PRACTICAL ACTION
Technology challenging poverty

LIQUID BIOFUELS
AND SUSTAINABLE DEVELOPMENT

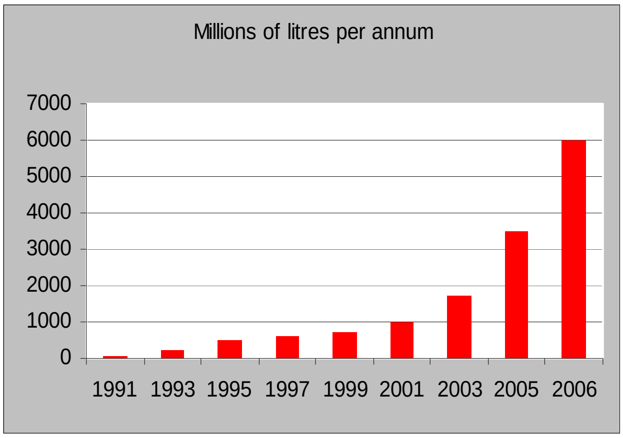
Introduction
Liquid fossil fuels, such as paraffin (kerosene) and fuel oil, have been with us for many years. Over the past decade, similar fuels, made by processing plants, trees and organic waste products have become much more widely available. The rapid growth in the use of biofuels stems from the soaring price of fossil oil, growing concern over security of supply and the environmental impact of fossil fuels. The three main types of liquid fuel looked at in this document comprise:
- Ethanol, made by fermenting sugar cane, grain, straw, grass and wood.
- Biodiesel, made from new or recycled vegetable oils and animal fats (e.g. from palm oil)
- Oils made by compressing seeds (such as jatropha oil). Production from algae is currently being researched.

Grown sustainably, biofuels have the potential to alleviate global warming and other negative environmental issues such as the disposal of vast quantities of organic wastes.

Used responsibly, biofuels can have a major impact on levels of pollutants, both within the homes of those living in poverty, and in the crowded cities of the developing world.

When biofuels first became widely available they were heralded as the new sustainable way to provide the world with energy. More recently, the use of land for growing crops which are solely for energy has led to major environmental issues.

The market in biofuels has grown very fast, as shown in the figures for biodiesel provided by the Biodiesel 2020 survey (Emerging Markets Online). As a result, environmentalists are calling for stricter global controls on production.



Biodiesel production *(source: Emerging markets online: biodiesel survey 2020)*

Growing biofuels
Sustainable cultivation
Of all opportunities for renewable energy from energy plantation biomass, sugar cane makes the most sense. In many African countries where sugar was developed under colonial economies, sugar was produced (mainly for export to Europe and beyond), while the residues, such as molasses, were dumped into the rivers, leaching the oxygen from the water and

Practical Action, The Schumacher Centre for Technology and Development, Bourton on Dunsmore, Rugby, Warwickshire, CV23 9QZ, UK
T +44 (0)1926 634400 | **F** +44 (0)1926 634401 | **E** infoserv@practicalaction.org.uk | **W** www.practicalaction.org

technical brief

destroying life. These sugar factories were very dirty operations - many still are. Developing a market for ethanol can form part of a beneficial re-use strategy that can clean sugar factories and use the residues that previously had no value and were dumped. With advanced technologies now available, biomass, such as trees and grasses, can also be used as feedstocks for ethanol production.

A vast variety of oil plants originate in the tropics and subtropics. Many oil-bearing plants, whose oils are often toxic to humans, grow on low-grade land, or in marginal locations unsuitable for food crops. Some of these plants are cultivated on waste lands to prevent further erosion and to inhibit desertification. Use of these oils for energy provision does not need to compete with food production. Examples of these oil plants are the Physic nut tree (Jatropha Curcas L.), the castor oil plant varieties (Ricinus communis L.) and the babassú palm (Orbignya phalerata Mart.), among others.

Some oil plants grow in symbiosis with food plants by being used, for example, as shade trees, or to provide barriers against animals; jatropha is not eaten by animals so can be used in this way. Plant oils from seeds such as jatropha (which grow in many regions of tropical and subtropical countries), can be harvested and the oil extracted using hand tools. This local oil production strengthens decentralized supply, provides employment and income opportunities for the local population and promotes sustainability. The presscake, a by-product of the oil processing, can be used either as fodder or as high-quality fertilizer. In general, all plant oils which are liquid at ambient temperatures can be utilized as cooking fuel (Stumpf, 2002).

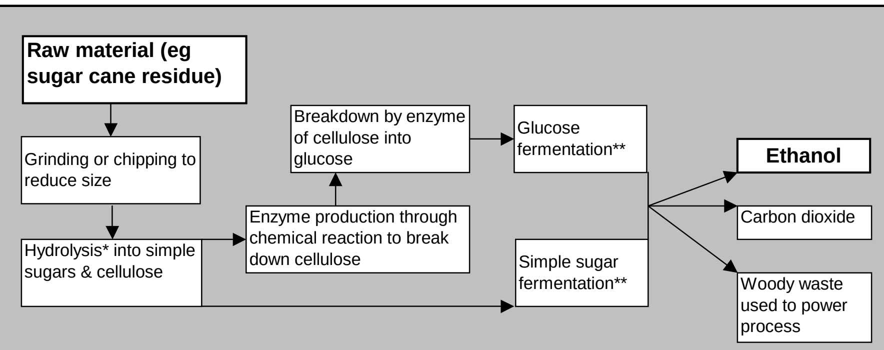
Large-scale cultivation of biofuels

The problems associated with growing biofuels stem from the industrialised world trying to grow its way out of its dependence on the internal combustion engine, and the huge profits that are to be made from growing palm oil and other high energy crops. A single hectare of oil palm may yield five tonnes of crude oil (Mongabay.com) – and where rainforests are cleared, for example in Malaysia, further profits can be made through the sale of timber from land clearance. There is evidence that not all cleared land is suitable for palms and that hardwood is the main objective. This indiscriminate culling of forests has led, for instance, to oil-palm plantations covering 5.3 million hectares of Indonesia (2004).The destruction of prime forest has led to major social and cultural upheaval for indigenous peoples whose rights have been ignored (Mongabay.com).

After 25 years, lands are often so leached of nutrients that they are abandoned and become scrubland where few plants will grow. In the USA, which is seeking to reduce its dependence on overseas oil products, subsidies may mask the costs of spraying both pesticides and fertilizers, and from using of large-scale farm machinery.

How are biofuels made?

Bio-ethanol

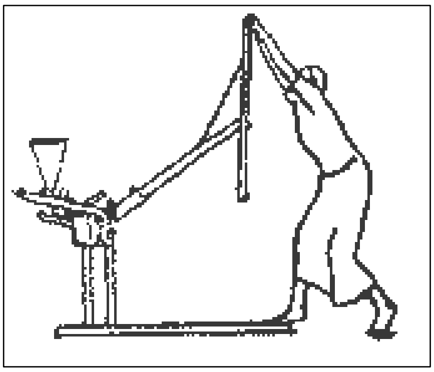


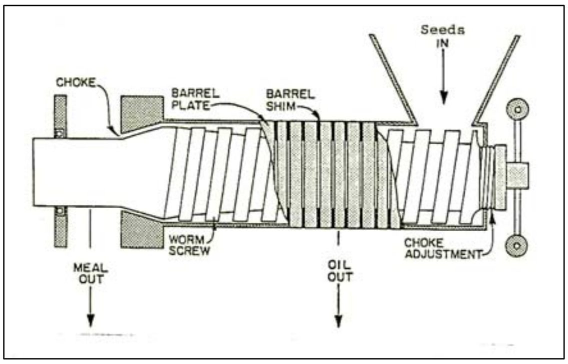
* Chemical reaction caused by addition of dilute sulphuric acid on the active ingredients in the feedstock

** Series of chemical reactions that convert sugars through action by yeast or bacteria to ethanol and carbon dioxide

The raw feedstock, such as sugar cane residues, is ground up to a small size and the active ingredients in the feedstock react with dilute sulphuric acid, breaking down into a mixture of simple sugars, cellulose and cellulose enzymes which are grown at this stage (or they can be bought in). The cellulose is further reacted with the cellulose enzymes to form glucose. Both the simple sugars and the glucose are fermented with yeasts or bacteria, forming ethanol, with carbon dioxide as a by-product. The non-reactive parts of the sugar cane remain as a woody waste which can be used as a fuel to drive the process.

Plant oils for energy

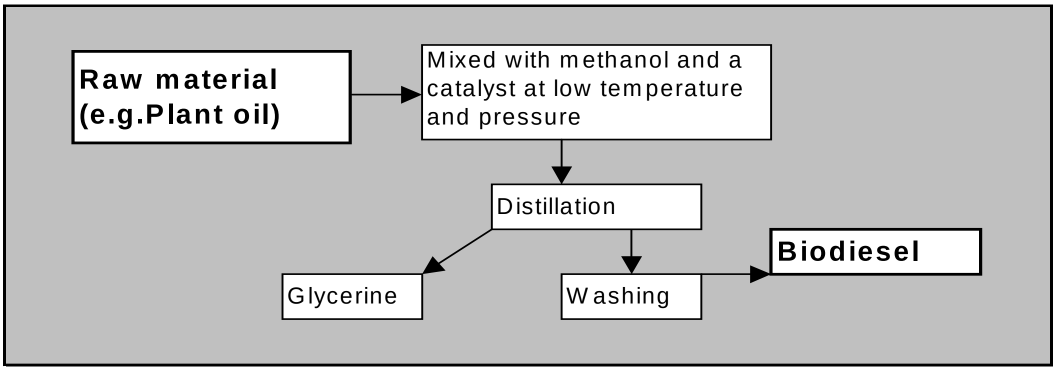




Plant oils can be extracted using hand tools, such as the Approtech oil expeller shown on the left (Approtech), or the motorised Sundhara-type oil presses, such as the one shown on the right (http://www.jatropha.de/expellers/).

These methods are similar to those used for food oil extraction. Practical Action has extensive information on these types of extraction, including a technical brief specifically on oil extraction.

Biodiesel



The raw oil is reacted with an excess of alcohol (often methanol or ethanol) in the presence of a catalyst (often potassium or sodium hydroxide). The products of this reaction are crude biodiesel and crude glycerine, with an excess alcohol, which is recovered and re-used.

Uses of biofuels

The main use of biofuels globally is within the transport sector, with bio-ethanol replacing petrol (gasoline) and bio-diesel replacing diesel. Governments have been keen to promote the use of such fuel for transport purposes as they can draw increased revenue from taxing its sale as motor fuel. In the longer term, unregulated planting of energy crops for the transport sector is likely to lead to land degradation, social unrest and famine.

For cooking and lighting within the home, biofuels are hugely beneficial, as they can be burnt completely cleanly. With over 4000 people dying each day globally as a result of indoor air pollution from cooking smoke, providing a clean local alternative fuel in those countries most affected can make substantial inroads into alleviating poverty. Clean cooking provides health, safety and quality of life benefits especially for women and children.

Biofuel stoves have been shown to be effective in reducing or eliminating the practice of gathering biomass; this can be especially critical where deforestation and desertification are pressing issues, or in conflict situations where women fuel-gatherers are particularly vulnerable to assault.

Developing countries with ideal climates for the rapid growth of fuel crops, such as sugar cane, are often the same ones suffering the greatest burden of disease and death from indoor air pollution. This document will discuss mainly the positive technologies for which biofuels should be grown.

Technologies for liquid biofuels

Biofuel stoves

Liquified Petroleum Gas (LPG) is a fossil-fuel derivative of two large energy industries: natural gas processing and crude oil refining. Currently the demand for LPG is growing at around 0.4% per annum and with the growth in demand in Asia growing at 3.5% per annum (LP Gas Association website (data 2004)). Any downturn in the supply of these two fossil fuels will lead to a reduction in the availability of supplies and consequent price increases. Other clean fuels are needed for cooking both to complement LPG in those countries which are not themselves oil rich, and to supply clean energy to those currently using biomass in traditional cooking stoves and three-stone fires.

Ethanol stoves

Ethanol is easily and safely handled, leading to their use, for years, for the recreational market such as yachts and outdoor activities.
Recently, robust, low-cost stoves have been designed specifically for households in the developing world.
This new market has lead to the establishment of ethanol fuel distribution systems, creating opportunities for local commerce. A good example is the CleanCook Stove. This stainless steel stove burns cleanly and has safety features designed particularly for the household:

Ethiopian refugee cooking on a CleanCook stove

- A fuel tank holds the ethanol in a special absorptive fibre so that it cannot spill out
- Fuel is denatured so that it cannot be ingested
- The tank is not pressurised so there is no risk of explosion
- The burner flame is easily adjusted or extinguished by means of a simple regulator

This stove is finding a market in both Africa and Latin America. Currently, manufacture of the stove for Ethiopia is being transferred to Addis Ababa, bringing skills and employment close to where the stove will be in use and providing clean fuel for refugee communities (O'Brien).

SuperBlu stove

Other manufacturers for ethanol stoves include the SuperBlu stove manufactured by Bluwave Ltd. The stove has been designed to be reliable, safe and easy to manufacture. The fuel consumption is highly efficient compared to paraffin stoves, and it burns cleanly with no smell. It has no consumable parts, such as wicks. In cold conditions, it converts into a heater by the simple means of a ceramic cylinder which fits on top of the stove. The cylinder heats up and retains and radiates the heat to warm the surrounds, and on top of the cylinder a space is provided for a kettle. A detailed discussion on testing of this stove can be found on the HEDON Household Energy Network website (Bluwave).

Plant oil stoves

There are a wide variety of plant oils that have potential for cooking, including coconut, jatropha, soya bean, corn, peanut, cotton, sunflower and many more. The Protos stove was developed in the Philippines by Leyte State University (LSU) in collaboration with Bosch and Siemens Home Appliance Group (BSH), who have supported and funded the work, alongside the German government (Guarte).

Protos plant oil cooker

A key feature of this type of stove is that fuel can be bought in very low quantities – and for people on small incomes, not having to save for a refill means that the tradition of buying enough just for the next day can be continued.

Plant oil is safe to use: it does not burn under normal room conditions, and burns cleanly, so is good for health.

Those piloting the use of the plant oil stove say that it cooks faster than a traditional kerosene stove and the cost of fuel tends to be lower. Most of the stove parts are manufactured locally, although the high precision components are still made by BSH. The German agency, GTZ, is testing the stove in the longer term in Tanzania. Already there is wide demand for the stove.

Biofuel lighting

Ethanol can be used to produce a clean bright light.

Petromax, who produce the BriteLyt Methanol/Ethanol/Alcohol Lantern, makes the best known of these lanterns. This lantern is manufactured currently in the USA (Britelyt).

The Nimbkar Agricultural Research Institute (NARI) in the Philippines has developed the Noorie lantern that burns very cleanly, producing light equivalent to that from a 100 W incandescent light bulb. By removing the top of the lamp, an attachment can allow the lantern to be used for small amounts of cooking

Noorie lantern with cooking attachment

Electricity generation

There are several types of vegetable oils that can be used to generate electricity in adapted diesel engines. For example, in the Amazon region, around 1000 small power plants (<500kW) use diesel to supply electricity to small towns and villages, whilst huge plantations of oil palm are cultivated for biofuels for export (Coelho, 2005).

Diesel is not subsidised, and the electricity is often too expensive for households to buy. Diesel engines adapted to burn vegetable oil are being tested in demonstration units in isolated villages. Where they have been installed, they have been found to be socially beneficial – particularly where the communities are very isolated. Such projects are potential candidates for carbon finance as they replace diesel, which can lead to lower costs for both installation and fuel.

In Mali, according to the news agency Reuters, some 700 communities have installed biodiesel generators powered by oil from the Jatropha curcas plant. The Malian government is promoting cultivation of the inedible oilseed bush to provide electricity for lighting homes, running water pumps and grain mills, and other critical uses. Mali hopes to eventually power all of the country's 12,000 villages with affordable, renewable energy sources. Jatropha has the additional benefit that it stabilizes soil in areas prone to erosion, and is used as a medicinal plant.

Mali is seeking to boost the standard of living of its 80-percent-rural population and to reduce migration from impoverished rural areas through electricity for light,air conditioning, vaccine storage and media. (Herro)

In rural Cambodia a scheme was piloted whereby jatropha nuts, which grow wild along the roadside, are collected by local villagers and traded by the local shopkeeper in exchange for goods to the value of the nuts. The nuts are bought by the oil-producer for this traded price and small oil-expellers located in some of the villages will be used to make jatropha oil. The oil was supplied to those businesses charging batteries and running standard diesel generators. The 'cake' from the crushed seeds is used for cattle feed (DATe).

Biofuels for transport

Ethanol is a high octane fuel and has replaced lead as an octane enhancer in petrol. By blending ethanol with petrol, oxygen is added to the fuel mixture so it burns more completely and reduces polluting emissions. Ethanol fuel blends are widely sold in the United States. The most common blend is 10% ethanol and 90% petrol (E10). Vehicle engines require no modifications to run on E10. Only flexible fuel vehicles can run on up to 85% ethanol and 15% petrol blends (E85).

Brazil is the leader in biofuel production, with a government decision more than twenty years ago to make the country self-sufficient in energy. By 2005, the number of cars sold that could run on both ethanol and petrol exceeded those sold that could use petrol alone.

By 2020, it is projected that biodiesel could represent as much as 20% of all on-road diesel used in Brazil, Europe, China and India. Biodiesel consumption in the U.S. grew from 25 million gallons per year in 2004 to over 250 million gallons in 2006. In the U.S. over fifty new, larger-scale plants are in construction and are expected to come online between 2007 and 2008 (Biodiesel 2020).

Biofuels and the environment

Biofuels can both benefit and destroy the environment – depending on the ways in which they replace fossil fuels. When fossil fuels burn, they add to the levels of greenhouse gases in the environment. Where these are replaced by renewably-grown biofuels, the carbon dioxide is re-absorbed by the plants as they grow, and energy does not need to be expended in transporting fossil fuels for long distances. Thus, using clean and sustainable practices, biofuels can benefit the environment, and add economic value to local communities.

However, where large plantations have been planted in rainforest areas, this benefit is completely overwhelmed by the damage done to the environment by burning the forest, which is an essential global 'sink' for these greenhouse gases. This large-scale, non-regulated approach can lead to land degradation as the soil is leached of its nutrients. Communities are often faced with eviction or land on which crops no longer grw.

The main use of biofuels is in the automotive sector. Again, there are both benefits and disadvantages. Ethanol can reduce carbon emissions through improved combustion, and reduced reliance on fossil fuels but access to a new source of fuel prevents shortages, so keeps the price of fuel down, encouraging more people to use private transport.

Used within the household context, biofuels have a very positive impact on the lives of those living in poverty. The kitchen environment remains the place where most women living in the developing world spend most of their time. Alleviating kitchen smoke improves health, saves money, improves women's status, saves very large amounts of time. In areas prone to drought, it can also help save the external environment by reducing pressures on trees and other vegetation used for fuel.

Future for biofuels

Biofuels are here to stay. Used responsibly, they can reduce the levels of pollutants currently affecting the planet, and can provide clean air in homes fit for human habitation. As new technologies become mainstreamed (such as fuel cells for the auto industry) it is to be hoped that these new technologies can improve the quality of life for those communities currently living in poverty, and provide a route to clean development for future generations.

Further information

Approtech Oil Processing Technologies
http://www.approtec.org/tech_oil.shtml

BluWave
http://www.hedon.info/docs/BluwaveEthanolStoveAssessment.pdf

BriteLyt Multi-Fuel Lanterns, Stoves & Petromax Lanterns
http://britelyt.groupee.net/prod1.html

DATe Biofuel for Sustainable Development and Poverty Alleviation in Rural Cambodia Development and Appropriate Technology report
http://www.jatropha.de/Cambodia/CambodiaBiofuelProjectDescription%20WebDe.pdf

Emerging Markets Online *BIODIESEL 2020:Multi-Client Study Volume 2, 2007-2008 Global Market Survey, Feedstock Trends and Forecasts (updated by Emerging Markets Online)*

Guarte, R. C. LPG Alternative Seen in New Plant Oil Stove (May 2006)
http://neda8.evis.net.ph/eddnews/stove/stove.htm

HEDON Household Energy Network Knowledge base search on 'Ethanol' This search provides sites for over 100 articles on Ethanol.
http://www.hedon.info/goto.php/search.htm?cx=011705051524267581131%3Aodc5tdp7re0&cof=FORID%3A11&q=Ethanol&sa=Search

HEDON Household Energy Network Ethanol page.
http://www.hedon.info/goto.php/Ethanol

Herro, Alano 'Eye on Mali: Jatropha Oil Lights Up Villages' in WorldChanging – Change your thinking
http://www.worldchanging.com/archives/006814.html

Mongabay.com *Massive oil palm expansion planned by Indonesia's richest man mongabay.com May 8, 2007*
http://news.mongabay.com/2007/0508-palm_oil.html

O'Brien, C. Introducing alcohol stoves to refugee communities in Boiling Point 52 2006 http://www.hedon.info/goto.php/IntroducingAlcoholStovesToRefugeeCommunities
or http://www.hedon.info/docs/BP52-7-OBrien.pdf

Stumpf, E. & Werner Mühlbauer, W. Plant-oil cooking stove for developing countries in Boiling Point 48, Practical Action 2002 https://practicalaction.org/docs/energy/docs48/bp48_pp37-38.pdf

Practical Action
The Schumacher Centre for Technology and Development
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/

This document was produced by Dr. L Bates for Practical Action in March 2007

technical brief