PRACTICAL ACTION
Technology challenging poverty

DIESEL ENGINES

technical brief

Introduction

The internal combustion (IC) engine has been used for many decades in developing countries playing a very important role in providing power for rural communities. Many stand-alone units are used for milling, small-scale electricity production, water pumping, etc. They are readily available, off-the-shelf in most major towns and cities in a range of sizes to suit various applications. There is usually a well-established spare parts and maintenance network, both at urban and rural centres.

Figure 1: One of the owner's family with a diesel electricity generator in Wau Nur, Kassala. Kenya.
Photo: Practical Action / Lucy Stevens.

There are two main types of IC engine defined by the type of fuel used; petrol (gasoline) or diesel. The petrol engine is widely used for small vehicles and light applications whereas diesel engines are more suited to continuous running for lengthy periods at higher load ratings and are therefore used more widely for stationary applications and commercial vehicles.

Principles of operation

The combustion process in the petrol engine and the diesel engine differ in the following ways.

In the petrol engine the petrol and air mixture is drawn into the cylinder, compressed (compression ratio ranging from 4:1 to 10:1), and ignited by a spark introduced by an electrical system.

In the diesel engine, air alone is drawn into the cylinder and is compressed to a much higher ratio (14:1 to 25:1) than in the petrol engine. As a result of this compression the air is heated to a temperature of 700 – 900 °C. Only then is a certain quantity of diesel fuel injected in to the cylinder and the fuel ignites because of the high temperature. Hence the petrol engine is often referred to as the spark ignition (SI) engine and the diesel as the compression ignition (CI) engine.

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

Secondly, there is the sub-division according to cycle type; the two stroke or four stroke cycle. This means that engines have an ignition phase on every revolution of the crankshaft or every other revolution.

The method for mixing and injecting air and fuel is different for the two cycle types. Most IC engines use the four stroke cycle.

The four stroke cycle - diesel engine

1st stroke: induction stroke - while the inlet valve is open the descending piston draws in fresh air.
2nd stroke: compression stroke - while the valves are closed the air is compressed to a pressure of up to 25 bar.
3rd stroke: ignition and power stroke - fuel is injected while the valves are closed (fuel injection actually starts at the end of the previous stroke), the fuel ignites spontaneously and the piston is forced downwards by the combustion gases.
4th stroke: exhaust stroke - the exhaust valve is open and the rising piston discharges the spent gases from the cylinder.

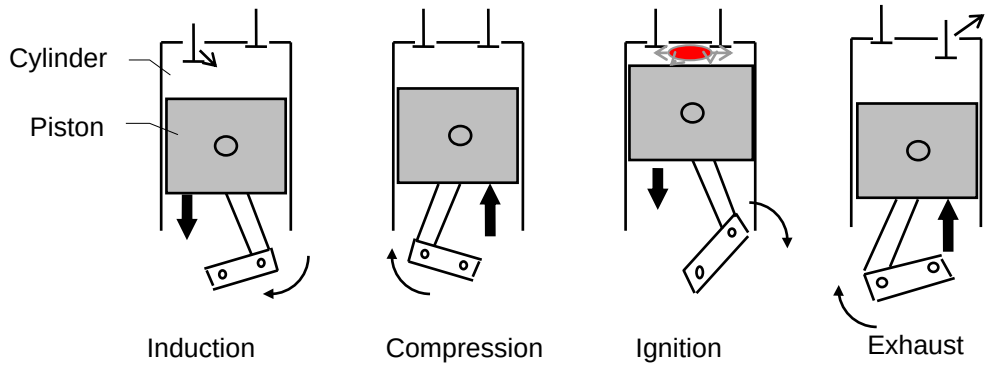

Figure 2: The four-stroke Diesel cycle

Since power is developed during only one stroke, the single cylinder four-stroke engine is not uniform in its power supply. Smoother running is obtained with multi cylinder engines because the cranks are staggered on the crankshaft. There are many variations of engine configuration e.g. 4 or 6 cylinder, in-line, horizontally opposed, vee or radial configurations.

The Table below shows the relative practical advantages and disadvantages of petrol and diesel engines.

Diesel	Petrol
Pros Lower fuel costs Higher efficiencies Readily available for a wide range of sizes and applications Lower running speeds	*Pros* Light - hence more portable Lower capital costs Cheaper to maintain Higher running speeds
Cons Maintenance is more expensive Heavier and bulkier for a given power Higher capital cost Pollution	*Cons* Not so durable - especially under continuous long-term usage Lower efficiency for equivalent power Fuel more expensive Narrower range of off-the-shelf engines available - smaller engines more readily available Pollution

Application and choice of engine

To decide which engine is most suitable for a specific application, several factors need to be considered. The two most important are the power and the speed of the engine. The power requirement is determined by the maximum load. The engine power rating should be 10-20 % more than the power demand imposed by the end use. This prevents overloading the engine by inadvertently adding extra load, during starting of motors or some types of lighting systems or as wear and tear on the engine pushes up its power consumption.

For example, a generator with a required output of 10 kW (kilowatts) and an efficiency of 75% would need an engine of the following capacity;

Output requirement	10 kW
Efficiency	0.75
Shaft power requirement	10 / 0.75 = 13.3 kW
Engine power requirement	13.3 kW x 10% = 14.63 kW

As engine power is often given in horse power (1 h.p. = 0.746 kW), choose an engine of size 19.6 h.p. or the next standard size above this figure.

Another important factor when choosing an engine is speed. Speed is measured at the output shaft and given in revolutions per minute (r.p.m.). An engine will operate over a range of speeds, with diesel engines typically running at lower speeds (1300 - 3000 rpm) and petrol engines at higher speeds (1500 - 5000 rpm). There will be an optimum speed at which fuel efficiency will be greatest. Engines should be run as closely as possible to their rated speed to avoid poor efficiency and build up of engine deposits due to incomplete combustion, which will lead to higher maintenance and running costs.

To determine the speed requirement of an engine we again look at the requirement of the load. For some applications the speed of the engine is not critical but for other applications, a generator for example, it is important to get a good speed match. If a good match can be obtained then direct coupling is possible; if not, then some form of gearing will be necessary, a gearbox or belt system for example, which will add to the overall cost and reduce the efficiency.

Other factors that should also be considered include: cooling system, abnormal environmental conditions (dust, dirt, etc.), fuel quality, speed governing (fixed or variable speed), poor maintenance, control system, starting equipment, drive type, ambient temperature, altitude, humidity, etc. Suppliers or manufacturers literature will specify the required information when purchasing an engine.

The efficiency of an engine depends on various factors, e.g. load factor (percentage of full load), engine size, and engine type. Some typical figures are given below. Other power system efficiencies are also quoted for comparison.

Type of engine	Efficiency (as a percentage) %
5 kW petrol engine (full load)	15
5 kW diesel engine (full load)	25
5 kW diesel engine (20% load)	10
50 kW diesel engine (full load)	35
500 kW diesel engine (full load)	45
50W windmill (battery charger)	15
500 kW wind turbine	40
5 kW hydro electric system	60
500 kW hydro electric system	85

[Source: The Power Guide, IT Publications, 1994.]

Uses and power requirements

As mentioned earlier there is an almost limitless range of applications for the diesel or petrol engine. Some typical rural applications and their power requirements are shown below:

Application	Typical power requirement
Small scale irrigation pumps	2 - 15 kW
Small scale electricity generation	2 - 50 kW
Battery charging	500 W
Grain milling or threshing	5 - 15 kW

Diesel generator sets

Due to their widespread use throughout the world, diesel generator sets deserve a further mention. Diesel generating sets come in a wide range of commercially available sizes, from about 5 kW up to 30 MW (30,000 kW).

They are long lasting and will usually have a useful lifespan of 7 -10 years (30,000 hours running time), but this can be drastically reduced if maintenance is poor.

They are used by individuals, electricity utilities and businesses and are often used to supply a small electrical grid in remote areas where the national grid has not yet reached. They are usually fitted with a governor which automatically controls the speed of the machine as the load varies, maintaining constant voltage and frequency. Efficiency depends on the loading of the machine and where the load pattern (pattern of electricity consumption throughout the day) requires, two or more smaller machines are used to achieve higher fuel efficiency. Diesel generator sets, being somewhat noisy, are usually sited in a separate power house away from the premises or outside the town (depending upon their application).

Petrol generator sets come in smaller sizes - from 500W up to several kW - and tend to have a much shorter lifespan (5000 hours running time) than their diesel counterparts. They are more suited to mobile, very small scale electricity needs.

Alternative fuels

Diesel is often too expensive for households to buy. Diesel engines adapted to burn vegetable oil are being tested in demonstration units in isolated villages.

There are several types of vegetable oils that can be used to generate electricity in adapted diesel engines.

Ethanol and methanol (also known as alcohols) substitute directly for petrol (gasoline), and vegetable oils can substitute directly for diesel fuels.

Ethanol is already used commercially as an engine fuel in Brazil and, when blended with petrol to form the blend known as gasohol, in a number of other countries.

There is a lot of work in Brazil developing their bio-diesel capacity in which they are attempting to include poorer small scale farmers in the North of the country rather than aiming for large scale commercial operations that, often exclude smaller farmers.

In another project in South Africa they are testing the impact of the hydrology of growing Jatropha trees for oil production.

Figure 3: Making biodiesel in Peru.
Photo: Soluciones Prácticas.

technical brief

Jatropha (also known as the purging nut) is currently regarded a as one of the most potentially promising plants for biodiesel oil production and research on its use is being carried in many regions of the tropics. Traditional Jatropha has been used as a living fence, the oil is non-edible but has been used for lighting or in making soap. It can produce 500 to 1000 litres per hectare.

Practical Action Latin America (Known as Soluciones Prácticas) has carried out work on Biodiesel in Peru, documents about the work are on the Spanish language website http://www.solucionespracticas.org.pe.

In India Professor Pushpito Gosh, director of the Central Salt and Marine Chemicals Research Institute in Bhavnagar Gujarat, has researched the characteristics of all the domestic non-edible vegetable oils and found Jatropha to be the most promising. He is now working on the first Jatropha project in the region supported by the German DEG – German Investment and Development Company. Using existing conditions and then converted into biodiesel through a pilot plant using a cold press method. Fuel specialists from Daimlerchrysler AG tested the end product which met EU standards.

In Tanzania, Ghana, Malawi and Indonesia the German company Energiebau Solarstromsysteme GmbH has supplied systems for decentralised power and introduced hybrid systems with solar and Jatropha biodiesel generators.

Energiebau Solarstromsysteme GmbH
Heinrich-Rohlmann-Str. 17
50829 Köln
Tel. +49(0)221 98966-0
Fax +49(0)221 98966-11
E-mail info@energiebau.de
Website: http://www.energiebau.de/
Reinhard Henning is a consultant in alternative energy and biodiesel oil extraction and use. He has worked with GTZ / Tinytech in Nepal and is currently working in Madagascar on the Jatropha tree integration into soil erosion control activities. He is also working in India Tamil Nadu where they are looking to produce fuel from Jatropha and are interested in the Manual Screw press of Practical Action. The extract by Rainhard Henning is shown below with links to the Jatropha website, which includes a section on stoves.

The Jatropha website at www.jatropha.de by Bagani Gbr, includes practical resources as well as a discussion forum.

The availability of alternative fuels for IC engines means that engines are still important for stationary applications to provide shaft power, particularly at the lower end of the power range.

Renewable energy sources

When choosing the type of power system for use in rural areas, renewable energy options should also be considered. Renewable energy sources, such as wind power, solar power, hydro power, and biomass energy can be harnessed locally and have low running costs. The dependence upon external market fluctuations is removed and there are no transport costs.

Sustainability has become another issue which many people are considering when choosing their power supplies. Renewable energy systems are less damaging to the environment.

In some cases hybrid or mixed systems are used to provide a flexible and cost effective alternative to diesel or petrol only systems. These are systems that combine two or more technologies which enhance one another's capabilities. For example, a wind turbine can be used in conjunction with a diesel generating set. When the output from the wind turbine drops below a certain power level, due to lack of wind, the diesel generator can be switched in to compensate. These systems can be a combination of purely renewable energy technologies or combine fossil fuel energy technologies depending on the circumstances. Careful planning is needed when considering such a system.

Cost

Cost plays an important role in the choice of technology for rural applications. There are two main costs to consider - the investment cost and the running costs. For diesel systems the investment costs tend to be relatively low compared with renewable energy technologies while the running costs will be high.

There are many factors which will determine the actual cost of the power supplied - generating capacity, load factor, efficiency, fuel costs, etc so running can vary widely.

In the long term, the fuel costs for a diesel or petrol engine will be high compared with the capital cost and this often causes problems where there are no guaranteed funds or income to buy fuel so many machines sit idle due to lack of funds. In many developing countries foreign exchange shortages mean that there can be regular shortages of fuel. Theft of fuel is also issue.

Suppliers, spare parts and maintenance

One important factor to consider when purchasing an engine is the availability of spare parts. If there is a dealership or supplier for the manufacturer in the area then there should be no problem obtaining spare parts. Importing spare parts can be expensive, take time to be delivered or unobtainable.

There is usually a wide range of manufacturers represented in major towns and cities in most countries throughout the world. It is worth checking this before purchase. Some countries are affected by embargoes or trade restrictions which can make it difficult to find spares.

Maintenance of any machine presents many problems. It is important to ensure that the machine will be regularly maintained by a competent person. In remote rural areas this can be difficult. There is often no one in the area that is knowledgeable of the machine and it will be very expensive and take time to bring in a skilled mechanic from the nearest town to carry out the maintenance. It is worth considering sending a local person for training so that the maintenance will be carried out regularly and competently.

Resources

- *Liquid Biofuels* Practical Action Technical Brief
- *Coconut Crude – Vanuatu* – Hands On fact sheet
  http://www.tve.org/ho/doc.cfm?aid=1431&lang=English
- *Donuts for Diesel, UK* - Hands On fact sheet
  http://www.tve.org/ho/doc.cfm?aid=870
- Soluciones Prácticas (Practical Action Latin America) biodiesel project
  www.solucionespracticas.org.pe/biodiesel/ (In Spanish)
- Production of Biodiésel. Fourth practical theoretical course of biodiesel. UNALM Web of biodiésel. www.solucionespracticas.org.pe/biodiesel/
- *Appropriate Technology*, Vol. 31/3, Sept 2004
  This issue of the Appropriate Technology journal contains a range of articles including: Renewable Energy: power from palm oil mill waste; biodiesel from Jatropha; AMA (Agricultural Mechanization in Asia, Africa and Latin America)
- *From the Fryer to the Fuel Tank: the complete guide to using vegetable oil as an alternative fuel*
  Author(s): Tickell J, Tickell K
  Pub. Details: USA, 1999
  This book provides concise, easy to understand instructions on how to use vegetable oil to fuel a diesel engine. The book is organized into two sections: Section one - gives historical, economic, and scientific context to using vegetable oil as a fuel. Section two - gives directions for making biodiesel, building a biodiesel processor, running a diesel engine on a mixture of kerosene and vegetable oil, and running a diesel engine on straight vegetable oil
- *Rural Lighting, a Guide for Development Workers*, Louineau, J., Dicko, M., et al, Practical Action Publications and The Stockholm Environment Institute, 1994.

technical brief

Other books of interest

Diesel and Gas Turbine Worldwide Catalogue: Engine Power Products Directory and Buyers Guide, Diesel and Gas turbine Publications, Wisconsin, USA
Grauw, C., *Getting the most from your Diesel Engine*, Botswana Technology Centre, Gaborone, Botswana, 1987.
Stone, R. *Introduction to Internal Combustion Engines*, Macmillan, London, 1992.

Manufacturers / Suppliers

Note: This is a selective list of suppliers and does not imply endorsement by Practical Action.

Small Scale Processing Units

TinyTech Plants
Tagore Road
Rajkot - 360 002
India
Tel: +91 281 2480166, 2468485, 2431086
Fax: +91 281 2467552
Email: tinytech@tinytechindia.com
Website: http://www.tinytechindia.com/
Produce oil expellers
Tiny Oil Extraction Plant http://www.tinytechindia.com/oil.htm
Tiny Edible Oil Refinery http://www.tinytechindia.com/refinery.htm
Tiny Palm Oil Mill http://www.tinytechindia.com/palm.htm

Alvan Blanch
Chelworth
Malmesbury
SN16 9SG
United Kingdom
Tel: +44 (0)1666 577333
Fax: 44 (0)1666 577339
E-Mail: info@alvanblanch.co.uk
Website: http://www.alvanblanch.co.uk
Biodiesel processing equipment http://www.alvanblanch.co.uk/vegetablioil.htm
A range of differing sized processing equipment
Biodiesel technology http://www.alvanblanch.co.uk/Biodiesel.htm

HydroDynamic Technology., Inc.
10019 Canoga Avenue
City of Los Angeles
Chatsworth, California 91311 USA
Tel: (818) 718-0905
Fax: (818) 718-1176
E-mail :info@HydroDynamicTechnology.com
www.BioForce9000.com
www.HydroDynamicTechnology.com
HydroDynamic Technology Inc. offers new generation equipment for producing biodiesel-biodiesel manufacturing plants which utilize hydrodynamic compounder technology. Biodiesel is methyl (ethyl) ester, derived from vegetable oils in process of esterification: methanol (ethanol) is added to vegetable oil in ratio 1:9 and processed together with small amount of base or acidic catalyst in reactor (hydrodynamic mixer and compounding pump in our technology). Continuous biodiesel production system, 4 (12,5) cubic meters per hour.

Diesel Engine Suppliers

Lister-Petter (diesel engines) Ltd.
Long Street
Dursley
Gloucestershire
GL11 4HS, U.K
Tel: +44 (0)1453 544141
Fax: +44 (0)1453 546732
Website: http://www.lister-petter.co.uk
Manufacturer and supplier of diesel engines.

F.G. Wilson Engineering Ltd.
Group Headquarters
Old Glenarm Road
Larne
Co. Antrim
BT40 1EJ
Northern Ireland, U.K
Tel: +44 (0)28 2826 1000
Fax: +44 (0)28 2826 1111
Website: http://www.fgwilson.com
With offices in the following countries:
France, Germany, Spain, Australia, Brazil, Hong Kong (China), China, Russia, Singapore, South Africa, United Arab Emirates, U.S.A.
Manufacturer of Diesel Generator Sets from 8 to 6500 kVA

Pumpsets Ltd.
Walworth Industrial Estate
PO Box 1615
Andover
Hants
SP10 5NP, U.K
Tel: +44 (0)1264 333 737 or 811 094,
Fax: +44 (0)1264 333 108 or 811 095,
Website: http://www.pumpsets.com
Suppliers of pumping equipment - including diesel, human powered and Oxfam Emergency Kits.

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/