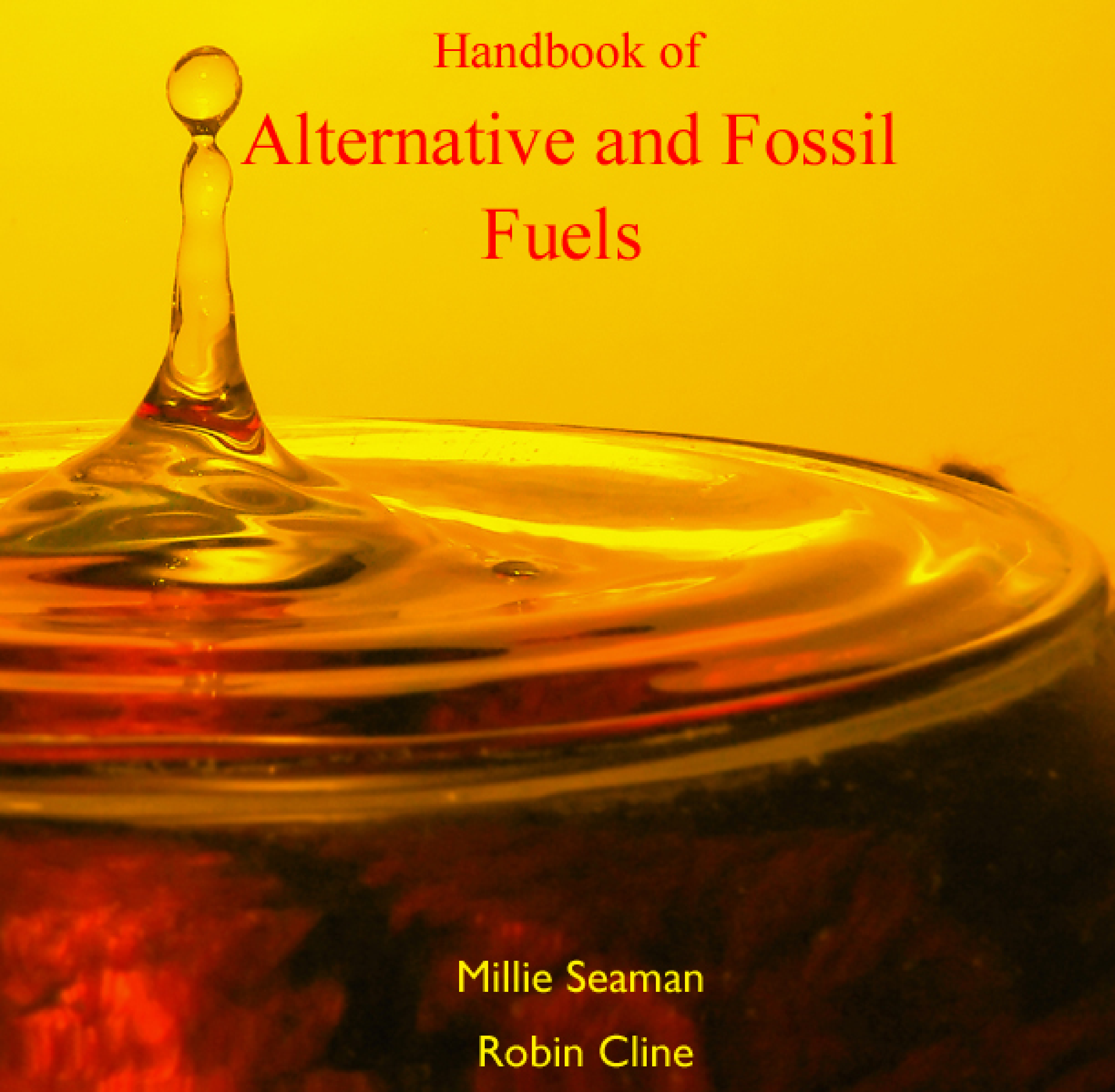

Handbook of

Alternative and Fossil Fuels

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Biofuel

Information on pump regarding ethanol fuel blend up to 10%, California

Bus run on biodiesel

Biofuels are a wide range of fuels which are in some way derived from biomass. The term covers solid biomass, liquid fuels and various biogases. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price spikes, the need for increased energy security, and concern over greenhouse gas emissions from fossil fuels.

Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil.

Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

Biofuels provided 1.8% of the world's transport fuel in 2008. Investment into biofuels production capacity exceeded $4 billion worldwide in 2007 and is growing.

Liquid fuels for transportation

Most transportation fuels are liquids, because vehicles usually require high energy density, as occurs in liquids and solids. High power density can be provided most inexpensively by an internal combustion engine; these engines require clean burning fuels, to keep the engine clean and minimize air pollution.

The fuels that are easiest to burn cleanly are typically liquids and gases. Thus liquids (and gases that can be stored in liquid form) meet the requirements of being both portable and clean burning. Also, liquids and gases can be pumped, which means handling is easily mechanized, and thus less laborious.

First generation biofuels

'First-generation biofuels' are biofuels made from sugar, starch, vegetable oil or animal fats using conventional technology. The basic feedstocks for the production of first generation biofuels are often seeds or grains such as sunflower seeds, which are pressed to yield vegetable oil that can be used in biodiesel, or wheat, which yields starch that is fermented into bioethanol. These feedstocks could instead enter the animal or human food chain, and as the global population has risen their use in producing biofuels has been criticised for diverting food away from the human food chain, leading to food shortages and price rises.

The most common biofuels are listed below.

Bioalcohols

Neat ethanol on the left (A), gasoline on the right (G) at a filling station in Brazil

Biologically produced alcohols, most commonly ethanol, and less commonly propanol and butanol, are produced by the action of microorganisms and enzymes through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult). Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine (in a similar way to biodiesel in diesel engines).

Ethanol fuel is the most common biofuel worldwide, particularly in Brazil. Alcohol fuels are produced by fermentation of sugars derived from wheat, corn, sugar beets, sugar cane, molasses and any sugar or starch that alcoholic beverages can be made from (like potato and fruit waste, etc.). The ethanol production methods used are enzyme digestion (to release sugars from stored starches), fermentation of the sugars, distillation and drying. The distillation process requires significant energy input for heat (often unsustainable natural gas fossil fuel, but cellulosic biomass such as bagasse, the waste left after sugar cane is pressed to extract its juice, can also be used more sustainably).

The Koenigsegg CCXR Edition at the 2008 Geneva Motor Show. This is an "environmentally friendly" version of the CCX, which can use E85 and E100.

Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Ethanol has a smaller energy density than gasoline, which means it takes more fuel (volume and mass) to produce the same amount of work. An advantage of ethanol (CH3CH2OH) is that it has a higher octane rating than ethanol-free gasoline available at roadside gas stations which allows an increase of an engine's compression ratio for increased thermal efficiency. In high altitude (thin air) locations, some states mandate a mix of gasoline and ethanol as a winter oxidizer to reduce atmospheric pollution emissions.

Ethanol is also used to fuel bioethanol fireplaces. As they do not require a chimney and are "flueless", bio ethanol fires are extremely useful for new build homes and apartments without a flue. The downside to these fireplaces, is that the heat output is slightly less than electric and gas fires.

In the current alcohol-from-corn production model in the United States, considering the total energy consumed by farm equipment, cultivation, planting, fertilizers, pesticides, herbicides, and fungicides made from petroleum, irrigation systems, harvesting, transport of feedstock to processing plants, fermentation, distillation, drying, transport to fuel terminals and retail pumps, and lower ethanol fuel energy content, the net energy content value added and delivered to consumers is very small. And, the net benefit (all things considered) does little to reduce un-sustainable imported oil and fossil fuels required to produce the ethanol.

Although ethanol-from-corn and other food stocks has implications both in terms of world food prices and limited, yet positive energy yield (in terms of energy delivered to customer/fossil fuels used), the technology has led to the development of cellulosic ethanol. According to a joint research agenda conducted through the U.S. Department of Energy, the fossil energy ratios (FER) for cellulosic ethanol, corn ethanol, and gasoline are 10.3, 1.36, and 0.81, respectively.

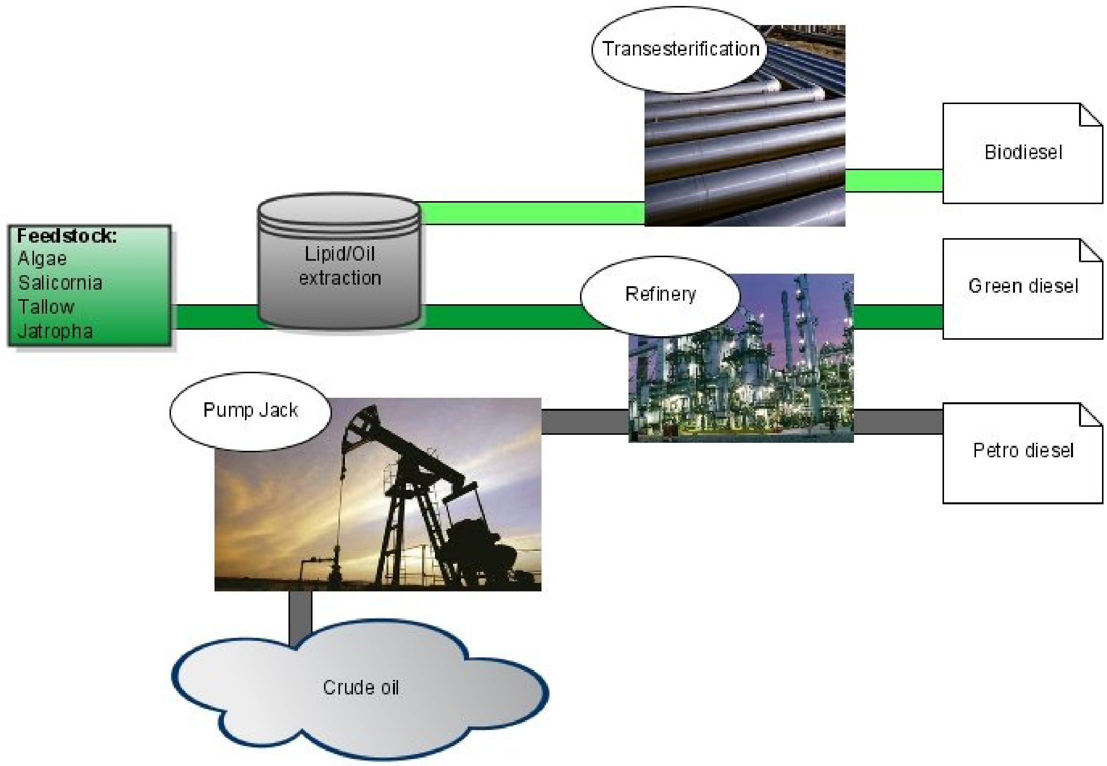
Many car manufacturers are now producing flexible-fuel vehicles (FFV's), which can safely run on any combination of bioethanol and petrol, up to 100% bioethanol. They dynamically sense exhaust oxygen content, and adjust the engine's computer systems, spark, and fuel injection accordingly. This adds initial cost and ongoing increased vehicle maintenance. As with all vehicles, efficiency falls and pollution emissions increase when FFV system maintenance is needed (regardless of the fuel mix being used), but is not performed. FFV internal combustion engines are becoming increasingly complex, as are multiple-propulsion-system FFV hybrid vehicles, which impacts cost, maintenance, reliability, and useful lifetime longevity.

Even dry ethanol has roughly one-third lower energy content per unit of volume compared to gasoline, so larger / heavier fuel tanks are required to travel the same distance, or more fuel stops are required. With large current unsustainable, non-scalable subsidies, ethanol fuel still costs much more per distance traveled than current high gasoline prices in the United States.

Methanol is currently produced from natural gas, a non-renewable fossil fuel. It can also be produced from biomass as biomethanol. The methanol economy is an interesting alternative to get to the hydrogen economy, compared to today's hydrogen production from natural gas. But this process is not the state-of-the-art clean solar thermal energy process, where hydrogen production is directly produced from water.

Butanol is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy and allegedly can be burned "straight" in existing gasoline engines (without modification to the engine or car), and is less corrosive and less water soluble than ethanol, and could be distributed via existing infrastructures. DuPont and BP are working together to help develop Butanol. E. coli have also been successfully engineered to produce Butanol by hijacking their amino acid metabolism.

Green diesel



Inputs and outputs of diesel and diesel-like fuels

Green diesel, also known as **renewable diesel**, is a form of diesel fuel which is derived from renewable feedstock by using biomass to liquid or vegetable oil refining technologies. Based on its feedstock it could be classified as biodiesel; however, based on the processing technology and chemical formula green diesel and biodiesel are different products. While biodiesel is processed using transesterification, green diesel is processed by the traditional fractional distillation like fossil origin diesel fuel (petrodiesel).

Feedstock

Green diesel feedstock can be sourced from a variety oils including canola, algae, jatropha and salicornia in addition to tallow.

Green diesel was used to power at least one vehicle during a transportation showcase at the 2009 United Nations Climate Change Conference in Copenhagen, Denmark in December 2009.

Also in December 2009, the South Dakota School of Mines and Technology received a $1M US grant from the United States government, in part to do research on green diesel, along with biodiesel and other bio fuel research for the United States Air Force.

“Green Diesel” as commonly known in Ireland should not be confused with dyed green diesel sold at a lower tax rate for off-road use, using the dye allows custom officers to determine if a person is using the cheaper diesel in higher taxed applications such as commercial haulage or cars.

Technology

At this stage the only commercial scale green diesel refinery process is the UOP/Eni "Ecofining" process.

Smaller scale refining can be carried out using technology from Renewable Fuel Products, Inc.

Vegetable oil

Waste vegetable oil which has been filtered

Vegetable oil is an alternative fuel for diesel engines and for heating oil burners. For engines designed to burn diesel fuel, the viscosity of vegetable oil must be lowered to allow for proper atomization of the fuel, otherwise incomplete combustion and carbon build up will ultimately damage the engine. Many enthusiasts refer to vegetable oil used as fuel as **waste vegetable oil** (WVO) if it is oil that was discarded from a restaurant or **straight vegetable oil** (SVO) or **pure plant oil** (PPO) to distinguish it from biodiesel.

History

Rudolf Diesel was the father of the engine which bears his name. His first attempts were to design an engine to run on coal dust, but later designed his engine to run on vegetable oil. The idea, he hoped, would make his engines more attractive to farmers having a source of fuel readily available. In a 1912 presentation to the British Institute of Mechanical Engineers, he cited a number of efforts in this area and remarked, "The fact that fat oils from vegetable sources can be used may seem insignificant today, but such oils may perhaps become in course of time of the same importance as some natural mineral oils and the tar products are now."

Periodic petroleum shortages spurred research into vegetable oil as a diesel substitute during the 1930s and 1940s, and again in the 1970s and early 1980s when straight vegetable oil enjoyed its highest level of scientific interest. The 1970s also saw the formation of the first commercial enterprise to allow consumers to run straight vegetable oil in their automobiles, Elsbett of Germany. In the 1990s Bougainville conflict, islanders cut off from oil supplies due to a blockade used coconut oil to fuel their vehicles.

Academic research into straight vegetable oil fell off sharply in the 1980s with falling petroleum prices and greater interest in biodiesel as an option that did not require extensive vehicle modification.

Application and usability

Older diesel Mercedes are popular for conversions to biodiesel or waste vegetable oil

While engineers and enthusiasts have been experimenting with using vegetable oils as fuel for a diesel engine since at least 1900, it is only recently that the necessary fuel properties and engine parameters for reliable operation have become apparent, only a handful of peer reviewed studies exist that show reliable long term use of vegetable oil: one for the German Deutz AG F3l912W. and another for a high speed common rail engine fitted to a Mercedes-Benz 220 C Class

Most diesel car engines are suitable for the use of SVO, also commonly called Pure Plant Oil (PPO), with suitable modifications. Principally, the viscosity and surface tension of the SVO/PPO must be reduced by preheating it, typically by using waste heat from the engine or electricity, otherwise poor atomization, incomplete combustion and carbonization may result. One common solution is to add a heat exchanger, and an additional fuel tank for "normal" diesel fuel (petrodiesel or biodiesel) and a three way valve to switch between this additional tank and the main tank of SVO/PPO. (This aftermarket modification typically costs about $1200 USD.) The engine is started on diesel, switched over to vegetable oil as soon as it is warmed up and switched back to diesel shortly before being switched off to ensure that no vegetable oil remains in the engine or fuel lines when it is started from cold again. In colder climates it is often necessary to heat the vegetable oil fuel lines and tank as it can become very viscous and even solidify.

Single tank conversions have been developed, largely in Germany, which have been used throughout Europe. These conversions are designed to provide reliable operation with rapeseed oil that meets the German rapeseed oil fuel standard DIN 51605. Modifications to the engines cold start regime assist combustion on start up and during the engine warm up phase. Suitably modified indirect injection (IDI) engines have proven to be operable with 100% PPO down to temperatures of -10°C. Direct injection (DI) engines generally have to be preheated with a block heater or diesel fired heater. The exception is the VW Tdi (Turbocharged Direct Injection) engine for which a number of German companies offer single tank conversions. For long term durability it has been found necessary to increase the oil change frequency and to pay increased attention to engine maintenance.

With unmodified engines the unfavorable effects may be reduced by blending, or "cutting", the SVO/PPO with diesel fuel; however, opinions vary as to the efficacy of this. Some WVO mechanics have found higher rates of wear and failure in fuel pumps and piston rings. This can generally be attributed to the use of oils with properties or contaminants that make them unsuitable for use in this type of application, poorly maintained engines, unsuitable engine modifications or operating regimes.

Many cars powered by indirect injection engines supplied by in-line injection pumps, or mechanical Bosch injection pumps are capable of running on pure SVO/PPO in all but winter temperatures. Indirect injection Mercedes-Benz vehicles with in-line injection pumps and cars featuring the PSA XUD engine tend to perform reasonably, especially as the latter is normally equipped with a coolant heated fuel filter. Engine reliability would depend on the condition of the engine. Attention to maintenance of the engine, particularly of the fuel injectors, cooling system and glow plugs will help to provide longevity. Ideally the engine would be converted.

Properties

The main form of SVO/PPO used in the UK is rapeseed oil (also known as canola oil, primarily in the United States and Canada) which has a freezing point of -10°C. However the use of sunflower oil, which gels at around -12°C, is currently being investigated as a means of improving cold weather starting. Unfortunately oils with lower gelling points tend to be less saturated (leading to a higher iodine number) and polymerize more easily in the presence of atmospheric oxygen.

Material compatibility

Free fatty acids in WVO can have a detrimental effect on metals. Copper and its alloys, such as brass, are affected. Zinc and zinc-plating (galvanization) are stripped by FFA's and tin, lead, iron, and steel are affected too. Stainless steel and aluminum are generally unaffected.

Examples

Some Pacific island nations are using coconut oil as fuel to reduce their expenses and their dependence on imported fuels while helping stabilize the coconut oil market. Coconut oil is only usable where temperatures do not drop below 17 degrees Celsius (62 degrees Fahrenheit), unless two-tank SVO/PPO kits or other tank-heating accessories, etc. are used. Fortunately, the same techniques developed to use, for example, canola and other oils in cold climates can be implemented to make coconut oil usable in temperatures lower than 17 degrees Celsius.

Home heating

With often minimal modification, most residential furnaces and boilers that are designed to burn No. 2 heating oil can be made to burn either biodiesel or filtered, preheated waste vegetable oil. These are generally not as clean-burning as petroleum fuel oil, but if processed at home, by the consumer, can result in considerable savings. Many restaurants will give away their used cooking oil either free or at minimal cost, and processing to biodiesel is fairly simple and inexpensive. Burning filtered WVO directly is somewhat more problematic, since it is much more viscous, but it can be accomplished with suitable preheating. WVO can thus be an economical heating option for those with the necessary mechanical and experimental aptitude, where fire regulations and insurance policy permit it.

Combined heat and power

A number of companies offer compressed ignition engine generators optimized to run on plant oils where the waste engine heat is recovered for heating.

Availability

Waste vegetable oil

As of 2000, the United States was producing in excess of 11 billion liters (2.9 billion U.S. gallons) of waste vegetable oil annually, mainly from industrial deep fryers in potato processing plants, snack food factories and fast food restaurants. If all those 11 billion liters could be collected and used to replace the energetically equivalent amount of petroleum (an ideal case), almost 1% of US oil consumption could be offset. Use of waste vegetable oil as a fuel competes with some other uses of the commodity, which has effects on its price as a fuel and increases its cost as an input to the other uses as well.

Pure vegetable oil (pure plant oil)

Pure plant oil (PPO) (or Straight Vegetable Oil (SVO)), in contrast to waste vegetable oil, is not a byproduct of other industries, and thus its prospects for use as fuel are not limited by the capacities of other industries. Production of vegetable oils for use as fuels is theoretically limited only by the agricultural capacity of a given economy. However, doing so detracts from the supply of other uses of pure vegetable oil.

Legal implications

Taxation of fuel

Taxation on SVO/PPO as a road fuel varies from country to country, and it is possible the revenue departments in many countries are even unaware of its use, or feel it insufficiently significant to legislate. Germany used to have 0% taxation, resulting in it being a leader in most developments of the fuel use. However SVO/PPO as a road fuel began to be taxed at 0,09 €/liter from 1 January 2008 in Germany, with incremental rises up to 0,45 €/liter by 2012. However, in Australia it has become illegal to produce any fuel if it is to be sold unless a license to do so is granted by the Federal Government. This is a chargeable offense with a fine of up to 20,000 dollars but this bracket may alter circumstantially. Also a jail term may result if offenders are aware of the illegality of selling the fuel.

USA

The legality of burning SVO in the United States of America is debated by many. Though vehicle conversions are available both as do it yourself kits or professionally installed in virtually every metropolitan area, the EPA clearly states vegetable oil (raw or recycled) is not registered for use as a vehicle fuel. Further, vehicles converted to use vegetable oil as fuel would "likely need to be certified by the EPA," and no such certifications have been done to date.

There seems to be no clear federal taxation system in the USA. Production of biodiesel in some US regions may require motor fuel taxes to be paid.

Japan

The Japanese Government has also exempted the use of SVO as a fuel from road tax.

Republic of Ireland

In the Republic of Ireland a pilot scheme is currently running (as of April 2006) whereby eight suppliers have been approved to sell SVO/PPO for use as a fuel without the payment of excise duty (Value Added Tax at 21% still applies, SVO from any other source still attracts excise duty at 36.8058 Euro cents per litre plus 21% VAT).

France

Despite its use being common in France, it would appear there has been no legislation to cover this.

UK

In the UK, it is legal once duty on the fuel is paid. In the UK, drivers using SVO/PPO have been prosecuted for failure to pay duty to Her Majesty's Revenue and Customs. The rate of taxation on SVO was originally set at a reduced rate of 27.1p per litre, but in late 2005, HMRC started to enforce the full diesel excise rate of 47.1p per litre.

Following a review in late 2006, HM Revenue & Customs has announced changes regarding the administration and collection of excise duty of biofuels and other fuel substitutes (Veg Oil). The changes came into effect on June 30, 2007. There is no longer a requirement to register to pay duty on vegetable oil used as road fuel for those who "produce" or use less than 2,500 litres per year. For those producing over this threshold the biodiesel rate now applies.

HMRC argued that SVOs/PPOs on the market from small producers did not meet the official definition of "biodiesel" in Section 2AA of The Hydrocarbon Oil Duties Act 1979 (HODA), and consequently was merely a "fuel substitute" chargeable at the normal diesel rate. Such a policy seemed to contradict the UK Government's commitments to the Kyoto Protocol and to many EU directives and had many consequences, including an attempt to make the increase retroactive, with one organization being presented with a £16,000 back tax bill. This change in the rate of excise duty has effectively removed any commercial incentive to use SVO/PPO, regardless of its desirability on environmental grounds; unless waste vegetable oil can be obtained free of charge, the combined price of SVO/PPO and taxation for its use usually exceeds the price of mineral diesel. HMRC's interpretation is being widely challenged by the SVO/PPO industry and the UK pure Plant Oil Association (UKPPOA) has been formed to represent the interests of people using vegetable oil as fuel and to lobby parliament.

Bioethers

Bio ethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers. They also enhance engine performance, whilst significantly reducing engine wear and toxic exhaust emissions. Greatly reducing the amount of ground-level ozone, they contribute to the quality of the air we breathe.

Syngas

Syngas, a mixture of carbon monoxide and hydrogen, is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is not sufficient to convert the biomass completely to carbon dioxide and water. Before partial combustion the biomass is dried, and sometimes pyrolysed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted.

- Syngas may be burned directly in internal combustion engines or turbines. The wood gas generator is a wood-fueled gasification reactor mounted on an internal combustion engine.
- Syngas can be used to produce methanol and hydrogen, or converted via the Fischer-Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Gasification normally relies on temperatures >700°C.
- Lower temperature gasification is desirable when co-producing biochar but results in a Syngas polluted with tar.

Solid biofuels

Examples include wood, sawdust, grass cuttings, domestic refuse, charcoal, agricultural waste, non-food energy crops (see picture), and dried manure.

When raw biomass is already in a suitable form (such as firewood), it can burn directly in a stove or furnace to provide heat or raise steam. When raw biomass is in an inconvenient form (such as sawdust, wood chips, grass, urban waste wood, agricultural residues), the typical process is to densify the biomass. This process includes grinding the raw biomass to an appropriate particulate size (known as hogfuel), which depending on the densification type can be from 1 to 3 cm (1 in), which is then concentrated into a fuel product. The current types of processes are wood pellet, cube, or puck. The pellet process is most common in Europe and is typically a pure wood product. The other types of densification are larger in size compared to a pellet and are compatible with a broadrange of input feedstocks. The resulting densified fuel is easier to transport and feed into thermal generation systems such as boilers.

A problem with the combustion of raw biomass is that it emits considerable amounts of pollutants such as particulates and PAHs (polycyclic aromatic hydrocarbons). Even modern pellet boilers generate much more pollutants than oil or natural gas boilers. Pellets made from agricultural residues are usually worse than wood pellets, producing much larger emissions of dioxins and chlorophenols.

Notwithstanding the above noted study, numerous studies have shown that biomass fuels have significantly less impact on the environment than fossil based fuels. Of note is the U.S. Department of Energy Laboratory, Operated by Midwest Research Institute Biomass Power and Conventional Fossil Systems with and without CO2}} Sequestration – Comparing the Energy Balance, Greenhouse Gas Emissions and Economics Study. Power generation emits significant amounts of greenhouse gases (GHGs), mainly carbon dioxide (CO_2). {{Sequestering CO_2 from the power plant flue gas can significantly reduce the GHGs from the power plant itself, but this is not the total picture. CO_2 capture and sequestration consumes additional energy, thus lowering the plant's fuel-to-electricity efficiency. To compensate for this, more fossil fuel must be procured and consumed to make up for lost capacity.

Taking this into consideration, the global warming potential (GWP), which is a combination of CO_2, methane (CH_4), and nitrous oxide (N_2O) emissions, and energy balance of the system need to be examined using a life cycle assessment. This takes into account the upstream processes which remain constant after CO_2 sequestration as well as the steps required for additional power generation. firing biomass instead of coal led to a 148% reduction in GWP.

A derivative of solid biofuel is biochar, which is produced by biomass pyrolysis. Bio-char made from agricultural waste can substitute for wood charcoal. As wood stock becomes scarce this alternative is gaining ground. In eastern Democratic Republic of Congo, for example, biomass briquettes are being marketed as an alternative to charcoal in order to protect Virunga National Park from deforestation associated with charcoal production.

Second generation biofuels

Supporters of biofuels claim that a more viable solution is to increase political and industrial support for, and rapidity of, second-generation biofuel implementation from non-food crops. These include waste biomass, the stalks of wheat, corn, wood, and special-energy-or-biomass crops (e.g. Miscanthus). Second generation (2G) biofuels use biomass to liquid technology, including cellulosic biofuels. Many second generation biofuels are under development such as biohydrogen, biomethanol, DMF, Bio-DME, Fischer-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel.

Cellulosic ethanol production uses non-food crops or inedible waste products and does not divert food away from the animal or human food chain. Lignocellulose is the "woody" structural material of plants. This feedstock is abundant and diverse, and in some cases (like citrus peels or sawdust) it is in itself a significant disposal problem.

Producing ethanol from cellulose is a difficult technical problem to solve. In nature, ruminant livestock (like cattle) eat grass and then use slow enzymatic digestive processes to break it into glucose (sugar). In cellulosic ethanol laboratories, various experimental processes are being developed to do the same thing, and then the sugars released can be fermented to make ethanol fuel. In 2009 scientists reported developing, using "synthetic biology", "15 new highly stable fungal enzyme catalysts that efficiently break down cellulose into sugars at high temperatures", adding to the 10 previously known. The use of high temperatures, has been identified as an important factor in improving the overall economic feasibility of the biofuel industry and the identification of enzymes that are stable and can operate efficiently at extreme temperatures is an area of active research. In addition, research conducted at TU Delft by Jack Pronk has shown that elephant yeast, when slightly modified can also create ethanol from non-edible ground sources (e.g. straw).

The recent discovery of the fungus Gliocladium roseum points toward the production of so-called myco-diesel from cellulose. This organism was recently discovered in the rainforests of northern Patagonia and has the unique capability of converting cellulose into medium length hydrocarbons typically found in diesel fuel. Scientists also work on experimental recombinant DNA genetic engineering organisms that could increase biofuel potential.

Scientists working in New Zealand have developed a technology to use industrial waste gases from steel mills as a feedstock for a microbial fermentation process to produce ethanol.

Second, third, and fourth generation biofuels are also called advanced biofuels.

Third generation biofuels

Algae fuel, also called oilgae or third generation biofuel, is a biofuel from algae. Algae are low-input, high-yield feedstocks to produce biofuels. Based on laboratory experiments, it is claimed that algae can produce up to 30 times more energy per acre than land crops such as soybeans, but these yields have yet to be produced commercially. With the higher prices of fossil fuels (petroleum), there is much interest in algaculture (farming algae). One advantage of many biofuels over most other fuel types is that they are biodegradable, and so relatively harmless to the environment if spilled. Algae fuel still has its difficulties though, for instance to produce algae fuels it must be mixed uniformly, which, if done by agitation, could affect biomass growth.

The United States Department of Energy estimates that if algae fuel replaced all the petroleum fuel in the United States, it would require only 15,000 square miles (38,849