# 2ND VEG OIL PROJECT
# DEMONSTRATION OF 2ND GENERATION VEGETABLE OIL FUELS IN ADVANCED ENGINES

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ABSTRACT: When used at a local level, Pure Plant Oil (PPO), has a potential for the most comprehensive benefits of all engine biofuels. However, like any other fuels, it will soon have to comply with severe emission standards, including a drastic decrease of particles emissions. Not only do minerals in fuels cause friction inside the engine, but they also block the particulate filters. It is then necessary to reduce as much as possible the residual mineral content in fuels. This projects aims at demonstrating that the combination of advanced engines and PPO of suitable quality can be a reliable one-tank solution. The project is ongoing from August 2008 to July 2011. The French part of it includes three VWP-converted John Deere demonstration tractors and the implementation of an OBE-patented filtering assistant on an existing mobile oil press. The first results are promising. Involving closely the farmers in this research enables to transfer the know-how to a local group and take into account very practical aspects of PPO production. This should help a future quality standard to fairly respect scientific, commercial, environmental and social concerns.
Keywords: Biofuel, Vegetable oil, Second generation, engine, emissions, filtration, minerals.

## 1 ABOUT AUTHOR AND PARTNERS

### 1.1 CUMAs

CUMAs are Cooperatives for the Common Use of Machinery in Agriculture (in French: *Cooperatives d'Utilisation de Matériel Agricole*). Over 800 of them are recorded in Rhône-Alpes, with 15'000 member farmers in them. FRCuma (Rhône-Alpes) is the Regional Federation in charge of political representation and technical support of these CUMAs. It is therefore involved in the promotion of practices complying with sustainable development priorities, especially energy wise: energy saving and renewable energy production.

The French CUMAs played a leading part in developing the production and the use of Pure Plant Oil (PPO) as fuel. This was decisive to obtain from the French authorities the Law amendment which now enables the use of PPO to power off-road farm machinery with a lightened tax system.

So it was essential that CUMAs and their network were involved in this *"2ndVegOil"* project. All the innovative equipment mentioned here below and demonstrated within the frame of this project have then been bought and/or operated by two CUMAs located in Rhône-Alpes.

This paper presents mainly the French contribution to the overall "*2nd Veg Oil*" project, which includes ten partners out of six different European countries and various other work packages.

### 1.2 Members of the project consortium

- *John Deere* (Germany): Project leader, worldwide largest producer of agricultural machines.
- *VWP* (Germany): worldwide leading company in the field of vegetable oil fuelled engines.
- *TUM* (Germany): one of the leading university chairs on internal combustion engines.
- *Lubrizol* (England): a major supplier of engine oils, formulating lubricants adapted to PPO powered engines.
- *Waldland* (Austria): holds the know-how to produce high quality PPO in decentralized oil presses.
- *RAEE* (France): an experienced regional energy agency, used to dissemination of trials results.
- *FRCUMA* (France): a link with farmers, in a national network of 13'000 cooperatives and 200'000 farmers.
- *ITP* (formerly *IBMER,* Poland): a leading institute for agriculture and energy in Poland.
- *NEN* (Netherland): secretariat of the CEN TC19 on petroleum products and liquid and gaseous (bio)fuels.
- *Regineering* / *IBDI* (Germany): a company of experts who share VWP's experience and now seconds it.

## 2 CONEXT OF THE PROJECT

When produced and used as engine fuel at a local scale, Pure Plant Oil has a potential for the most comprehensive ecologic, economic and social benefits of all biofuels. However, like any other fuels, it will soon have to comply with severe emission standards. The coming Tier 4 standards which will soon apply to farm tractors mean a drastic decrease of particles emissions. Not only do minerals in fuels cause friction inside the engine, but they also poison the catalysors and block the particulate filters which will be required to achieve the coming emission standards. It is then necessary to reduce as much as possible the residual mineral content in fuels. This projects aims at demonstrating that the combination of advanced engines and PPO of suitable quality can be a reliable one-tank solution.

## 3 THE ADVATAGES OF PURE PLANT OIL

### 3.1 Energy balance

All other biofuels have a longer production chain and higher associated energy losses. The production of PPO involves few process steps and can be done economically with small production units. The production process leads only to small energy losses, because no thermal or chemical process steps are involved.

### 3.2 Co-products

Oil seeds plants have – at least - two products (figure 1): oil and cake. At the farm level, the cake is often the major and much south-after outlet, since it can be used as protein-rich animal feed, or even human food. Whatever its final use (engine, heaters, cooking or even animal feed too), the oil is then considered as a by-product, to be used as profitably as possible. In addition, the straw of oil plants can be used for generation. These points should be taken into account when comparing its energy balance with plants cultivated only for biogas.

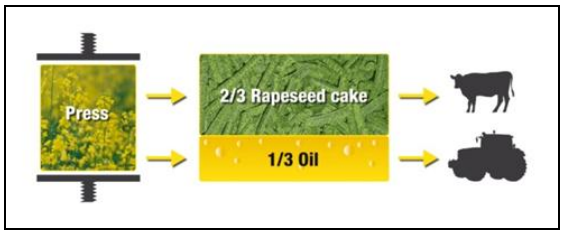



**Figure 1**: Oil seeds have -at least- two main products

### 3.3 Environment friendly

The non-toxicity and the low flammability are further advantages from a logistics point of view. In addition, PPOs are to be considered as safe and environmentally friendly fuels since they are totally harmlessness for ground and water. Therefore they are perfectly suitable for environmentally sensible areas and for vehicles operating in agriculture.

### 3.4 Rural economy and social coherence

PPO production can be conducted in decentralized small units, without loosing cost-effectiveness and provides potential for additional income generation on farms, thereby strengthening rural economic structures and social coherence in the EU, as well as in hot arid and tropical countries.

Promoting vegetable oil as fuel is a strong contribution to social and economical sustainability because it provides new economic opportunities for Small and Medium Enterprises (SMEs) and especially farmers in rural area. Vegetable oil can be produced – and used - by farmers and SMEs. This leaves a larger part of the value-creation to the farmer, instead of considering him only as a supplier of biomass.

This distinguishes vegetable oil notably from bio-ethanol and also from synthetic fuels which are produced by the thermo-chemical pathway. The latter requires large production units in order to achieve an acceptable overall efficiency. This centralization induces increased transportations costs to gather the raw matter from an extended collection area.

In this project, a focus is put on methods for producing 2nd generation vegetable oil fuels in small decentralized oil presses, which can be owned and operated by farmers, cooperatives or SMEs. Further, vehicles running on vegetable oil offer new opportunities for small mechanical workshops to enter in the business of engine conversion and maintenance of vegetable oil fuelled vehicles. In this project, local workshops in the target areas in France, Austria and Poland have been trained on the basics of engine conversion and maintenance.

PPOs, within a local scale short cycle, are then to be considered as a limited but very efficient contribution to the energy mix.

## 4 CHALLENGES MET BY PPO AS ENGINE FUELS

The low flammability of pure vegetable oil makes it unsuitable for use in conventional diesel engines at first. Different engine adaptation concepts exist which help to overcome this principle difficulty, including bi-valent operation (start and stop with normal diesel / continuous operation with vegetable oil when engine is hot enough), pre-heating of vegetable oil and a number of mechanical modifications, notably of the injection system. Apart from trans-esterification to biodiesel and cracking/ hydrogenation of pure vegetable oil to BtL - both of them considered as different biofuels - no attempts have been made so far to improve Pure Plant Oil, in order to better match with engine requirements.

When used in non-modified engines, pure vegetable oil not only leads to engine damages, in particular in advanced engines (such as high pressure common rail), but also to unacceptably high pollutant emissions levels. Especially, particulate emissions at cold starting are rather high, while at most other operating ranges pure vegetable oil shows advantages compared to conventional diesel.

Pure vegetable oil chemical and physical properties which are relevant for engine combustion at up-to-now considered emission levels (up to EURO 3) depend strongly on the oil press parameters. This leads to very different oil qualities on the market. Engine operation problems in previous fleet demonstration projects were almost exclusively due to vegetable oil not fitting to the only presently existing norm, the German pre-norm DIN V 51605. Hence, fuel quality definition and control are paramount if vegetable oil should play a larger role in the biofuels market.

## 5 OBJECTIVES OF THE PROJECT

### 5.1 Objectives of the European project

• Widen the range of considered oils, in order to increase the available fuel potential in limited competition with food and raw material production and in compliance with sustainable development (especially organic farming).

- Rape seed oil is currently the most used of all vegetable oils for transport. However, due to restriction in agronomy (needs rotation) and ecology (hard to cultivate organically), rape seed production can hardly be further widened.
- For sunflowers, the situation is just a slightly better.
- The species *Camelina Sativa* is a rather discreet and thus often unrecognized plant. Yet, it can be grown under EU climate in mixed-cropping, especially in

organic farming, providing then an additional 100-300 liters/ha oil production without need of extra land, neither yield losses of the main crop for food (e.g. cereals or peas).

- Jatropha grows in hot arid and tropical countries and bears non-edible fruits.

• Develop new fuel concepts for 2nd generation vegetable fuel oils better fitting to specific engine requirements under a broader range of operating conditions. This will be achieved through intra-blending of different vegetable oils and development of additives, without giving up the specific advantages of non-toxicity and low flammability. As PPO other than rape and sunflower oil have also different properties regarding engine combustion and emissions, this increases the challenges of fuel quality and emissions control.

• Improve the plant oil filtering process, in order to achieve ultra-pure vegetable oil with reduction of undesired substances to the limit of traceability and thus to ensure a continuous an homogeneously high quality. This is intended through an additive which is only a filtering assistant and does not stay in final PPO.

• Develop new engine concepts for a wider range of pure vegetable oils used as engine fuel.

• Develop and demonstrate lubricant oils for engines running on pure vegetable oil. Investigate additives and formulas for improved engine oil (lubricants), in order to better adapt the lubricant properties to present and future diesel engines.

• Demonstrate a fleet of 16 advanced tractors (with common-rail engines, partially equipped with soot filters) complying with EU stage 3A to 4 / US TIER 3 to 4 emission limits.

• Transfer to hybrid engines the here above mentioned fuel and engine concepts. This is to profit fully from the advantages of vegetable oil under quasi-steady load conditions and thus prepare the base to achieve EU Stage 4 (comparable with EURO 6) emission levels in road vehicles, which will be applicable from 2012 onwards. Hybrid engines are considered as the most advanced engine concept which still includes an internal combustion engine, achieving low exhaust gas emissions and saving energy. Tractors as well as hybrid engines operate at quasi-constant load conditions. The results of the tractor demonstration fleets shall be transferred to hybrid engines by study on a test stand.

This project anticipates the forthcoming development of hybrid vehicles. With a comprehensive activity on hybrid engine development, this project prepares the ground for a quick implementation of vegetable oil application in hybrid engines as soon as these will come on the market at a more affordable price.

• Prepare some proposals for a future European fuel standard applicable to PPO. This should include practical opinions from farmers on the field in order to ensure both large scale development of a reliable bio-fuel standard (with matching engines) and the capability of farmer to continue its production at a local level.

5.2 Main objectives at the French level

- Demonstrate a fleet of three farm tractors powered with 2nd Generation (rape) Pure Plant Oil.
- Experience a converted oil press and get the know-how to produce a high quality PPO.
- Promote the efficiency of production and use of both PPO and co-product within a local scale short cycle.

## 6 SPECIFIC APPROACH AND INNOVATION

### 6.1 Toward a combined one tank solution

Until now, pure vegetable oil has never been adapted to existing diesel engines (except through trans-esterification to biodiesel), but always the engine has been adapted to the fuel. In this project, a double strategy is followed: engines as well as the fuel are adapted such that both match and the combination allows for achieving high engine performance at minimum fuel consumption fitting with most severe emission limits.

The advanced engine concept which is tested is a one-tank solution (starts, runs and stop with PPO). It includes (figure 2):

- An engine internal preheating system (for cold start)
- A reinforced fuel supply system (higher viscosity)
- An adapted Electronic Control Unit software.

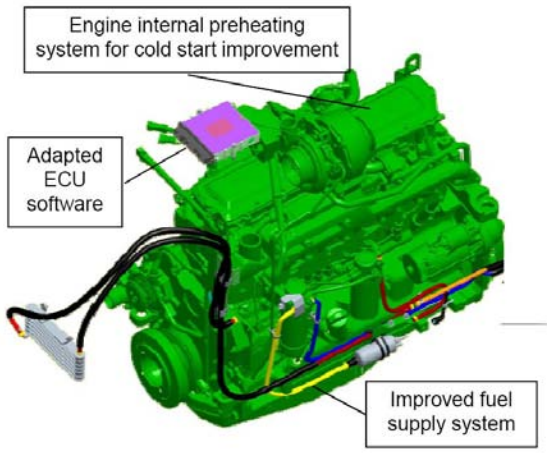



**Figure 2**: The VWP-JD advanced engine concept.

### 6.2 Minerals must be taken away

In the FP5 project “100% RENET”, VWP has found out which chemical oil parameters are decisive for fuelling advanced engines with closed particulate filter. Engine technique and especially particulate filters have problems with phosphor (P), calcium (Ca) and magnesium (Mg). These minerals finally block the particulate filters or cause friction inside the engine (pistons, valve etc.).

The German pre-norm DIN V 51605, as a first quality standard for vegetable oil, set a limit of 32 ppm (mg/kg) for the sum of the contents of P, Ca and Mg (in the following denoted as “P+Ca+Mg”). This value now turns out to be much too high for advanced engine concepts, notably for engines with a closed particulate filter. Hence, a special cleaning and purification process has to be found and established in a regular standard decentralized oil mill.

6.3 An innovative cleaning process

VWP and Waldland bring into this project foreground on a cleaning process for pure vegetable oil, suitable for small decentralized oil mills run by SMEs, which allows achieving continuously less than 10 ppm (mg/kg) P+Ca+Mg. By developing and optimising this innovative cleaning process (figure 3), the sum content of P+Ca+Mg should be brought down to the current limit of traceability (0.5 ppm).

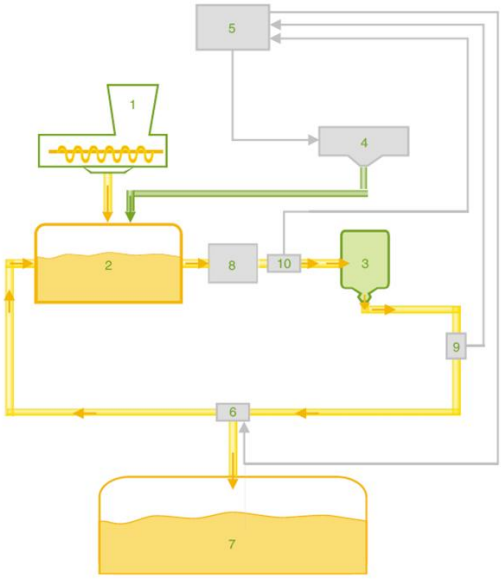
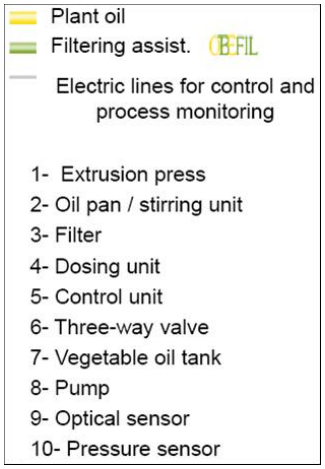



**Figure 3**: (above) and caption (below) :
Filtering assitant implementation on an existing oil press.




Attention must also be paid that the considered filter additives are widely available on the market in order to avoid that oil presses will become dependent on a single or limited number of suppliers of filter additives if they want to achieve a high 2nd generation vegetable oil quality.

7 DEMONSTRATION PLAN

The project period is from August 2008 to July 2011 (figure 4).

7.1 At the European level

- 18 demonstation tractors:
  - 14 Stage 3A
  - 4 Stage 3B
  - 4 Stage 4
- 4 different models of John Deere Tractors, ranging from 107kW to 136 kW (initial rated power):
  - JD 6830 Premium
  - JD 6930 Premium
  - JD 7430 Premium
  - JD 7530 Premium)
- In four partner countries:
  - Poland
  - Germany
  - Austria
  - France
- Powered by four different vegetable oils:
  - Rapeseed (mainly)
  - Sunflower
  - Camelina
  - Jatropha
- Protected by 2 experimental Lubrizol lubricants and JD « *Protect 100* » fuel additive (as for diesel).

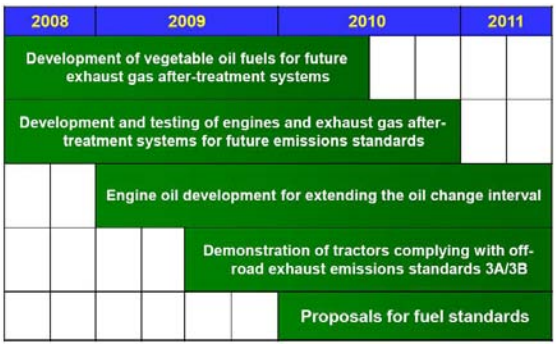



**Figure 4**: Program schedule

7.2 At the French level:

- Three demonstration tractors supplied by John Deere (Germany) and adapted by VWP (Germany). Two Stage 3A (JD6830 Premium and JD 7530 Premium) and one Stage 3B (JD 7530 Premium).
- A filtering assistant has been implemented in a reference press in January 2010 by OBE (Austria) in order to produce pure rape seed oil complying with "*2ndVegOil*" quality standards and transfer the know-how to a local group of farmers. This is an existing mobile press which had been previously run for the production of regular PPO (for engine fuel, heating and human consumption) and cake for animal feed, with a maximum capacity of 100 kg seeds per hour (e.g. around 35 liters PPO per hour).

## 8 FIRST RESULTS

The project is still ongoing. The third –and most advanced- demonstration tractor has been delivered recently. However, the first results indicate that:

- The first two tractors (JD 6830 and 7530 Premium) have been run successfully for more than 1000 cumulated operating hours with 2ndVegOil quality fuel since spring 2009. All parameters are up to standards, but a slight loss in power according to the users' point of view. This is consistent with John Deere's prevision: up to 15% loss of power was first announced, because the demonstration tractors must also comply with the regulation (not to exceed maximum rated power if ever turned back to diesel). This inconvenience could be later solved by software upgrades and adjustments to the type of fuel. In addition, an unexpected problem occurred with excessive clogging of the fuel filters. This seems to be linked to the original 1µm oil press, which could turn to be altered of defective. Intermediate oil samplings and monitoring of the farmers practices are being conducted to clear this question and check any potential interaction with the demonstration device and especially the filtering assistant.

- The first oil samples showed that the intermediate target was achieved (Ca+Mg+P content below 3.5 ppm), and the on-going work is now heading to drop below the current detection limits of 0.5 ppm. Several excellent oil batches have already been produced and some of the late analyses have proved it was possible to reach this target with on-farm production conditions. The next challenge to be faced now is to understand and master relevant parameters to ensure a continuous production of "0 ppm" vegetable oil (i.e. below the current detection limits) while increasing the sampling interval.

## 9 CONCLUSION AND PROSPECTS

Though we must wait until summer 2011 for final conclusions to be obtained, the first results from tractors demonstration as well as converted oil press are already promising: original targets have been achieved according to the project schedule.

- Minor oil quality and tractor power concerns are identified and are being handled.

- Advanced technologies are being tested under real field conditions.

- Farmers transferred the know-how and adapted it to local production conditions (small scale mobile press).

- The commercial offer will be widened for reliable and guaranteed one-tank solution.

- Involving the farmers in this research will enable to take into account very practical aspects of PPO production.

This is essential both for the technical improvement of the equipment and the elaboration of a European standard for Pure Vegetable Oils as engine fuels. This future quality standard should be rigorous enough to encourage engine manufactures to develop series of PPO powered tractors under full guaranty. It should also remain pragmatic enough to be applied by a large number of farmers, in order to keep the multi-fold benefits of the short cycle PPO production.

The process of a CWA has just started (CEN Workshop Agreement / European Committee of Normalization). The combined experience of all our project partners should then be decisive in achieving a fair respect of all scientific, commercial, environmental and social concerns.

## 10 ACKNOWLEDGEMENTS

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## 11 LOGOS OF PARTNERS AND CO-FUNDERS


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