LONG-TERM EXPERIENCE WITH PURE PLANT OIL AS A COST-EFFECTIVE AND ECOLOGICALLY SOUND FUEL

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ABSTRACT: The use of pure plant oils (PPO) as a transportation fuel has a number of advantages not only compared to fossil fuels, but also compared to other bio-fuels: 1) PPO can be produced with simple technology directly on the farm, thus permitting (a) new economic activities along the entire fuel production chain for the farmers themselves, (b) co-use of oil cake as protein-rich animal food, thus replacing soy imports and meat-and-bone meal, thereby reducing the risk of spreading the bovine spongiform epidemic, and (c) closed regional economic, energy and material flow loops. 2) PPO is non-toxic and not dangerous for the environment, i.e. the optimum fuel for use in water protection areas. 3) PPO has a high flash-point and therefore is explosion-proof, i.e. it is a very safe fuel permitting for a simple logistics. 4) Emissions from PPO used in suitably adapted motors are lower than diesel motor emissions. 5) If produced through mixed-cropping, PPO is a by-product of food production and does not require separate agricultural land for its production. The yield of the food component however is stabilized or even increased.
Keywords: cold-pressed vegetable oils, transport sector, combined heat and power generation (CHP)

1 OVERVIEW

This paper reports on results of 10 years experience with diesel motor adaption to bi-valent pure plant oil (PPO)/ diesel operation. Vereinigte Werkstätten für Pflanzenöltechnologie (VWP) holds 7 patents and 1 registered design on this topic. Further patents on the latest development results have been applied for. The closed-circuit management of PPO was a project of the EXPO 2000 in Hannover. Within the German 100 tractor programme, at present 56 tractors have successfully been converted with VWP technology and run with PPO.

Various models of car motors have been converted and a standard service package for car owners has been developed. In addition, the VWP technology has successfully been used for converting a 20kWel and, within the "100% RENET" project, a mass-produced 5kWel CHP to PPO operation. Series production of such small PPO CHP, e.g. for independent power generation in remote or protected areas, is planned. Experiences on use as a fuel have been done with rape, sunflower and false flax oil from mixed-cropping.

2 PURE PLANT OIL

The use of PPO as a transport fuel can be traced back to the origins of the diesel engine, which was exhibited for the first time by Rudolf Diesel at the World Exposition in Paris in 1896 and which already ran on groundnut oil. PPO has a high viscosity which prevents evaporation of the fuel. This feature plus its high flash point (> 300 °C) makes it absolutely explosion-proof, a factor which should not be underestimated as a safety advantage in road traffic.

Moreover, the use of PPO poses no threat to either water, soil or the air and last but not least, PPO presents a form of hydrogen storage which allows to achieve the highest hydrogen density of all known storage media – at ambient temperature and pressure! Thus by its natural properties PPO is a merely perfect transportation fuel.

Figure 1: First 100% RENET PPO car – a winner of the Michelin Challenge Bibendum Rally 2002.

3 APPLICATION OF PPO IN TRANSPORT

Commercially available PPO cannot be used directly as a fuel for conventional diesel engines, mainly because of the high level of viscosity which would cause the coking of nozzles, seals, etc. and make the engine unusable. Conventional engines therefore have to be converted before being able to combust PPO.

The specially designed, technologically sophisticated PPO-fuelled engines of the first generation were not successful in the marketplace. However, VWP succeeded in adapting mass-produced engines to run on PPO.

Founded in 1993, VWP has been working on possible applications of PPO, in particular as a fuel for combustion engines. VWP's developments include a technology to convert standard diesel-fuelled engines of cars and co-generation plants to permit PPO use.

The following challenges could be met when altering the engine design:

- initiating and sustaining the combustion process;
- attaining a temporarily higher temperature level;
- dealing with the higher temperature in the combustion chamber;
- injection and vaporisation of PPO with a viscosity differing from that of diesel by a factor of ≥10;
- general management of the fuel flow, including all lines in the fuel tank system; the latter notably need to cope with variations in fuel viscosity due to temperature changes or bi-valent operation with diesel and PPO.

Figure 2: One of the tractors converted to PPO in the 100% RENET project

Because of the marked variation in the viscosity of PPO under changing temperatures, the fuel flow in the inlets and outlets can only be controlled satisfactorily if pressure and volume can be regulated as a function of temperature and viscosity. The relatively low cetane number as an indicator of ignitability, or rather lack thereof, and the high flashpoint called for new approaches to both injection and combustion technology.

Type	Motor	Power	Profile	Distance/ operation time
VW Golf III 1,9 TD	turb.cham.	55 kW	standard	17.172 km
VW Golf III 1,9 TD	turb.cham.	55 kW	standard	4.430 km
BMW 525 tds	turb.cham.	105 kW	standard	5.013 km
VW Golf III 1,9 TDI	dir.inject.	66 kW	short dist.	9.800 km
VW Golf IV 1,9 TDI	dir.inject.	66 kW	long dist.	12.650 km
VW Passat 1,9 TDI	dir.inject.	66 kW	short dist.	4.653 km
Deutz Agrotron 120 MK3 (tractor)	dir.inject.	88 kW	field	980 hours
DeutzAgrotron 100 MK3 (tractor)	dir.inject.	74 kW	barnyard	872 hours
VW Caddy 1,9 SDI	dir.inject.	47 kW	long dist.	77.757 km
VW Caddy 1,9 SDI	dir.inject.	47 kW	short dist.	15.455 km

Table I: Pilot vehicles in 100% RENET project

Endurance and general capabilities of converted vehicles were documented, e.g. within a project co-financed by the Bavarian Ministry of Economics and the Ministry of Agriculture of Baden-Württemberg which run over 6 years and covered tests on a fleet of 150 vehicles.

The latest developments, putting the focus on direct injection motors, took place within the EC FP5 100% RENET project: 6 cars, 2 tractors and 2 vans have been converted to PPO use and submitted to long term pilot operation within the District of Fürstenfeldbruck, a sustainable energy community aiming at 100% supply from RES until 2030 (www.ziel21.de).

The vehicles have been operating successfully and without any particular technical observation. The pilot users run them almost 100% of the time with PPO. Only during vacations, diesel is filled in due to lack of availability of PPO outside the pilot area.

Table I summarises the main parameters of the pilot operation. Note the exceptional long distances (high operation hours in the case of the tractors) that some vehicles have run since their conversion to PPO operation! Both vans are used for deliveries in the area, thus operating with very frequent stops and goes and on very different roads at a broad range of speeds, thus covering a broad range of test situations. The first car has participated in the Michelin Challenge Bibendum Rally 2002 and won a prize (see Figure 1).

During the course of the development work 7 patents and one industrial design were awarded and a further patent has been applied within the 100% RENET project. As a result a broad range of diesel engines can be started today directly with PPO without requiring fossil diesel.

4 APPLICATION OF PPO IN CHP

PPO-fuelled CHP plants rated at 20 kW_{el} and 5 kW_{el} have successfully been developed and tested. The 5 kW_{el} CHP plant is based on the heating-oil version of the mass-produced CHP "Dachs" from the company Senertec (www.senertec.com).

The first converted 5 kW_{el} CHP has now been operating for 7000 hours without problems on the premises of VWP. Six further units have been installed since autumn 2003 on the premises of different pilot users covering a broad range of load profiles. They have now been operating for several 100 to 4000 hours without encountering any problem.

Figure 3: Pilot user butcher Jais and wife with their PPO fuelled CHP. Foto: G. Reger

During the pilot operation phase, the maintenance intervals are kept at 900 hours, still one third of the standard Senertec maintenance intervals. After the pilot phase, longer maintenance periods of at least 1400 hours are expected to be possible.

A patent for the modifications has been applied for by VWP. Senertec intents to market the PPO-fuelled

CHP as an additional member of the "Dachs family", the set of CHP units operating with natural gas, bio-diesel or heating oil, and participates in the pilot tests with its representative in the District of Fürstenfeldbruck who is in charge of installation and maintenance.

Following the philosophy of "standard system and service packages" as a means of promoting RES to end users and coming closer to the target of 100% RES supply, sets of standard contracts, services and information and training materials for PPO-fuelled small CHP are developed within the 100% RENET project.

5 ADVANTAGES FOR THE ENVIRONMENT

The use of PPO as a transportation fuel has an over-all positive impact on the emission ratings of engines. The boundary values for NO_X, CO and HC emissions from diesel vehicles are met with a deviation of +/- 10%. Compared with diesel engines, those fuelled with PPO show a reduction in particulate emissions of at least 50%. The CO_2 cycle is a closed loop, and SO_2 emissions have been reduced to virtually zero. In addition, it has been found that noise emissions from engines fuelled with PPO can be significantly diminished in comparison with those from conventional diesel engines because of the suppression of pressure peaks.

6 DECENTRALISED PRODUCTION OF PPO

The global PPO market is supplied almost exclusively by major oil presses with annual extraction capacities of several 10,000 tons.

Figure 4: Decentralised oil-press on the Kramerbräuhof, a pioneering farm for mixed-cropping

For economic and ecological reasons, VWP prefers to supply its PPO-fuelled vehicles and CHP with oil from decentralised, small-scale production sites. Decen-tralised cold-pressing leaves 12% of the oil in the cake, opposed to industrial extraction with hexane, but that the residual oil in the cake enhances its value as fodder and has now made oilcake a preferred fodder in animal production as a substitute for soy and meat-and-bone meal.

Moreover, the oil obtained from farming operations, after pressing and filtering, has a higher quality than that obtained from industrial procedures. The hexane-extracted oil from industry also still has to be de-slimed, de-odourised, distilled, and subjected to various other processes before it can be used in engines. All this calls for a high input of energy which is further augmented by the long distances covered when seed and subsequently the separated oil and cake are transported to and from a centralised extraction location.

Decentralised oil production on farms thus combines economics with ecology by delivering a product which is superior to its industrially produced counterpart in terms of quality, ecological sensitivity and price.

7 MIXED-CROPPING

Mixed-cropping is a re-discovered agricultural methodology which consists in growing two or more plant species with similar growth periods together on the same field at the same time. It permits co-use of agricultural land for food crops such as cereals or fodder peas with oleaginous plants such as false flax (*camelina sativa*) or bird rape (*brassica campestris L. s.l.*).

Figure 5: Early germinating false flax covers the soil and prevents later germinating weeds to sprout

The presence of the oleaginous plants has a number of positive effects on the main crops such as the following, which have been observed notably for the combination of fodder peas and false flax.

Figure 6: Pea plants wind round, and are propped up by, false flax thereby keeping better off the soil

False flax germs early and develops quickly broad leaves in a rosette which cover the soil, thus preventing later germinating weeds to sprout; this permits to totally avoid the use of herbicides – in conventional agriculture!

The false flax plants prop up the fodder pea plants, thus preventing the ripening pods to sink to the soil, thereby avoiding losses due to moisture and fungi; this permits to strongly reduce the use of fungicides and to harvest the peas about one week later. The latter leads to a higher dry mass content of the peas and a higher market value. In the case of strong thunderstorms, the risk of strong losses is reduced, thus permitting more equalised yields and income.

In some experiences, a positive effect of mixed-cropping on damage causing insects has been observed, thus permitting also to reduce the use of pesticides in these cases.

Figure 7: Pea plants propped up by false flax can easily be harvested even after thunderstorms

Since less chemicals can be brought out on the fields, the farmers spend less time on the fields and save working time and personnel costs.

Apart from the obvious ecological benefits, these effects entrain a considerable reduction of costs for food production through mixed-cropping, while the yields of the food component are not reduced, but rather increased, as several years of research and pilot cultivation have shown. Taking this off-setting of food production costs into account, very cost-effective PPO can be produced from a broad range of oleaginous plants.

Figure 8: Peas and false flax seeds after harvest – they are separated in slightly modified seed cleaning machines

Besides that, mixed-cropping provides an extra option for producing PPO in addition to the predominant rape and sunflower oils. If one assumes that mixed-cropping is practiced for all cereals and fodder peas crown in the EU25, this could provide some 1.4 million toe (60 PJ) of new plant oils (NPO) – in addition to the main crop which benefits from the NPO plant component. This is much more than the EU's bio-diesel production (425,000 toe or 17.8 PJ in 1999).

First experiments have shown that the use of NPO from mixed-cropping as a fuel in specifically adapted diesel engines is possible, but still requires further development work.

More detailed results of the Interest Community Mixed-Cropping, focusing on false flax/ cereals combinations, are presented at this conference in session OB6 by F. Heimler et al. from the Technoloy and Promotion Centre within the Competence Centre for Renewable Primary Products, Straubing (www.tfz.bayern.de), a partner of the Interest Community. Details on achieved results are also presented in German under www.mischfruchtanbau.de.

8 CONCLUSIONS

PPO are an economically and ecologically very interesting fuel option for both mobile and stationary motors. It has a considerable potential, notably if mixed-cropping and NPO are considered. Experiences with a broad range of motor types have proven that mass-produced diesel motors that have been converted to PPO use have no draw-backs compared to non-adapted motors running with fossil diesel fuel and the investment in the adaptation of a motor pays back for the user. The extension of this experience to NPO is the next step to be gone.

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