EIP-AGRI Focus Group

Enhancing production and use of renewable energy on the farm

MINIPAPER:

"*Biofuels in a short circular farm economy*"

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Introduction

Abstract

This mini-paper presents an evaluation of biofuels with regard to their potential to enhance the use of renewable energies on (mobile machinery of) farms by taking a differentiated view on the origin and processing of raw materials of biofuels. In this perspective, biofuels which can be produced and used in short cycle on the farm itself, and which comply more generally with wider sustainability criteria are in the focus. This principle has led the choice and delimitation of those biofuels which were submitted to a detailed scoring according to 19 criteria grouped by 6 categories. As a result of the evaluation, pure plant oil from local existing arable land gets the highest score (3.2 on a range from 0 to 4) followed by biodiesel produced locally on the farm from such oil (3.0).

Motivation

Biofuels are renewable energy and can provide a contribution to climate change abatement and energy supply security, provided that their production does not lead itself to climate gas emissions and use of resources which counteracts the positive effects. The latter is a crucial point and the EU Renewable Energy Directive (EU, RED, 2009) lists typical values for climate gas emission abatement. However, these values do not reflect combined production of biofuels and by-products such as protein fodder produced jointly with pure vegetable oil (PO) production, nor the benefit of rape seed or other oil plants as preceding crop in rotation (preceding crop effect) (Christen, Sieling, & Hanus, 1992) and opportunity to use nitrogen fixating plants in rotation before rape seed and thus decrease the need of mineral fertilization (Kage & Pahlmann, 2013). The current proposal for a revision of the RED of November 2016 (EU, RED - Proposal for Amendment, 2016) discusses comprehensively indirect land use changes (ILUC) (Bispo, Gabriele, Makowski, & others, 2017), but without taking a differentiated picture of various biofuel production options and their integration into agricultural processes. A comprehensive evaluation of biofuel options as energy sources for agricultural processes should take by-products, crop rotations, and a differentiated view of ILUC into account. Such an approach leads to a much more positive picture of PO. According to calculations of the Technology and Promotion Centre (TFZ), Straubing/Germany, the emission saving rate for PO from rapeseed is 91 % compared to 57 % indicated by the RED if all these effects are taken into account (TFZ-Kompakt 13: Klimaschutz mit Rapsölkraftstoff, 2016). In a similar way, biodiesel produced on the farm itself from locally produced PO and biogas produced from local agricultural residues get a much better rating if a differentiated view is taken. Production and use of biofuels from local origin, procedures allowing for high climate gas emission abatement and synergies of food and fuel production are very much facilitated by local energy communities (Tischer, Stöhr, Karg, & Lurz, 2010).

Within a mix of different renewable energies, biofuels have the advantage of being a storable fuel with a high energy density, thus making them a valuable option in the transport and mobile machine sector. Biofuels can be used directly in existing combustion engines or after some modification of the engine, the fuel injection and the exhaust gas treatment systems (John Deere, Technologie und Förderzentrum Straubing, B.A.U.M. Consult GmbH, 2015). Most of the required modifications can be done by engine software adaptation.
However, one of the biggest disadvantages of biofuels compared to the renewable energy sources with the highest potential, PV electricity and wind power, is the much larger ground area per unit energy required for their production. The available potential is not sufficient for replacing fossil energy in the whole transport and mobile machinery sector, but sufficient to cover the fuel needs of agriculture and forestry (TFZ-Kompakt 13: Klimaschutz mit Rapsölkraftstoff, 2016).

Best Farming Practices and Frame Conditions

Circular farming approaches

In a wider context, local production and use of biofuels is an element of circular farming (www.circular-farming-2030.org, 2018) which applies the principles of circular economy (Wikipedia: circular economy, 2018) to agriculture. It aims at closed loops of material and energy flows in order to make food production sustainable, and comprises the minimisation of external inputs such as fossil energy and the maximum use of outputs, e.g. of manure as fertiliser. Biofuels produced on the farm itself and used for covering the fuel needed for agricultural machinery can be an important element of circular farming. EU Commissioner Phil Hogan (Hogan, Phil Hogan, 9 November 2015, 2015): *'Indeed, beyond food and other traditional uses of biomass, for example pulp and paper, agriculture and forestry also contribute to produce new bio-based products. … It could mean bioenergy such as biogas and biofuels. Indeed, biofuels are in some ways a case of going "back to the future". Farming used to be circular, with horses or oxen being fed on crops grown by the farmer. Biofuels, while not an option to replace fossil fuels in all uses, could at least make the agricultural sector more circular - it is estimated that 10% of arable land would suffice for this purpose. There are already tractors that can operate with both, diesel or biofuel, emphasizing the innovative nature of the agricultural machinery sector.'*

Suitability of biofuels for agricultural machinery

Most biofuels can be used in agricultural machinery with no or very little modification. In particular synthetic biofuels can be produced with properties so similar to those of fossil diesel that they can be used straightforwardly. However in case of PO, the suitability for (adapted) diesel engines and quality issues have for many years been discussed very controversially. Nowadays, agricultural machines complying with emission standard EU stage 4 and running on PO are practicable as has been demonstrated in the PraxTrak project (John Deere, Technologie und Förderzentrum Straubing, B.A.U.M. Consult GmbH, 2015). From the beginning of 2015, John Deere offered a limited pre-series edition of tractors running on PO complying with emission standard EU stage 3B to respond to the demand in the frame of the Bavarian market introduction programme RapsTrak200 and has been carrying out extensive field tests since 2016 with EU stage 4. EU Commissioner Phil Hogan took note of this and gave a supportive comment on PO fuelled agricultural machinery: *'I am […] happy to see that such developments are actively supported in Bavaria, for example through your RapsTrak200 project which supports investment in farming machinery powered by biofuels.* (Hogan, Speech at Bavarian Farmers' Association Assembly, 2015) Right now, PO fuelled machines are a cost-effective option for farms with $\geq$ 100 ha arable land. R&D is needed for achieving compliance of PO fuelled machines with EU stage 5 and for secure automated fuel identification, in order to allow for fully flexible fuelling with various PO, biodiesel and, and mineral diesel fuel. The latter offers an alternative in case that PO or biofuel are not available or temporarily not cost-effective for the farmer.

Safety

Biofuels as any fuels are inflammable goods which need to be handled with care. However, the degree to which different fuels are inflammable is different, with PO being the least critical one.
In the specific context of farming, the degree to which biofuels are hazardous to soil and ground water in case of a leakage is important. Generally, biofuels are less hazardous than fossil diesel. Even synthetic biofuels with properties close to fossil diesel are lacking aromatic components, i.e. the most dangerous ones. However, PO again is in a particular position because it is absolutely non-hazardous to soil and ground water.

Methodology and Criteria and Input for Evaluating Biofuels

Investigated Biofuels and Biofuel Value Chains

The food or fuel debate connected to the renewable energy directive (RED) can still be seen as an obstacle to introduction of several biofuels. It is related to the question of indirect land use change ("iluc") which is intensively considered in the RED for a global approach towards general applications of fuels in transport and mobility. Nevertheless the RED does not consider specific benefits from biofuels when produced and applied in agriculture as a sub-sector of a larger bioeconomy. This is the matter of the "Renewable Energy on the Farm".

The methodology applied in this paper reflects this specific differentiation especially by distinguishing the type of biofuel in combination with its origin of different nature and in combination with specific agricultural conditions.

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Combinations of biofuels and origins included are pure plant oil (POn) and biodiesel (Bn) from

1. local existing arable land (PO1, B1),
2. non-local existing arable land (PO2, B2),
3. soil newly converted into arable land (PO3, B3), notably primary forest converted into agricultural land for producing palm oil and similar oils.

Further potentially important biofuels investigated are

- hydrogenated vegetable oil (HVO),
- biogas and bio-methane by anaerobic digestion from
  - agricultural residues (BG1, BM1) or
  - energy crops (BG2, BM2),
- bioethanol (Eth), and
- advanced biofuels (AdF), involving complex industrial processing for their production.

The choice has been guided by the principle of giving priority to fuels which can be produced entirely or partly by farmers themselves, and by the principle of delimiting such fuels clearly from those for which this is not the case. Thus, fuels derived from farm sources have got a higher score[MIS1]. Further, sustainability is a core criterion which has also led the selection of biofuels for further evaluation. In contrast to (EU, RED - Proposal for Amendment, 2016) aiming at phasing out the use of first generation biofuels, they are included here for the specific application as fuels for agricultural operations because of their high potential in this field.

Following and further developing the criteria and procedure presented by (Remmele, Eckel, & Widmann, 2013), 19 criteria for evaluating the biofuels considered for further investigation have been selected and grouped into six categories which were given a different weight:

1. potential for agricultural production	(weight 3),
2. suitability for agricultural machinery	(weight 3),
3. supply security and quality issues	(weight 2),
4. affordability compared to fossil fuel use case	(weight 3),
5. safety	(weight 1), and
6. sustainability	(weight 5).

All 19 criteria are listed in the table on next page.

Each member of the expert group was invited to score each biofuel according to each criterion by an integer number on a scale from 0 to 4 to indicate the degree of compliance with the criterion: 0 = no, 1 = low, 2 = fair, 3 = high, 4 = full. Then sub-scores within categories of criteria and the total weighted score of the sub-scores were calculated. Finally, the average values of the expert scorings were determined.

For most criteria, the meaning of the degree of compliance is self-explanatory. For the following specific criteria, the meaning is:

<u>Availability of suitable agricultural machinery</u>: 4 = standard agricultural machinery allows using the fuel, 3 = pre-series produced agricultural machinery allows using the fuel, 2 = modified standard agricultural machinery allows using the fuel + fossil fuel, 1 = modified standard agricultural machinery allows using only designated biofuel, 0 = no agricultural machinery allows using the fuel.

<u>Part of biofuel in usable fuel mixture</u>: 4 = pure biofuel can be used, 3 = biofuel can be with small admixture of fossil fuel, 2 = mixture of biofuel and fossil fuel can be used, 1 = only minor admixture of biofuel to fossil fuel can be used, 0 = biofuel cannot be used.

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Evaluation Results

An overview about the results from the evaluation process is given in the biofuel evaluation table below.

Comments on specific biofuels

Pure plant oil from local existing arable land (PO1): The decisive point leading to a high score for pure plant oil from local agricultural production is that all production steps can be implemented on a farm, including the oil purification ensuring fuel quality. See e.g. Waldland/VWP process or process developed by ITP Poznań, (Pasyniuk & Golimowski, The study of rapeseed oil production technology of reduced macronutrients content as an engine fuel, 2013), (Pasyniuk & Golimowski, Work indicators test for prototype John Deere 6830 agricultural tractor fuelled with pure vegetable oil, 2011), (Pasyniuk, Golimowski, & Golimowska, Operational examinations of agricultural tractors John Deere 6830 supplied with rape oil, 2013), (Łaska, Paszniuk, Adamczyk, & Golimowski, 2016). Further, pure vegetable oils are specifically suitable for utility vehicles operating in sensible environments such as agricultural and forestry machinery, fishing boats and municipal vehicles. A further aspect often omitted, but considered here is that pure plant oil from local farm production is basically a by-product of oil seed cake which is a formidable domestic source of protein for cattle breeding.

Biodiesel from pure plant oil from local existing arable land (B1): The situation is similar as for pure plant oil from the same source. All production steps can be implemented on a farm, including transesterification (see e.g. example of SEEG in Mureck in Styria/ Austria). Simply, methanol for the transesterification process needs to be purchased and reasonable use of the by-product glycerine can generally not be made on the farm itself.

Pure plant oil and biodiesel from other than local existing arable land (PO2, PO3, B2, B3): All options have the disadvantage of not being suitable for local energy communities and circular economy schemes at local scale.

Hydrogenated vegetable oil (HVO): Produced in industrial facilities from pure plant oil, HVO combines the disadvantages of pure plant oil (limited biomass resource) with the disadvantages of biofuels that need industrial processing thus being unsuitable for local energy communities and circular economy schemes at local scale. An advantage is that HVO is very similar to fossil diesel and can be used in existing agricultural machinery without major modifications.

Biogas (BG1, BG2) and biomethane (BM1, BM2): Generally, the cultivation of energy crop mono-cultures such as maize is socially not well accepted and this has lowered the scoring of biogas and bio-methane from energy crops. However, the cultivation of a larger variety of crops for biogas production increases crop diversity in agricultural areas. Also, grass-legumes need little added nitrogen and digestate as by-product is a sustainable, safe and homogenous source of nutrients for local plant production even if there is no animal husbandry on the farm.

Bioethanol (Eth): Similar as HVO, ethanol is suitable as fuel for agricultural machinery, but unsuitable for local energy communities and circular economy schemes at local scale.

Advanced biofuels (ABF): Advance biofuels have generally the advantage that they can be produced from other biomass than agricultural products or residues, e.g. from wood or algae. For this reason, their potential is much larger and competition with food and fodder production can be avoided. Also, ABF have properties close to those of fossil fuels, thus requiring little or no adaption of existing engines. This makes ABF a suitable option for replacing fossil fuels in the transport sector in general. However, looking at applications on farms, they have, in contrast to 1st generation biofuels such as pure plant oil, biodiesel and biogas, the disadvantage that they required large industrial facilities cannot be produced by local energy communities.

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Biofuel evaluation table

	pure plant oil			biodiesel				biogas		bio-methane			
	PO1	PO2	PO3	B1	B2	B3	HVO	BG1	BG2	BM1	BM2	Eth	AFB
Potential for local agri-cultural production (weight 3)													
input materials can be produced on the farm itself	4.0	0.0	0.0	3.5	0.0	0.0	3.0	4.0	3.3	3.8	3.3	4.0	2.5
input materials are by-products of local food production	2.0	1.0	0.0	2.0	1.0	0.0	0.3	4.0	0.5	3.8	2.8	2.0	2.0
processing machinery is mature for on-farm use	4.0	4.0	4.0	4.0	4.0	4.0	1.3	2.3	2.3	2.5	2.5	1.0	0.5
sub-score	3.3	1.7	1.3	3.2	1.7	1.3	1.5	3.4	2.0	3.3	2.8	2.3	1.7
Suitability for agricultural machinery (weight 3)													
availability of suitable agricultural machinery	2.8	2.8	2.0	4.0	4.0	4.0	3.5	1.5	1.5	1.5	1.5	1.5	3.0
part of biofuel in usable fuel mixture	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.5	1.5	2.0	2.0	3.3	4.0
easiness of storing and handling of fuel on farm	4.0	4.0	4.0	3.8	3.8	3.8	4.0	2.5	2.5	2.5	2.5	3.8	4.0
energy density	3.8	3.8	3.8	3.8	4.0	4.0	3.8	1.8	1.8	2.5	2.5	2.8	3.5
sub-score	3.6	3.4	3.3	3.6	3.7	3.7	3.6	1.7	1.7	2.0	2.0	2.7	3.4
Affordability compared to fossil fuel use case (weight 2)													
affordability of agricultural machinery	2.0	2.0	2.0	3.5	3.5	3.5	2.8	1.0	1.0	1.5	1.5	2.0	2.3
affordability of fuel processing machinery	4.0	4.0	4.0	3.3	3.3	3.3	1.0	2.5	2.5	1.8	1.8	1.8	0.3
affordability of fuel	4.0	3.5	3.5	3.5	3.0	3.0	1.0	3.5	3.5	3.0	3.0	1.0	0.0
sub-score	3.3	3.2	3.2	3.4	3.3	3.3	1.6	2.3	2.3	2.1	2.1	1.6	0.8
Supply security and quality issues (weight 3)													
availability of fuel in case of major disturbances of trade	4.0	1.8	1.0	2.5	1.0	1.0	0.3	4.0	4.0	4.0	4.0	2.5	2.3
fuel quality and fuel engine compliance can be ensured	2.8	3.5	2.8	3.3	4.0	3.3	3.5	1.8	1.8	2.8	2.8	3.3	3.3
sub-score	2.8	2.5	1.6	2.5	2.2	1.9	1.5	2.4	2.4	2.8	2.8	2.3	2.2
Safety (weight 1)													
safe as regards risk of explosion	4.0	4.0	4.0	3.3	3.3	3.3	3.3	2.5	2.5	1.8	1.8	1.8	0.3
non-hazardous to groundwater and soil	4.0	4.0	4.0	2.8	2.8	2.8	2.8	4.0	4.0	4.0	4.0	3.3	1.0
sub-score	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.3	3.3	2.9	2.9	2.5	0.6
Sustainability (weight 5)													
greenhouse abatement potential	3.5	3.0	2.3	2.8	2.0	1.3	1.3	3.5	2.8	2.8	2.0	2.8	2.3
reduction of air pollutants	2.3	2.3	2.3	2.3	2.3	2.3	2.3	3.3	3.0	3.3	3.0	2.8	3.0
efficiency of fuel production/ use	4.0	3.3	3.3	3.0	2.3	2.3	2.0	4.0	3.3	2.8	2.0	2.0	0.3
avoidance of extra land-use	2.5	2.5	1.8	2.5	2.5	1.8	1.8	4.0	1.0	4.0	1.0	1.3	2.3
social acceptance of fuel production and use	4.0	3.3	1.8	3.5	2.8	1.3	1.3	3.3	1.8	3.3	1.8	2.3	2.3
sub-score	3.0	2.6	2.1	2.6	2.2	1.6	1.6	3.2	2.1	2.9	1.7	1.9	1.7
Total weighted score	3.2	2.7	2.3	3.0	2.5	2.2	2.0	2.7	2.1	2.7	2.3	2.2	1.9

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Conclusions & Recommendations

Biofuels are renewable energy and can provide a contribution to climate change abatement. However, their potential is much lower than the potential for electricity generation from PV and wind power. Also, biofuel production requires a much larger land area per unit energy than the latter. Hence, biofuels can only be a solution for specific applications, in particular if biomass is produced on arable land thus competing with food and fodder production. Biofuel from local production used to fuel agricultural machinery within rural energy community and circular economy schemes is such an application and can be recommended if less than 10 % of the local arable land is used for fuel production and if synergies with food and fodder production are achieved through by-products and suitable crop rotation.

The biofuels with the highest potential for rural energy communities and circular economy approaches are 1st generation biofuels, in particular pure plant oil. The latter can be considered a by-product of local protein-rich fodder production, can be produced with sufficient quality in small farm-based oil presses and agricultural machines running on pure plant oil are available. The same is in principal true for Biodiesel from pure plant oil from local (domestic) existing arable land while the production effort for biodiesel (B100) is obviously a little higher compared to pure (non-transesterified) plant oil. On the other hand B100 (from domestic sources) is a fuel which immediately could replace fossil fuel also in the existing fleet. In this sense both fuels can be seen as complementary pathways to energy self-sufficient farming. Global sourcing, production, and distribution of biodiesel as today cannot be recommended due to poor efficiency of the value and logistic chain and due to land use change effects. Other fuels such as biogas, bio-methane, HVO, advanced biofuels could on the long run additional complimentary solutions if existing obstacles such as poor effective energy density of gaseous fuels, poor efficiency and high economic efforts of transformation processes (advanced biofuels) could technologically be overcome. For ethanol, there is currently no technology visible for application immobile farm machinery since spark ignited engines are not in use at mobile working machines.

For promoting sustainable use of biofuels for fuelling agricultural machines within rural energy community and circular economy schemes, full tax exemption and exemption from restrictive requirements and bureaucratic procedures is paramount.

Due to the fact that fuel production might be challenging for single farm, farm cooperatives or local groups should establish and demonstrate regional structures for energy self-supply. Industrial manufacturers are needed to support relevant engine technology and this could be combined with other pathways towards sustainable energy supply for mobile machinery (such as electromobility) or in combination of new technology development for engine technology applicable for multiple types of fuels which would help to overcome the problem of price volatility. Only a combination, of multiple technologies, multiple energy carriers etc. will likely be sufficient for farming which is in balance energy neutral. New concepts for decentralized energy production and application are appreciated so long there technology and business approaches reasonable with respect to sustainability.

The RED should reflect specific benefits of integrated energy production and consumption on farm or in the farm environment.

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