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2nd Generation Pure Plant Oil in Flex Fuel Engines

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Flex Fuel Engines as Balancing Power for 100% Renewable Energy Hybrid Systems on Galapagos Islands: Requirements to Engine and Fuel Technology

INTRODUCTION

Since 2001 four oil spills from tank ships threatened Ecuador's Galapagos Islands (Fig 1), killing over 10.000 marine iguanas and other species.

As consequence to the Ecuadorian "Zero Fossil Fuel on Galapagos Island Initiative" 100% renewable energy hybrid systems with photovoltaic, wind, battery and pure plant oil (ppo) generators for frequency control/grid balancing have been installed 2010 on Floreana Island.

To avoid engine deposits and damages a new ppo fuel quality as well as a new engine and software design for dynamic load operation in hybrid systems was developed.

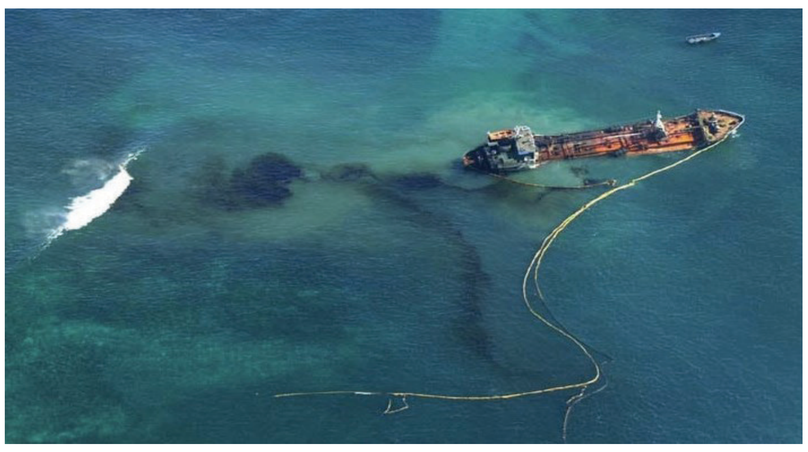

Fig 1: Sunken Jessica at Galapagos Islands

NEW REQUIRED DIN 51623 FUEL QUALITY

Modern diesel engines, especially with high-end exhaust gas emission treatment systems, require fuels with reduced ash-building elements like phosphorous (P), calcium (Ca), magnesia (Mg) to avoid engine fouling, poisoned catalytic converters and blocked particulate filters. With the newly patented VWP/Waldland purification process P, Ca/Mg can be reduced to analytical limits which comply with latest DIN 51623 fuel standards(Fig 2).

Prüfparameter	Methode	Prüfergebnis
Dichte (15 °C)	DIN EN ISO 12185	919,2
Flammpunkt P.-M.	DIN EN ISO 2719	>101
Kin. Viskosität (40 °C)	DIN EN ISO 3104	34,12
Heizwert, unterer	DIN 51 900-2 mod.[a]	37,26
Cetanzahl (ACZ)	DIN EN 15195	49,7
Iodzahl	DIN EN 14111	103
Schwefelgehalt	DIN EN ISO 20884	<1
Gesamtverschmutzung	DIN EN 12662	59
Säurezahl	DIN EN 14104	3,86
Oxidationsstabilität 110 °C	DIN EN 14112	9,2
Phosphorgehalt	DIN EN 14107	<0,5
Calciumgehalt	DIN 51627-6	<0,5
Magnesiumgehalt		<0,5
Wassergehalt K.-F.	DIN EN ISO 12937	761/769*

Fig 2 : Jatropha oil DIN 51623 analyses (VWP)

Such 2nd generation DIN 51623 plant oils can provide 100% renewable energy hybrid systems even in remote areas or islands with a sustainable, affordable and regional produced high quality fuel.

REQUIREMENT TO ENGINE TECHNOLOGY

To increase fuel safety especially in remote areas or islands a new flex-fuel CR diesel engine fueled with 2nd generation plant oils, diesel or blends of these fuels was developed.

In a second step the flex fuel engine was adapted to a dynamic operation. Fig 3 shows the electricity demand (red curve) of the Galapagos Island Floreana and the interaction of jatropha oil operated flex fuel gen sets with a photovoltaic and battery unit for regulating and balancing the corresponding 100% renewable electricity supply for 24 hours and a shifting load curve.

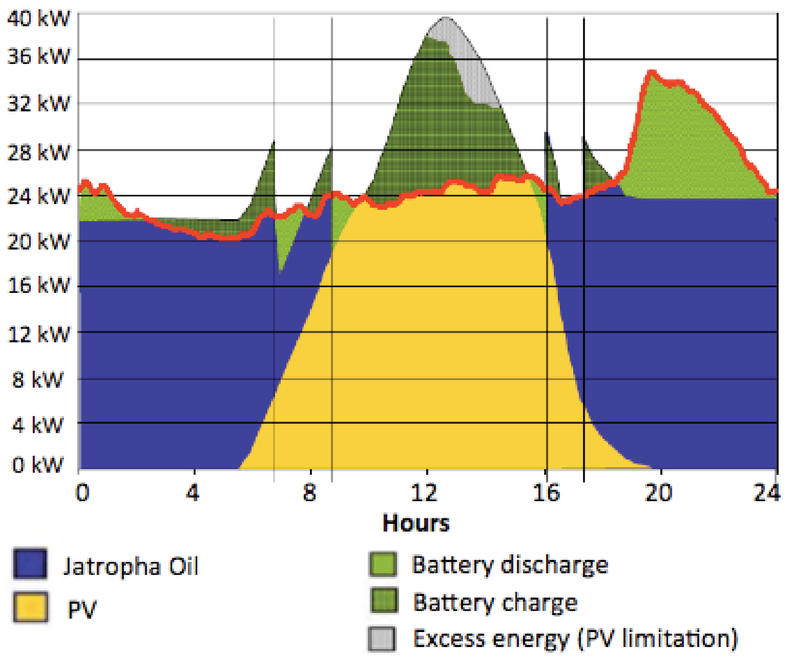

Fig 3: Electricity demand and supply of Floreana Island. (P. Carvajal, Ministry of Electricity, 2012, Ecuador)

For extended minimum and maximum load levels and faster ramping and grid regulation capability more than 20 software tables needed new software/injection designs. Fig 4 gives one example for a changed software design with corrections in red and blue colors.

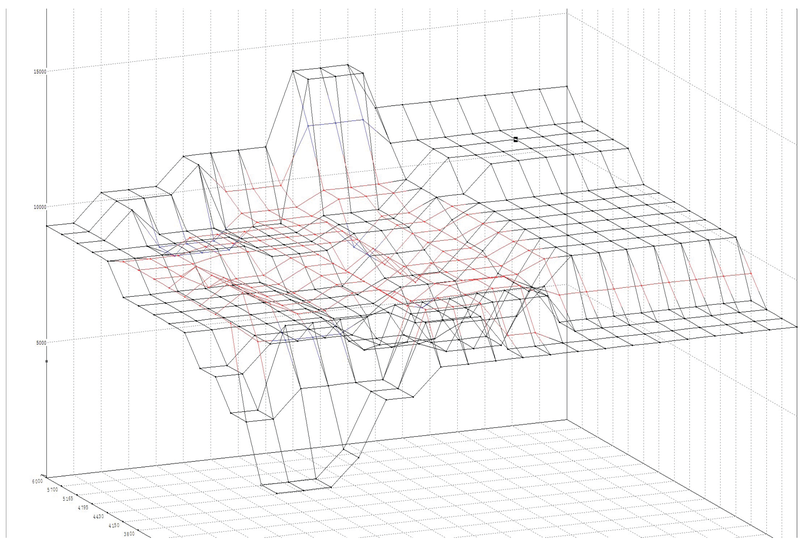

Fig 4: new injection design rail pressure (dtsdesign)

Several test bench runs with varying fuels and varying dynamic engine operation cycles have been conducted to find a common denominator in respect to emission control, fuel efficiency, and functionality for Flex Fuel engines in dynamic load modus for hybrid systems.
Fig. 5 shows emission tests based on a variation of injection mass and crank angles with Jatropha and diesel as fuel.

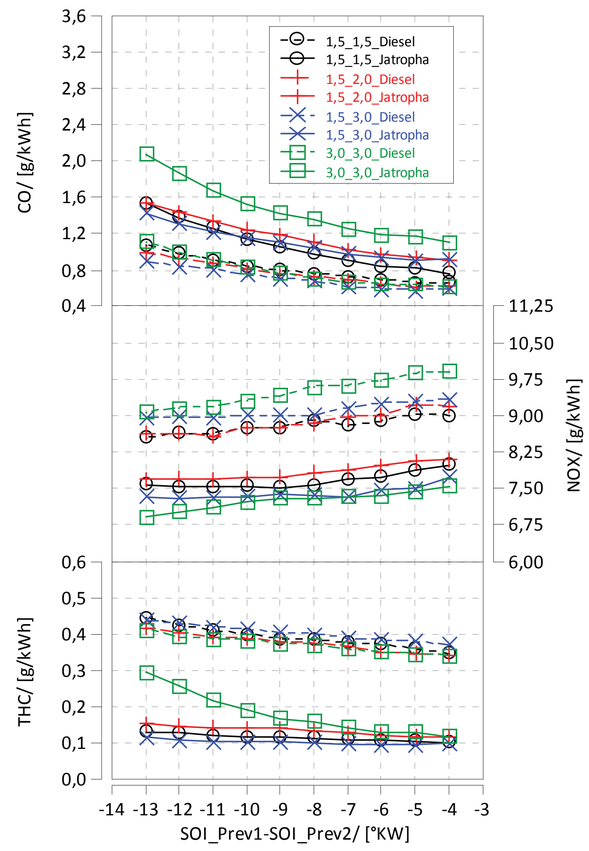

Fig.5: Variation of the injection mass of pre-injections (PI) in mg/stk and the start of injection (SOI) between the first and the second pre-injection with a constant crank angle (CA) of 4°CA between the second pre-injection and the main injection using jatropha oil and diesel at 1500 1/min and 80 Nm (Center of combustion mass at 9,7 °CA after top dead center) source: OTH Regensburg, Zacherl et al. 2016

CONCLUSION

2nd generation DIN 51623 plant oil fuels and innovative flex-fuel engines can be used for electricity production in a stand-alone gen-set or as energy storage and grid regulating technology within a hybrid system of different renewable energies.

5 years experiences with a 100% renewable energy hybrid system on Galapagos Islands demonstrate that the change from a centralized finite fossil fuel energy era to a decentralized and infinite renewable energy concept is technically immediately practicable and economically and ecologically feasible.

The "Zero Fossil Fuel for Galapagos Islands" initiative can be a blueprint for a technological evolution to change world's standards for electricity and mobility- also for the so called Energiewende in Germany:

To shift Biomass energy in Germany from base load to peak load would open the grid for more PV and wind energy, reduce the demand for bio energy and also the risk for monocultures, food and fuel conflict.

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