free oil. Too much moisture in the copra can create issues with water in the oil. It can also cause the copra to grow mold during storage, reducing oil quality.

Before the copra can be pressed in the mill, it must be chipped into small pieces within the range of about 1–10 millimeter (mm) cubes. This increases the surface area and makes it easier to extract a higher percentage of the oil from the flesh. A range of machines are available for this purpose and are commonly called *flaking mills*, *disk mills*, *hammer mills*, or specifically built *copra cutters*.

Oil Extraction

A continuous-screw press uses a reduction screw turning inside a press cage to mechanically expel oil from the copra. The press cage can consist of either a barrel with small holes, a series of bars separated by shims (washer-like rings or wedges), or a number of adjoining disks that fit together with small teeth to allow the oil through. A hopper feeds copra into the open end of the screw, and the pressed copra meal exits the other end. An adjustable cone or plug creates a restriction along the screw, causing high pressures to build up and forcing the oil out through the press cage.



Small disk mill of the FFC range is powered by a 3kW motor.



11kW flaking mill can process up to 1T/hour.

Crushing capacities vary according to the physical size of the press and can vary from a few kilograms per hour to several hundred kilograms per hour. Capacity is also determined by how a press is operated. Tightening the adjustable cone and slowing the revolution speed will increase pressure and produce more oil, but it will also compromise the throughput speed. In the end, it is up to the operator to choose how to balance the processing speed and how much residual oil remains in the meal.

These are the four key considerations when choosing an oil press:

- Volume of oil required, which will determine press size
- Power consumption and availability of power supply (for example, three-phase, single-phase)
- Serviceability, spare parts, and customer service and support
- Price, both the purchase cost and running costs

The quality of oil produced in this process mainly depends on the quality of the copra used. The faster the entire process from splitting the nut to extracting the oil, the better the oil quality will be. Oil produced from sun-dried or hot-air-dried copra is usually of higher quality than oil from smoke-dried copra, which contains higher contaminant concentrations in the form of particulates that can damage the engine if not filtered sufficiently. Although substandard oils will burn in diesel engines, practical experience has shown that better-quality coconut oil will provide longer-term, trouble-free operation of your engine.

Oil expellers are made in many countries throughout the world. The most affordable models are made in China, with Indian varieties following. (Presses made in countries such as Germany, England, and the United States will not be discussed because of their significant expense.)

Chinese Presses

Many of the Chinese presses are well engineered and properly constructed, but are commonly designed to process hard seeds such as canola, jatropha, cotton,



Continuous-screw oil expellers come in a range of shapes and sizes, but all generally operate on the same mechanical principle.

and sunflower. Hard seeds require smaller tolerances between the thickest part of the screw shaft (referred to here as the knuckle) and the press cage, compared with those for coconut. When these presses are used with coconut, there is not enough space between the knuckle and the cage for the coconut meal to pass through, creating a bottleneck and causing the shaft to seize. (This problem does not occur with all Chinese presses, and with those that it does, it can be remedied relatively easily. If you have or purchase a Chinese press, it is advisable to first try using it with coconut before you attempt to fix it using the method described below.)

To fix a Chinese press that is seizing regularly, reduce the thickness of the knuckle by grinding off a thin layer.

Larger presses that process more than about 100 kilograms per hour (kg/hr) of copra will usually have a double-tapered screw with two knuckles, and as such, there will be two locations where grinding needs to take place. If your press is seizing only occasionally, you will need to grind about 1–2mm from the diameter of the knuckle. In presses seizing regularly, 3–4mm should be ground from the knuckle. If you are unsure how much to remove, grind off less rather than more, try the press again, and then grind away more if necessary.

Although this process may sound daunting, it is a relatively simple matter and can be done using nothing more than an electric grinder and a vernier caliper, which are used to check the diameter. Using the caliper, check the thickness of the knuckle, deduct the required amount (say, 2mm), and set the caliper to that diameter. Using the caliper, mark out the area on the shaft that requires grinding. Remove the press cage and press-cage housing so that the screw shaft is exposed, but still fitted into the drive shaft. Start the motor so that the exposed shaft rotates in place, in much the same way as if on a lathe. With a steady hand, grind away the marked area, regularly checking progress with the caliper.

Indian Presses

Indian presses typically cost up to twice as much (or more) as Chinese presses and are in general built no stronger or better. They are, however, specifically designed for pressing coconut oil, meaning that there is no need to make modifications and that general operation is easier. In addition, they tend to use different gear ratios, which allow them to run a smaller motor compared with that in similarly sized Chinese presses.

With regard to operational performance, Indian presses slightly outperform Chinese presses on power efficiency and general ease of use; however, Indian presses are more expensive than Chinese presses. One important factor in choosing a press is the ease of obtaining replacement parts. If there is a local dealer or agent selling a particular type of press, it is probably best to purchase what he or she is selling or convince that person to import the variety that you want.

Filtration

The most critical step in oil production relates to removing all of the suspended solids from the pressed oil. These particles will act as abrasives in your engine and can create blockages in the fuel-delivery system, particularly the injectors. There are a number of methods for filtering coconut oil, but regardless of the method used, a final safety filtration to 5 microns should be completed.

These are the four filtration methods:

- Settling tanks
- Plate-pressure filters
- Filter cartridges, bags (disposable and washable)
- Coarse filters (homemade)

Because centrifuges are not considered practical for rural applications because of their significant expense, we shall not discuss them further. Although it is possible to use just one of the above methods, it is common practice to use a combination of two, three, or all four of these methods. The goal here is to develop a system that is practical and cost-effective; therefore, the methods chosen will depend on your personal circumstances, location, and access to materials.

Settling Tanks

If coconut oil is allowed to stand for a period of time, the suspended particles will settle out at the base of the containing vessel, leaving clean oil that can be decanted from the top. Large particles will drop out first, while smaller particles take longer. Temperature also affects settling rates because cooler oil is thicker and will require longer to settle. As a rule of thumb, however, it takes about two weeks for coconut oil to settle to a rating of 5 microns, and a one-week settling period is the recommended minimum.

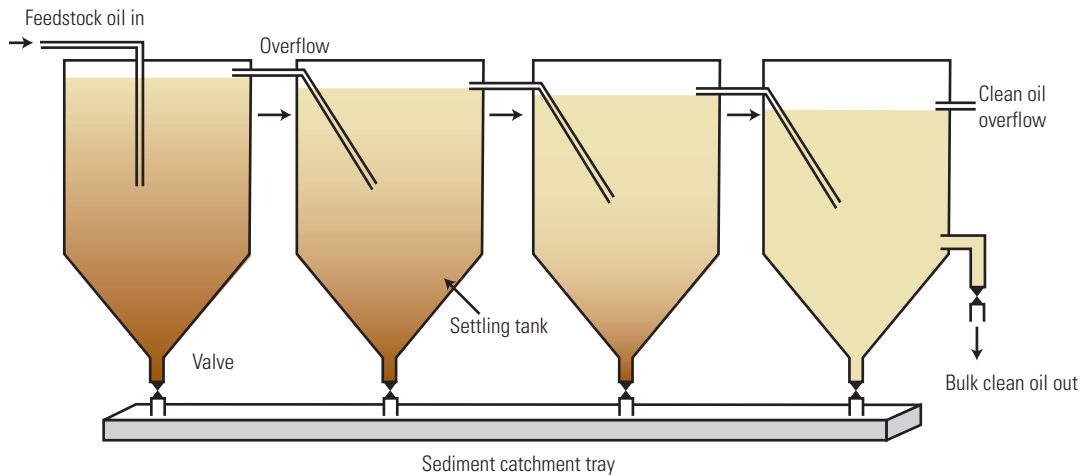
TIP: Two weeks of settling is usually enough to remove all suspended particles down to 5 microns.

The other benefit of settling is that it removes other non-solid contaminants also: Small droplets of suspended free water are able to coalesce and drop out, as are minor concentrations of vegetable gums. The tiny fraction of fat that has a higher melting point will also drop out over two weeks of settling.

Settling can be achieved by storing oil in single containers for two weeks or by using a series of containers linked together in a “cascade” arrangement. This latter option is more suited to semicontinuous-to-continuous operations and is more effective if each successive container is larger (specifically, broader) than the tank before it. If settling tanks are located outside, it is a good idea to paint them black so they absorb more of the heat of the sun, which increases settling rates.

Whatever method you choose, the amount of storage for settling needs to be sized accordingly for your operation. For instance, if you are producing 100 liters (L) per

FIGURE 10: SERIES OF CASCADING SETTLING TANKS



If there is sufficient holding time, a series of cascading settling tanks is a low-cost and low-tech method of producing oil with a low-particle load.

day, five days per week, you will need 1,000L (100 × 5 × 2 weeks) of storage. For an operation of this size, 200L drums would be appropriate. For larger operations, water tanks (not galvanized steel, but polyethylene), intermediate bulk containers (IBCs), or any other tanks suitable for chemical storage can be used. Old fuel tanks (in the range of 2,000–5,000L) can often be bought cheaply. They make good settling or storage containers, but should be used only for fuel-grade oil, not for food or cosmetic oils.

All settling tanks require a drainage valve at the base to periodically remove the sediment buildup. Ideally, tanks should have a sloping base so that all settled material will collect immediately above the valve, allowing easy and effective drainage.

Although settled oil may visibly appear clear, it should always be passed through a 5-micron safety filter before being used in an engine. Settling is not a fast method of filtering, but it is an effective, low-cost, low-energy option; it reduces filter-cartridge replacement and is suitable to remote areas.

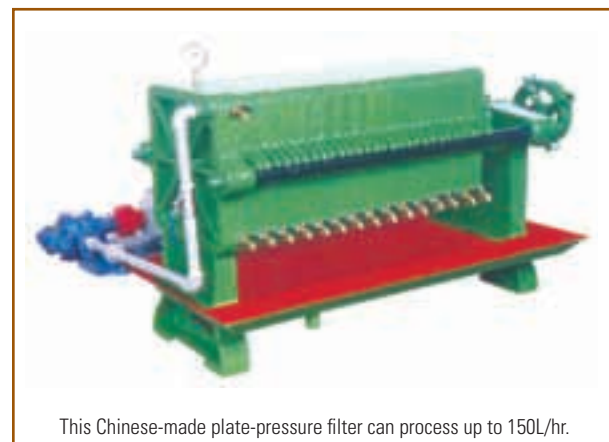
Plate-Pressure Filters

A plate-pressure filter allows the rapid, continuous filtration of freshly pressed vegetable oil. As the name implies, these filters consist of a number of plates clamped together in a horizontal stack, with sheets of filter cloth sandwiched between them. Oil is pumped under pressure into the plate chambers, allowing solids to build up on the filter cloths and filtered oil to escape through the

outlet ports. There is usually a pressure gauge to indicate when it is time to change the filter cloths. They can be cleaned by first scraping the bulk of the debris off the cloths before washing them in hot water.

Plate-pressure filters do not typically produce oil rated to 5 microns. (The standard filter cloths are usually rated at or near 60 microns.) As sediment builds up on the cloths, however, they filter to increasingly lower ratings because the sediment itself acts as a filter.

Manufacturers of screw presses usually make plate-pressure filters to match their presses, with the two machines often coming in a package. Filter capacity should be slightly higher than that of the presses to allow for the downtime required to remove the filter cloths for cleaning. Typically, the cost of a plate-pressure



filter is about 40–60 percent compared with that of a screw press.

Plate-pressure filters are generally more expensive than settling tanks, but take up less area. If the oil entering the press has a significant proportion of solids, filter-cloth changes will be regular and can become a burden. In most cases, it is advisable to coarse-filter or briefly settle the oil first to remove the larger particles before pumping it through the plate-pressure filter. As with settling tanks, filtered oil should be passed through a 5-micron safety filter before using in an engine.

Safety Filters

Safety filters can come in a wide variety of filter mediums, shapes, and sizes. Their purpose is to act as a backup to the primary filtering system to ensure that the oil is filtered to 5 microns or less before it is used. Diesel-fuel filters with replaceable cartridges make suitable safety filters. It is advisable to use in-line safety filters whenever filtered oil is transferred from one tank or drum to another.



Diesel-fuel filters make suitable safety filters.

Homemade Filters

There are many options when making homemade filters, using a wide range of available filter mediums. For initial coarse filtering, for example, shade cloth or layers of shade cloth can provide a simple, low-cost, reusable method of removing larger particles. Other suitable materials can include old towels, sheets, women's stockings, and flywire mesh. In locations where access to abundant clean sand is available, a simple sand filter can be used for anything from coarse to fine filtering. The grade of filtration simply depends on the size of the sand particles, which can be graded by sieving.

Hand Presses

Hand presses use dried, grated coconut flesh as the feedstock. The oil produced is of a high quality and is clear, has little odor, and is generally suitable for food and cosmetic purposes. Hand pressing is a significantly cheaper option to start producing coconut oil than mini-mills; however, it is labor intensive and produces only up to 4L/hr. For the purpose of producing fuel, it is considered practical to use only with small, intermittently run



Hand presses available in the Pacific: PSS press (left), Kokonut Pacific press (right)

engines, such as a family-owned generator that might be run for a few hours every night or so. As with minimills, it involves a three-step process from nut to oil.

Other manual methods of oil production, such as (a) grating and boiling or (b) grating, hand squeezing, and settling, are considered too inefficient to produce sufficient quantities of coconut oil for fuel (and will not be discussed further).

Feedstock Preparation

Fresh nuts are split in half, and the coconut flesh is grated, using either a traditional scraper blade, a hand-operated rotary scraper, or an electric-powered scraper. The grated coconut flesh is then dried by either laying it out in the sun for a few hours, using a purpose-built solar dryer or a wood-fired, indirect-heat plate dryer, in which the shredded flesh is constantly turned and mixed on a heated plate (refer to picture). The dried coconut is ready for pressing when it feels slightly crispy to the touch and all but a tiny percentage of moisture is left.



courtesy of SOPAC

Indirect-heat plate dryer



Traditional stool scraper



Rotary hand scraper



Electric scraper

Oil Extraction

In the Pacific region, two types of coconut hand press are available, both of which produce up to 4L/hr of coconut oil. One is manufactured in Papua New Guinea (PNG) by Project Support Services (PSS) and is available in Papua New Guinea and the Solomon Islands via a partner organization (supplier details appear at the end of this guide). It is a continuous-operation press that uses a sliding piston, a press cage, and an adjustable cone valve. Hundreds of such presses have been sold throughout PNG for village-based production of cooking oil, body oil, and soap.

The second press is manufactured by an Australian company, Kokonut Pacific, and the extraction process is called direct microexpelling (DME). DME systems have been installed throughout several Pacific island countries and Indonesia. The system is sold as a complete processing package (including training) and is geared toward the production of high-value food-grade oil that is purchased back and marketed by Kokonut Pacific. Because of their high-quality components, these systems are significantly more expensive than the PSS units made in PNG.

Filtering

Filtering options for low-volume hand-pressed oil should be kept as simple as possible. The most appropriate options include settling, homemade filters (such as sand filters), and a final safety filter using a standard 5-micron fuel filter.

Oil Quality

In The Diesel Engine, we looked at the inherent “characteristic” properties of coconut oil, such as viscosity and cetane number, alongside those of diesel and rapeseed



A simple gravity-filter system is a suitable option for filtering the low volumes of coconut oil produced by hand pressing.

oil. The “variable” properties of coconut oil, however, relate to the quality of the oil, which is in turn influenced by the production process, storage, and handling.

In Europe, a quality standard (DIN V 51 605) has been established for fuel-grade rapeseed oil that outlines upper and lower limits for various properties. The variable properties within this standard (listed in table 2) can be used as a quality guide for any vegetable oil.

In the context of using coconut oil in diesel engines located in rural areas of Pacific island countries, it is unrealistic to expect that coconut oil will ever be subject to the necessary analyses to determine all of the above variables. For this reason, it is more appropriate to have some “rules of thumb” that can be carried out with relative ease in a rural setting. The key variables that need to be addressed are total solid particles, water content, and free-fatty-acid concentration.

NOTE: The three key factors with regard to oil quality are total solid particles, water content, and free fatty acids.

Total Solid Particles

Solid particles in the oil can be small particles of coconut flesh, dust, carbon from smoked copra, rust from an old drum, and so forth. Any of these can cause obstructions in the fuel-supply system, lead to abrasions in the injection system, and contribute to the formation of deposits in the combustion chamber. Oil should be filtered to a grade of 5 microns or less to avoid these issues, which is the purpose of the safety filter. The engine should also be fitted with a 5-micron fuel filter as a final backup.

Water Content

The water content in coconut oil results from the moisture contained in the pressed coconut, poor storage conditions, or both. It can be present in oil as “free water,” which will eventually drop out of the oil if left to settle, and as “suspended oil,” which is bound up in the oil through weak chemical bonds. Pure coconut oil and water are immiscible (incapable of mixing), and any suspended water is generally an indication of some form of oil degradation or contamination. Water in the oil encourages growth of microorganisms and thereby accelerates degradation.

If you let coconut oil settle for a period of two weeks, you can practically guarantee that all of the free water

TABLE 2: QUALITY STANDARD FOR RAPESEED OIL

Variable Property	Unit	Min/Max Value
Total contamination	mg/kg	max 24
Acid value	mg KOH/g	max 2
Oxidation stability (110°C)	h	min 6
Phosphorus content	mg/kg	max 12
Magnesium and calcium content	mg/kg	max 20
Ash content	mass-%	max 0.01
Water content	mass-%	max 0.075

Source: http://bloomingfutures.com/fuel_standards_for_PPO_vegetable_oil.html

Note:

Total contamination—amount of suspended particles present
Acid value—free-fatty-acid content (a value of 2 is approximately equivalent to 1 percent)

Oxidation stability—measure of oil’s propensity to oxidize or degrade

Phosphorus content—amount of phospholipids

Magnesium and calcium content—measure of alkali content

Ash content—proportion of inorganic solids

Water content—proportion of water in the oil

mg—milligram(s)

kg—kilogram

KOH—potassium hydroxide

g—gram

h—hour

mass-%—percentage of entire amount

will have settled out. Heat encourages water to settle, as it does for solid particles, and it is beneficial for settling or storage tanks to be exposed to the sun and painted black.

Fuel-grade coconut oil should be clear and transparent, with a slight amber color. If the oil has been filtered and looks cloudy, this usually indicates that there is water in the oil. A simple test to determine this is the hot-pan test. Heat a saucepan or frying pan to about 150°C and pour about 5–10mm of oil into the pan. If any small bubbles start forming at the base of the pan, the oil has too much water. If the oil starts to snap or pop, it has significantly too much water.

TIP: If the coconut oil bubbles, snaps, or pops during a hot-pan test, the oil contains too much water, and it will need to be dewatered before use.

Dewatering oil involves heating it to above 100°C for a period of time to boil off any residual water. This can be done by any method suitable and with whatever materials

are available. If you plan to do it in 200L drums using fire, do not expose the drum directly to the fire. Take special care, particularly if using coconut shells—they burn very hot, and the fire can burn through the metal drum. Instead, place the drum on a hot plate, and build the fire underneath the plate.

Free Fatty Acids

Free fatty acids are indicative of oil degradation and are formed by oxidation of the triglyceride molecule. In short, one of the bound fatty-acid chains of the triglyceride is separated from the molecule and becomes a “free” fatty acid.

Free fatty acids are weak organic acids and readily combust in diesel engines. In the low concentrations typically found in coconut oil, these acids have very few corrosive effects on the metallic components of the engines. In higher concentrations and in the presence of water, they can attack some metals (especially zinc and copper) to release metallic ions. They can also cause some types of rubber and plastic to prematurely degrade and can lead to oxidation and bacterial contamination within storage tanks.

The formation of a free fatty acid also implies the formation of a diglyceride molecule. Diglycerides readily combust in diesel engines too, but also act as emulsifying agents. This means that they bind and hold tiny water droplets in suspension within the oil, making it impossible to dewater the oil through settling alone. Because acids operate in the presence of water, oil with high free-fatty-acid and diglyceride concentrations need to be dewatered more thoroughly, usually by the application of heat. However, small concentrations of free fatty acids, diglycerides, and water do not pose an issue for fuel-grade coconut oil.

Most free fatty acids in coconut oil are formed during the drying process, between the time that the nut is cracked and the time it pressed. The quicker the drying time and the shorter the period that copra is stored, the less free fatty acids will form. Hot-air-dried copra typically produces less free fatty acids than smoke-dried copra. Hand-pressed oil does not usually have any issues with free-fatty-acid formation.

A relatively simple chemical test is available to determine the free-fatty-acid value and is listed at the rear of this guide. An acid value below 2 indicates high-quality oil, below 4 moderate-quality oil, and below 8 low-quality oil. Oil with values above 8 should probably not be used in your engine. The greater the acid value, the

more thoroughly the oil will need to be dewatered and the shorter the storage time should be to avoid further degradation.

If chemical analysis is not feasible or available, the general rule is to avoid low-grade copra, particularly if it has been smoked and is burned or rancid or has mold. In addition, copra that has been stored for long periods of time (that is, more than a month) should be avoided.

TIP: The shorter the time between cracking the nut and pressing the oil, the less free fatty acids are formed. Low-grade copra should be avoided.

Storage and Handling Options

Good-quality coconut oil is one of the most stable vegetable oils and is highly resistant to rancidity because it has a very high degree of saturation—higher, in fact, than any other vegetable oil—which means that it can be stored for a long time before it begins to deteriorate. Producers of high-grade food and cosmetic coconut oil claim that their oils show very little deterioration within 2–5 years. This length of time, however, is very dependent on the initial quality of the oil. Particular factors that reduce storage times include free-fatty-acid concentration, water content, and organic-solids content. It is probably safe to assume that fuel-grade coconut oil will have a storage life of between six months and a year before it begins to significantly deteriorate. Your nose is possibly the best judge to indicate whether the oil has become rancid or not; if you suspect that it has, do not use it in your engine.

Coconut oil can be stored in a variety of containers and tanks. Common options include 200L fuel drums, steel fuel tanks, polyethylene tanks or drums, intermediate bulk containers (IBCs), or any other vessels suitable for fuel or chemical storage. In most cases, what you can source most cheaply will determine what you use. Metals such as copper and zinc (galvanized steel) should be avoided because they can react with free fatty acids. The inherent solvency characteristic of coconut oil has also been known to strip off paints and liners of tanks (such as 200L drums).

Unlike those for diesel fuel, there are no special requirements with regard to safety and exposure to coconut oil, and it can be handled with relative ease because of its benign nature. It is nontoxic and inflammable, has a flash point around 200°C, and even has a low incidence of allergic reactivity.

By-Products

The final topic in this section with regard to processing coconut oil relates to its by-products. Producing coconut oil also yields a significant amount of coconut meal (that is, the coconut meat left over after oil extraction), for which there are a number of productive uses. It can be used in cooking to bake biscuits, cakes, and breads or even added to curries or stews. It makes a high-value

feedstock for cows, pigs, or chickens and can be sold to commercial producers or used locally. Because of the high fiber content of the meal, it should constitute only up to 30 percent of the diet for monogastric animals such as pigs and chickens. Ruminant animals such as cows, sheep, and goats that have four stomachs can tolerate significantly more in their diets. Finally, the meal makes a very good organic fertilizer that can be added to gardens.

Appendix 1: Analyze Your Free Fatty Acids: The Titration Test

The following test can be used to determine the free-fatty-acid value of your coconut oil. Although the procedure might look daunting at first, it is in fact relatively simple. Sourcing the chemicals will be the hard part, but most should be available at any chemical-supply store.

Utensils and Ingredients

- 1 medicine glass, glass beaker, or small glass jar
- 2 liters (L) of demineralized water (tank water or bottled water will do)
- 2 grams (g) of 100 percent pure potassium hydroxide (KOH) (use care to keep the KOH dry, even preventing exposure to humid air, because it will absorb atmospheric water)
- 10 milliliters (ml) of 99 percent pure isopropyl alcohol (IPA)
- 2 small (1 ml) diabetic syringes (available from chemists), with needles removed and holes enlarged (using a small drill bit)
- Phenolphthalein pH indicator solution
- Coconut oil
- Electric scales accurate to 0.1 gram
- Rubber or latex gloves and safety glasses

Step-by-Step Titration

- Add 2g KOH to the demineralized water container to make KOH reference water. (This can be used again for up to one year.)
- Using syringe, measure 10ml of IPA into glass jar.
- Add two drops (about 0.2ml) of phenolphthalein indicator to IPA, and swirl to mix.

- Using syringe, add 1ml of coconut oil to the phenolphthalein/IPA solution. Vigorously swirl jar to ensure complete mixture of the oil and solution.
- Draw 1ml of KOH reference water into syringe. Carefully drip KOH water into the phenolphthalein/IPA/coconut-oil solution while swirling the beaker with the other hand.
- The solution will be a milky color at the start of the test and will turn a uniform bright pink when the titration is complete. The solution will turn pink when the KOH water is initially added, but will return to milky color as you continue to swirl the jar. The solution must be uniformly pink for at least 30 seconds before the titration is complete.
- Record the amount of KOH reference water in milliliters used to complete the titration. This number represents the number of grams of KOH required to neutralize the free fatty acids in 1L of coconut oil (that is, g/L).
- To convert to acid value—grams per kilogram (g/kg)—multiply this number by 1.081 (1 divided by 0.915, which is the density of coconut oil).

Free-fatty-acid concentration is a good indicator of general oil quality. It is advisable to perform regular titrations of your oil, particularly when you are starting out, so you begin to understand the correlation between copra quality and oil quality.

An acid value below 2 indicates high-quality oil, below 4 moderate-quality oil, and below 8 low-quality oil. Oil with values above 8 should probably not be used in your engine. Oil with high acid values requires more thorough dewatering.

Appendix 2: Coconut Oil Statistics

TABLE A.1: QUALITY STANDARD FOR RAPESEED OIL

Energy content of coconut oil	35.0	MJ per L
Energy content of diesel fuel	41.0	MJ per L
Density of coconut oil	0.915	kg per L
Density of diesel fuel	0.84	kg per L
Oil content of copra	620–680	ml per kg
Extraction rate of copra oil, large mill	600–650	ml per kg
Extraction rate of copra oil, minimill	500–600	ml per kg
1,000 coconuts are (on average) equivalent to:		
Coconuts	1.20	metric tons
Husks	0.39	metric tons
Shells	0.17	metric tons
Cocowater	0.24	metric tons
Green copra	0.37	metric tons
Dry copra	0.20	metric tons
Copra meal	0.08	metric tons
Copra oil	0.12	metric tons
Dry copra	5 (3–7)	nuts per kg
Copra oil	12 (10–15)	nuts per L
1m ³ copra	0.53	metric tons
1m ³ copra meal	0.47	metric tons
Typical yield	2,470	L oil per ha per year
Small-generator coconut-oil consumption	0.4–0.5	L per kWh

Note:

MJ—millions of Joules
 L—liter
 ml—thousandth of a liter
 kg—kilogram
 m³—cubic meter
 ha—hectare
 kWh—kilowatt hour

Appendix 3: Equipment and Suppliers

This section contains information about where to source the appropriate equipment and expertise for processing coconut oil and running an engine on coconut oil. Because this guide has been specifically written for participating countries of the Sustainable Energy Financing Project, which include Papua New Guinea, Fiji, the Solomon Islands, and Vanuatu, information about equipment and suppliers is tailored for these Pacific countries.

Because of the limited number of companies in the Pacific selling oil-processing equipment, the first half of this section provides information relating to international manufacturers and agents for oil-processing equipment. The second half of this section provides supplier information for each country. Every attempt has been made to provide complete and relevant information.

Oil Processing Equipment

The following list details some oil presses available on the market, mostly those from Chinese and Indian manufacturers. It is in no way a complete list, but rather covers the presses that are currently operating in Pacific countries and where reliable usage data are available. Details regarding copra-cutting equipment and plate-pressure filters are omitted because the manufacturers and agents that sell oil presses also provide a range of complementary copra cutters and filters. Prices have not been included, but Chinese equipment prices are generally about half those of Indian equipment.

Chinese Equipment

A large range of oil presses are made in China, and many of the same models are manufactured by different companies and sold through a number of agents. Most presses are designed for hard seeds, and some will require minor modification (discussed previously) to operate trouble-free with coconut. The most recognized manufacturer is Henan Double Elephants Machinery I/E Co., Ltd., which manufactures all of the presses listed below and some larger varieties that are yet untried in the Pacific. Product and contact details are listed on its Web site at www.holyphant.com.

Anyang Gemco Energy Machinery Co., Ltd. (www.agitc.cn) and Anyang General International Co. Ltd. (www.agico.com.cn) also manufactures some of the presses listed below. Other press varieties are available, but because of a lack of relevant experience in the Pacific, they have not been included. The following three trade Web sites will link you to other manufacturers and agents: www.alibaba.com, www.diytrade.com, www.made-in-china.com.

Project Support Services (PSS) of Papua New Guinea is currently the only known supplier of Chinese presses in the Pacific region. PSS stocks most of the presses listed below; makes any necessary modifications for coconut; can order other varieties; and provides parts, servicing, and training for all equipment. The firm has an agent in the Solomon Islands and is willing to work with other companies working in the Pacific. (Company contact details are listed under country suppliers.)



6YL-68

Output: 20L/hr (quoted)

Weight: 170kg

Power: 5.5kW

Dimensions: 930×490×820

Currently untried, but appears to be a smaller version of the 6YL-78 and would similarly have a single tapered-screw shaft and alternative press-cage bar configurations to suit different feedstocks.



6YL-78

Output: 30L/hr

Weight: 210kg

Power: 5.5kW

Dimensions: 1000×550×580

Press comes with either 16 or 20 press-cage bars, depending on feedstock. 20-bar configuration is more suited to coconut. Single tapered-screw shaft needs the knuckle reduced in diameter by 2mm.



6YL-80 and 6YL-100

Output: 60 and 100L/hr
Weight: 330 and 480kg
Power: 5.5 and 7.5kW
Dimensions: 1000×550×580 & 700×670×1320

The 6YL-80 is an identical (but smaller) version of the 6YL-100. Both employ a double tapered-screw shaft. Operational experience with the 6YL-100 indicates that it performs well and seizes rarely. Shaft knuckles could be reduced by 1mm to eliminate any problem with seizing.



6YL-95A

Output: 110L/hr
Weight: 530kg
Power: 7.5 to 11kW
Dimensions: 1600×700×1350

The 6YL-95A has a double tapered-screw shaft that unmodified is prone to seizing. Grinding 2mm off the diameter of both knuckles makes this unit a reliable and solid performer.



ZX-105

Output: 150L/hr (quoted)
Weight: 560kg
Power: 11 to 15kW
Dimensions: 1825×700×1350

The ZX-105 is a 20cm-longer version of the 6YL-95A. Trials with this machine have yet to prove whether this extra length offers any operational improvement. Double-tapered shaft needs the knuckles reduced by at least 2mm.

Indian Equipment

Indian machinery is tailored specifically for processing coconut oil by the manufacturer, and there is no requirement to modify shafts (as with some of the Chinese presses). Indian presses tend to use lower gear ratios and, as such, can be powered by smaller motors compared with those for Chinese presses. What Indian presses offer in greater efficiency and trouble-free operation, however, is offset by their increased cost.

Many companies in India manufacture oil presses and related equipment. Tinytech is probably the best-recognized manufacturer of minimills in the world and offers an integrated package of presses, copra cutters, and filters. (Contact and product details can be found at www.tinytechindia.com.) Agents for Tinytech currently operating in the Pacific include Celtrack Holdings in Fiji and Solomon Tropical Products in the Solomon Islands (both listed under country suppliers).

Apart from Tinytech, there are only a few other examples of small-Indian-press sources operating in the Pacific. Coconut Bioenergy in the Solomon Islands has some experience with Indian presses and is the agent for Goyum Screw Press, which makes presses ranging from 50 to 6,000L/hr. Solomon Tropical Products, the agent for Tinytech in the Solomon Islands, also offers an Indian press made by Kumar Metal Industries and a Malaysian press by Muar Ban Lee Engineering.



Tinytech Oil Mill

Output: 60L/hr (quoted)
Weight: 500kg
Power: 7.5kW
Size: 1.6 m3

Contact: Tinytech
www.tinytechindia.com

Tinytech presses are successfully operating throughout the Pacific. Tinytech makes only one size of press. For larger capacities, two or more presses can be linked together. The firm also manufactures copra cutters and plate-pressure filters to suit press size.

**Goyum 10**

Output: 50L/hr (quoted)
 Dimensions: 1300×475×1075
 Power: 4kW
 Contact: Goyum Screw Press
www.goyumindia.com

Goyum Screw Press manufactures a range of presses with capacities ranging from 50 to 6,000L/hr. The firm also manufactures a range of copra cutters and filters to suit press size.

**Kumar Simplex No. 1**

Output: 70L/hr (quoted)
 Power: 7.5kW
 Contact:
 Kumar Metal Industries
www.kumarmetal.com

Kumar Metal Industries manufactures presses with capacities ranging from 70 to 2,000L/hr. The firm also manufactures a range of copra cutters and filters to suit press size.

Additional Indian manufacturers of oil presses and processing equipment include the following:

- Allied Expeller Industries—
<http://allied.indusindustrial.com>
- Gobind Expeller Company—
www.gobindexpeller.com
- Guru Teg Engg. Co.—
www.gurtegexpeller.com
- Mitsun Engineering—
<http://mitsunengineering.com>
- United Oil Mill Machinery & Spares Private Ltd.—
www.umas-india.com
- Vijay Expeller Company—
www.vijayexpellers.com

Other Equipment Providers

China and India are obviously not the only countries manufacturing coconut-oil-processing machinery. They are, however, the main suppliers of equipment currently being operated throughout the Pacific that is both affordable and effective. Other countries within the general region that make a range of oil-processing machinery include Malaysia, the Philippines, Pakistan, Sri Lanka, and Indonesia. With no known installations in the Pacific, there is a lack of available information about the performance of machines from these countries. The exception to this includes a company from Australia and a company from Malaysia, which are listed below.

**Techso—Tech 14**

Output: 10–15L/hr
 Power: 2.2kW
 Location: Brisbane, Australia
 Contact:
 Techso www.techso.net

Techso manufactures and sells oil-processing equipment and tailors complete packages to accommodate any operational capacity. It has significant experience working in the Pacific region.

**Muar Ban Lee Engineering—EK-12-CT**

Output: 330L/hr
 Weight: 3800kg
 Power: 40kW

Dimensions: 4425×1099×1308

Location: Malaysia

Contact: MBL www.mbl.com

The EK-12-CT is the smallest press produced by MBL, which primarily services the commercial palm oil industry with very large presses. The firm provides cutting and filtering equipment also.

Country Suppliers

Papua New Guinea (PNG)

Project Support Services (PSS)

Ph: +675 472 0088
Fax: +675 472 0044
pssltd@daltron.com.pg
www.psspng.com
Malahang Industrial Estate, Lae, Morobe Province,
PNG

PSS is the only stockist in PNG of complete oil-processing equipment (in the form of minimills), including copra cutters, screw presses, and filtration equipment. All machinery is sourced from China, and presses are modified to suit coconut as required. PSS also fabricates coconut-oil hand presses and filtration systems for very small-scale production. PSS also sells a range of historical-style Changfa engines that can be operated unmodified on straight coconut oil and can be coupled with alternators or power pedestrian tractors. The firm offers training, service, and maintenance of all equipment and machinery.

Bishop Brothers

Ph: +675 325 2900
Fax: +675 325 4104
www.bishopbros.com.pg
Wards Rd., Hohola, Port Moresby, PNG

Bishop Brothers stocks a range of industrial products, including generators, filters, and all the necessary parts to adapt engines. The firm has a large engineering workshop and has designed and fabricated an effective and affordable stainless-steel heat exchanger for engine conversion. Bishop Brothers has branches throughout PNG and one in the Solomon Islands.

Lohberger Engineering

Ph: +675 325 2122
Fax: +675 325 2704
loheng@online.net.pg
www.lohberger.com.pg
Lawes Road, Konedobu, Port Moresby, PNG

Lohberger offers engineering services and stocks a range of industrial supplies, including generators, filters, and all of the necessary parts to adapt engines. The firm's engineering workshop has the facilities to fabricate heat exchangers and to preadapt engines for use with coconut oil.

Brian Bell

Ph: +675 325 5411
Fax: +675 325 0167
www.brianbell.com.pg
PO Box 1228, Boroko, Port Moresby, PNG

Brian Bell's industrial division sells a large range of diesel generators and necessary supplies for adapting engines to run on coconut oil. The firm has five store locations across PNG.

Farmset

Ph: +675 732 1955
Fax: +675 732 2423
gorokasales@farmset.com.pg
Airport Rd, Goroka, PNG

Farmset mainly services the agricultural sector, can order oil-processing machinery, and sells some small diesel generators.

Agmark

Ph: +675 982 9055
Fax: +675 982 9056
itamur@agmark.com.pg
www.agmark.com.pg
NGI Haus, Williams Road, Rabaul, PNG

Agmark has five store locations across PNG and generally services the agricultural sector. The firm does sell a range of diesel generators and can order oil-processing machinery.

Moresby Truck and Tractor

Ph: +675 325 8255
Fax: +675 325 8803
mtt@global.net.pg
Kenmore Trade Centre, Waigani, Port Moresby, PNG

Moresby Truck and Tractor stocks a large range of industrial parts, including filters, valves, hoses, and other necessary parts for converting engines.

Hastings Deering PNG

Ph: +675 300 8300
Mb: +675 687 2014
www.hastingsdeering.com.au
Spring Garden Rd, Hohola, Port Moresby, PNG

Hastings Deering is the licensed supplier of CAT engines and generators.

Eltech Engineering

Ph: +675 323 1988
Fax: +675 323 2810
ees@eltechpg.com
PO Box 228, Gordons, Port Moresby, PNG

Eltech is the licensed supplier of Deutz engines and generators.

UMW Niugini

Ph: +675 472 2444
Fax: +675 472 3342
msims@umw.com.pg
Aircorps Rd, Lae, PNG

UMW is the licensed dealer and distributor for FG Wilson generators and Atlas Copco equipment.

Fiji

SOPAC Energy Division

Ph: +679 338 1377
Fax: +679 338 0040
www.sopac.org
Suva, Fiji

SOPAC is the Pacific Islands Applied Geoscience Commission. It is an intergovernmental, regional organization dedicated to providing services to promote sustainable development. The energy division of SOPAC has a wealth of experience in using coconut oil as fuel.

Celtrock Holdings

Ian Chute ianchute@connect.com.fj

Celtrock Holdings Ltd. is the agent for Tinytech mini-mills and is the only provider of oil-processing equipment in Fiji. The firm can design and install equipment for a range of capacities and offers training and backup services for all equipment that it sells. Ian Chute can order alternative oil-processing machinery from China or India on request and can assist with engine selection and conversion.

Seamech Engineering and Hydraulic Shop

Ph: +679 330 1882
Fax: +679 330 0866
drossbrodie@mac.com
21 Matua St, Walu Bay, Suva, Fiji

Seamech has experience in converting diesel engines to run on coconut oil. The firm has a large workshop with the capabilities to fabricate heat exchangers and to refit engines to run on coconut oil. It is the official agent for Deutz in Fiji, but orders engines out of Australia as required.

Clyde Engineering

Ph: +679 338 6000
Fax: +679 337 0431
www.clydepac.com
31 Viria Rd, Vatuwaqa, Suva, Fiji

Clyde Engineering stocks a large range of small, medium, and large diesel generators. It sells filters, valves, and all of the other necessary equipment for engine conversion. The firm has the capability to make heat exchangers and can fit out any generator to run on coconut oil.

Powerlite Generators Ltd.

Ph: +679 338 4088
Fax: +679 338 4096
powerlite@connect.com.fj
19 Shalimar St, Raiwasa, Suva, Fiji

Powerlite is the agent for Hatz diesel generators and can order any other brand of generator out of Australia.

Industrial and Marine Engineering Ltd (IMEL)

Ph: +679 331 2133
Fax: +679 3301364
i.seru.imel@carpenters.com.fj
Eliza St, Walu Bay, Suva, Fiji

IMEL has a very large engineering workshop and mostly works on large industrial and marine jobs. Its workshop has the capability to fabricate heat exchangers or refit engines.

Carptrac

Ph: +679 330 8622
Fax: +679 330 8329
i.temo.motors@carpenters.com.fj
88 Foster Rd, Walu Bay, Suva, Fiji

Carptrac is the licensed agent for CAT engines and generators.

The Solomon Islands

Solomon Tropical Products

Ph: +677 38553
Fax: +677 38552 stp@solomon.com.sb
PO Box 1870, Honiara, Solomon Islands

Solomon Tropical Products is the agent for Tinytech minimills. The firm itself operates two Indian presses and one Malaysian press and sells coconut oil and coconut-oil products locally and internationally. It can design and install equipment for a range of capacities and offers training, backup services, and advice on engine-related issues.

Coconut Bio-Energy

Ph: +677 39933
smithv@solomon.com.sb
PO Box R148, Ranadi, Honiara, Solomon Islands

Coconut Bio-Energy is the agent for Goyum Screw Press machinery and can install, train, and provide service for any minimill facility across a large range of capacities. The firm commercially produces coconut oil for international export and has experience in working with Indian presses and U.S.-built Anderson presses. Coconut Bio-Energy is in the process of making an agreement with the Solomon Islands Energy Authority to sell power produced from coconut oil back into the grid.

SET Marketing

Ph/Fax: +677 25221
sethori@solomon.com.sb
PO Box 1952, Honiara, Solomon Islands

SET Marketing is the Solomon Islands agent for Project Support Services (PSS) in PNG. (Refer to PSS in PNG section above for product and service listing.)

ProSolutions

Ph: +677 28027
colindyer@solomon.com.sb
PO Box 1675, Honiara, Solomon Islands

ProSolutions is in partnership with Kokonut Pacific (www.kokonutpacific.com) and sells the DME hand press and filtration units that produce high-grade virgin coconut oil. Colin Dyer has worked throughout a number of Pacific island countries on coconut-oil biofuel projects.

Island Enterprises

Ph: +677 30152
Fax: +677 30188
phil@ielsi.com.sb
PO Box 364, Honiara, Solomon Islands

Island Enterprises sells a range of modern- and historical-style diesel-powered generators. Phil Bradford (MD) has some experience with Lister copies out of India and has visited a number of Listeroid factories. The firm sells all of the necessary equipment to convert engines, has an extensive workshop, can fabricate heat exchangers, and can refit engines to run on coconut oil.

Bishop Brothers

Ph: +677 30046
Fax: +677 30047
honsales@bishopbros.com.pg
www.bishopbros.com.pg
PO Box R276, Ranadi, Honiara, Solomon Islands

Bishop Brothers stocks a range of industrial products, including generators, filters, and all of the necessary parts to adapt engines. The firm currently lacks a workshop, but can have tried and tested heat exchangers made in Port Moresby and sent across.

Vanuatu

Bodiam Pacific Engineering

Ph: +678 47590
Fax: +678 26138 alex@bodiam.vu
PO Box 1548, Port Vila, Vanuatu

Alex Bodiam has a wealth of experience in using coconut oil as a diesel-fuel replacement and commercially sells refined coconut-oil fuel at service stations. He stocks no generators, but can order any variety as required. His large workshop has the facilities to fabricate heat exchangers and to refit engines to run on coconut oil.

Motor Traders

Ph: +678 23430
Fax: +678 23513
motor-traders@vanuatu.com.vu
Port Vila, Vanuatu

Tony Deamer of Motor Traders is one of the pioneers of coconut-oil biofuel in the Pacific. His family business sells coconut-oil fuel, which is locally called Island Fuel. He does not sell generators, but makes heat exchangers for conversion.

South Pacific Electrics Vanuatu

Ph: +678 22034
Fax: +678 22877
masuino@vanuatu.com.vu
PO Box 1548, Port Vila, Vanuatu

South Pacific Electrics does not have generators in stock, but can order in a range of brands from Australia on request. The firm stocks the Fleetguard range of filters.

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