Options for small-scale biodiesel production to self-supply the energy needs of isolated communities in Amazonia

Over 83% of rural families living in the Amazonian jungle of Peru have no access to electrical energy because of the difficulty and high cost of extending the electricity grid to the region. The sustainable use of biomass to generate energy could make a significant contribution in this regard, in particular in the form of liquid biofuels such as biodiesel and vegetable oils. One advantage of this option is that the diesel generators already in place in such communities can be used

Practical Action, in partnership with UNALM (La Molina National Agrarian University) has been working since 2003 on developing and testing technological models and a range of Amazonian oil-yielding seeds for the small-scale production of biodiesel in isolated regions of Amazonia. The aim of the project has been to design a sustainable system for the production and use of biodiesel by isolated communities in the Amazonian jungle of Peru, in accordance with the most suitable resources; to test its performance as a fuel for transportation and domestic and productive activities; and to enable biodiesel to be established as a possible solution to the problems experienced by such settlements in accessing energy.

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Introduction

Over 83% of rural families living in the Amazonian jungle of Peru have no access to electrical energy because of the difficulty and high cost of extending the electricity grid to the region. Of the nearly 196,000 homes in the area, only 32,000 have electricity (INEI 2008), in many cases produced using electrical generators run on diesel. In the remaining 164,000 homes, families use candles or kerosene for lighting, and batteries to operate radios and televisions. Where diesel-powered electrical generators are used, the high price of fossil fuels makes them problematic to operate: such devices are usually run for just a few hours a day, or even just a few days a year. Meanwhile, the need to transport fuel by river increases both the probability of pollution and also the price, despite subsidies, meaning that villagers cannot depend on diesel as a source of energy, and can use it only occasionally. The price of diesel in Lima is now around 4.00 USD per gallon, and costs around 3.00 USD a gallon in the towns in the jungle, because of government subsidies. In some isolated communities or provinces such as Purús, the cost of fuels such as petrol ranges from 8.30 to 20.00 USD per gallon, depending on availability.

There is therefore a need to research and promote alternative sources of low-cost energy which will reduce the negative environmental impacts of generation and use. The sustainable use of biomass to generate energy could make a significant contribution in this regard, in particular in the form of liquid biofuels such as biodiesel and vegetable oils. One advantage of this option is that the diesel generators already in place in such communities can be used.

Practical Action, in partnership with UNALM (La Molina National Agrarian University, Lima), has been working since 2003 on developing and testing technological models and a range of Amazonian oil-yielding seeds for the small-scale production of biodiesel in isolated regions of Amazonia. The aim of the project has been to design a sustainable system for the production and use of biodiesel by isolated communities in the Amazonian jungle of Peru, in accordance with the most suitable resources; to test its performance as a fuel for transportation and domestic and productive activities; and to enable biodiesel to be established as a possible solution to the problems experienced by such settlements in accessing energy. The main technological barriers preventing the fuel from being produced simply in situ by villagers have now been overcome.

2008 saw the start-up of the validation phase of a biodiesel production system in actual field conditions. This experience will help build up valuable data regarding the technical, economic, social and environmental feasibility of small-scale biodiesel production in isolated areas of Amazonia, while also contributing to the international debate on the suitability of small-scale biofuels or agro-fuels.

It should be mentioned that the UN Food and Agriculture Organisation

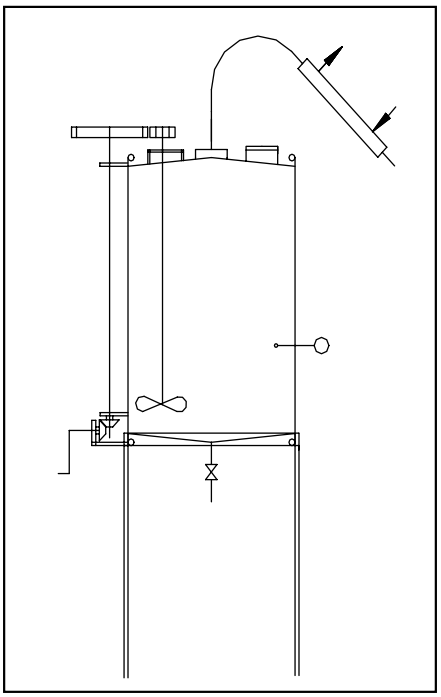


Figure 1: Basic reactor for small-scale local biodiesel production (Photo: PA/UNALM)

(FAO), in its document 'Opportunities and Challenges of Biofuel Production for Food Security and the Environment in Latin America and the Caribbean', presented at the 30th Regional Conference for Latin America and the Caribbean, in April 2008, highlighted the fact that "the production of liquid biofuels can also help small farmers produce their own energy for their agricultural machinery and generate their own electricity, especially those in isolated areas".

Practical Action and UNALM Research

Practical Action undertook the first documented trials of biodiesel production in Peru in the year 2000, tested out successfully on rotavators at UNALM's Faculty of Agricultural Engineering. In 2003 the two institutions set up a permanent research team which remains in operation today, based at UNALM's Renewable Energies Laboratory, to examine possible scenarios for the production and use of biodiesel on a small scale in Peru.

In addition to support for private and commercial ventures, its work has focused on the evaluation of two possible alternatives: small-scale local production in isolated Amazonian communities using the oils of abundant vegetable species, either native or introduced as a possible solution to these communities' energy problems; and production based on used vegetable oils in urban areas to be employed as an additive to diesel fuel for land vehicles in order to reduce emissions of pollutant gases and as an end-of-life alternative for used oil. The aim of both scenarios was to identify the conditions required in order to make small-scale biodiesel production feasible technically, economically, socially, legally and environmentally, and to find solutions to the barriers identified (Castro et al. 2007).

With the support of CONCYTEC (The National Council for Science, Technology and Technological Innovation), the following projects were undertaken: between 2003 and 2005, the first scientific/technological biodiesel research in Peru, entitled Small-Scale Biodiesel Production Using Amazonian Oil-Yielding Produce; between 2004 and 2005, the study Design of a Sustainable System for Biodiesel Production and Use Appropriate to Isolated Communities in the Amazonian Jungle, which also involved UNI (The National University of Engineering); between 2005 and 2006, the project Construction and Start-up of a Model Biodiesel Production Plant; and more recently, between 2006 and 2007, research has continued on the Dehydration of Ethanol on a Small Scale for Biodiesel Production in Isolated Communities in the Amazonian Jungle.

The achievements so far have been the: successful trials of biodiesel production and use based on spent oils and both native and introduced oil-yielding species; development and testing of low-cost technological models for small-scale biodiesel production; establishment of the first regular used-oil recycling system for biodiesel production in Peru and the construction of the first medium-scale pilot biodiesel production plant, with capacity to produce 2,000 gallons of biodiesel per month. Progress has also been made on the theoretical design of a sustainable biodiesel production and use system appropriate for isolated forest communities, with research being completed in order to resolve the main technical stumbling block preventing biodiesel from being established as a viable source of energy in isolated areas of Amazonia: access to anhydrous ethanol, as the methanol which is most commonly used for biodiesel production is a crude oil derivative. A number of barriers do, though, still exist in educational, social and/or economic terms. The field validation phase of Practical Action's work began in 2008, with a focus on identifying and attempting to overcome the remaining barriers.

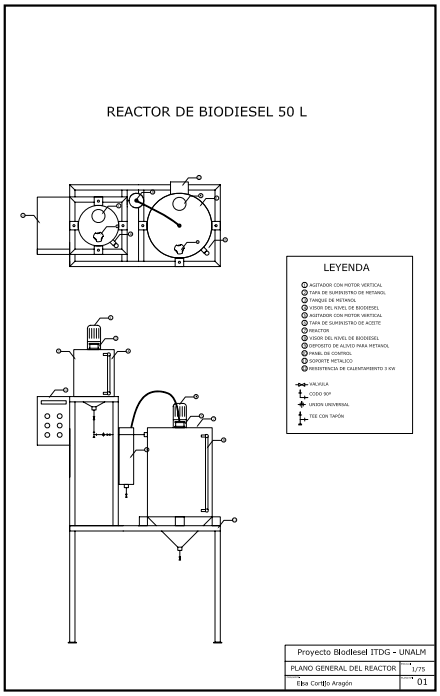
Below we set out the main advances and developments achieved in the work of Practical Action and UNALM:

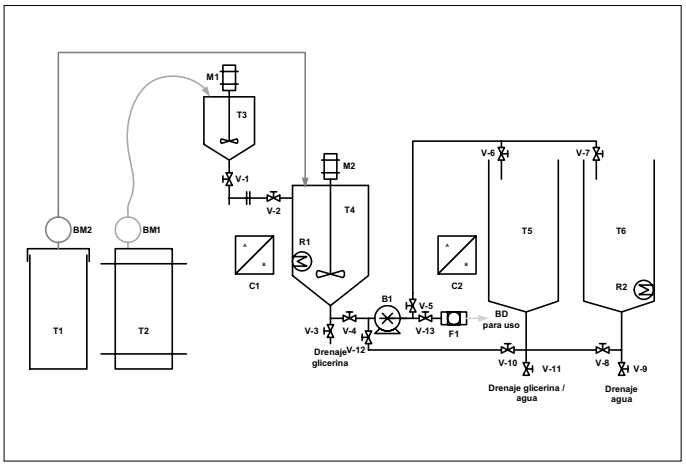
Biodiesel production in forest communities

For this scenario an especially simple, low-cost technological model was developed, manufactured from recycled materials, and designed for small-scale local production (Fig. 1). The device essentially involves the use of a small hydraulic press to obtain oil, operated by means of a hydraulic jack which exerts pressure on a piston positioned at the base of an iron housing. When the necessary quantity of oil has been produced, this undergoes a basic analysis to measure acidity, an essential calculation in order to work out the quantity of catalyst to be used in order to produce the biodiesel. Once the acidity has been gauged, a mixture of alcohol (methanol or anhydrous ethanol) and the catalyst is prepared, before proceeding to transesterification, the name given to the process by which biodiesel is produced, which takes place in a small 50 litre capacity stainless steel reactor fitted with a manual stirrer operated by means of a handle and gears (Calle et al. 2005). The required heat can be provided by means of briquettes produced using the pulp which is left in the press itself following extraction of the oil. After the required reaction time, the mixture is allowed to decant for several hours, following which the decanted glycerine is first extracted from the base of the reactor, followed by the biodiesel, which requires purification in order to eliminate any traces of glycerine, oil and fatty acids which may have remained unreacted. Once the biodiesel has been cleaned, it is filtered and can be used in any diesel engine.

Figure 2: Reactor for biodiesel production (Photo: PA/UNALM)

Figure 3: Pilot biodiesel production plant at the UNALM (Photo: PA/UNALM)





Small-scale dehydration of ethanol for biodiesel production

Transesterification, the chemical process most often employed to produce biodiesel, requires 20% alcohol, for which methanol is normally used. In isolated areas, however, it is highly problematic, costly and risky to obtain and transport methanol, although ethanol can be obtained, mainly from cane cultivation. The problem is that the ethanol required for biodiesel production must be of more than 99.5º purity. This level is difficult to attain because of the azeotropic mixture of water with alcohol above 96°, and is normally achieved using industrial-scale processes which involve costly equipment and infrastructure. During the research work a number of different types of absorbent were employed as molecular sieves, ranging from maize cobs to various chemical substances. After several months of research 99.5º ethanol was produced, which gave a yield of more than 80% in biodiesel production.

UNALM used-oil recycling system: Biodiesel Bus

One of the first tangible results of the research undertaken by Practical Action and UNALM was the implementation of a pilot system for biodiesel production and use on the university campus itself, recycling the used oil discarded by the university canteen to supply one of the regular student transport buses with a mixture of 20% biodiesel and 80% conventional diesel (a mixture known as B20). The system involves collection of the oil, purification and transformation into biodiesel, to supply a bus of the university fleet by means of a special fuel pump installed in the UNALM General Services area. When the project began in 2003 the cost of a gallon of diesel was around 2.50 USD, while the cost of producing biodiesel at the UNALM was approximately 1.33 USD per gallon, excluding the price of the oil used for production, as this is obtained free of charge from the canteen. The price of the UNALM biodiesel is now around 2.30 USD per gallon, as a result of the rising cost of methanol. You can see an extra figure illustrating the UNALM used-oil recycling system and Biodiesel Bus via the ***@HEDON*** link on the next page.

The transesterification process takes place in a pilot reactor designed and built by the project's technical team, with capacity for 50 litres per batch (Acosta et al. 2008), comprising a raised tank with capacity for 15 litres, for the production of the methoxide, which flows by gravity to the main tank, where it is mixed with the oil to produce biodiesel (Fig. 2).

This reactor requires a supply of electrical energy to power the motors and the electrical heating element, and water as a coolant for condensation and recovery of the methanol following distillation.

These supplies can be employed in both urban environments and in oil-producing industries (Calle et al. 2005).

The quality of the fuel produced in this reactor has been analysed and tested on various engines and vehicles, allowing a number of theses to be established as to the use of biodiesel from various raw materials, such as spent oil, refined oil and palm oil.

Pilot small-scale biodiesel production plant

In order to develop a plant with high potential for replication to serve as a model for the dissemination and transfer of biodiesel production technology across the public, private and academic sectors, a pilot biodiesel production plant was set up in February 2006, with capacity for 200 litres/batch (Fig 3).

This plant, developed using mostly local technology, features a methoxide preparation tank, a main reactor for transesterification, a purification system which cleans the biodiesel using water by aspersion, and an electric dryer (Coello et al. 2006).

Validation phase of a biodiesel production system in actual field conditions

In 2008 Practical Action began testing of the first pilot small-scale biodiesel production system in isolated jungle areas. The aim of this phase is to test the suitability and feasibility of promoting the production and use of biodiesel as a source of clean, economically and socially viable energy for isolated communities in the Amazonian regions of the country.

This phase involves establishing a biodiesel production system at the Nuevo Tiwinsa Agro-fishery Association of small-scale palm producers in Peru's Amazonian Ucayali region, with the aim of self-supplying their energy needs for electrical generation and transportation. In partnership with the association, an appropriate management model will be designed and established for the operation and maintenance of the system, and for distribution and potentially the sale of the biodiesel. An assessment will also be made of the technical, economic, social and environmental viability of the experimental small-scale production of biodiesel for electrical generation and transport use. The ultimate aim will be to publicise the scope, possibilities and limitations of biodiesel as an option for energy self-sufficiency in Amazonia, mainly for the purpose of generating electricity and for use in transport.

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* Extra Figure: UNALM Biodiesel Bus

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