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Renewable fuels and alternative drive concepts for non-road mobile machinery

Agriculture and forestry face the future challenge of finding climate-friendly and regenerative methods of powering their field and forest machinery. Alternative fuel and drive concepts have been presented by industry in the past but, so far, these have been unable to establish themselves against the dominating diesel-fuelled internal combustion engine. Such concepts include internal combustion engines and the fuels fatty acid methyl ester "biodiesel", rapeseed oil/vegetable oil fuel, "HVO" hydrogenated vegetable oils and biomethane, but also electrical drive with energy supply via fuel cells with hydrogen or using accumulators. The alternatives were discussed and evaluated according to 14 criteria in a technical discussion with experts from industry, associations and scientific institutions. Currently, the use of rapeseed oil fuel and biodiesel in internal combustion engines for agricultural and forestry work machinery is most advantageous for more climate protection and resource saving and is simultaneously rapidly applicable.

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Biofuel, alternative driving concept, tractors, combustion engine, electric motor

Abstract
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Challenges resulting from current changes in energy policy pose the question of how agricultural and forestry machinery can operate in fields and woodlands in a climate-friendly and regenerative way. Solutions here feature the following major targets:

- Reduction in consumption of fossil resources through savings and efficiency increases as well as through use of regenerative energy
- Reduction of greenhouse gas emissions and, with that, of the "carbon footprint" of agriculture and forestry products
- Support of supply security of food and raw materials through using fuels that are less susceptible to crises
- Adding value to rural output through increasing production of fuels and, where possible, coupled products.

Framework conditions

Alternative machinery power supplies in agriculture and forestry compete with the dominating diesel-fuelled internal combustion engine. Hereby, the German Energy Tax Act supports fossil diesel fuel use in agriculture and forestry through consumption-based partial reimbursement of the applied energy tax. Fuels from biodiesel and rapeseed oil or other vegetable oils are supported by complete reimbursement of the energy tax. Currently, however, the resultant difference in tax payment normally still does not represent a competitive advantage for the regenerative fuels biodiesel, rapeseed or other vegetable oils.

Biofuels are subject to different international and national regulations which, in part, involve more requirements than those for diesel fuel. For example, on the EU level the Renewable Energy Directive (2009/28/EG) and the Fuel Quality Directive (2009/30/EG) and, on the national level, for example the Federal Immission Control Act (BImSchG), the Federal Immission Control Ordinance (BImSchV) and the Biofuel Sustainability Ordinance (Biokraft-NachV). This ordinance stipulate that biofuel must currently be able to demonstrate a greenhouse gas reduction potential of at least 35 %. From 2017, 50 % reduction potential has to be demonstrated and from 2018, new production plants will have to prove a reduction potential of 60 %. Failure to achieve these targets means loss of energy tax benefits

and eligibility for biofuel quota. With regard to energy conversion via internal combustion engine, the requirements for limited gas and particle emissions within the Directives 1997/68/EG or 2004/26/EG (Nonroad Directive) must be obeyed. Thus, the US Tier 4/EU stage IV regulation applicable from 2014 means, compared to 1999 regulations, reductions of 96.5 % and 95.7 % for particle emissions and nitrogen NOx respectively.

In total, diesel consumption in agriculture and forestry in Germany in 2012 was around 1.58 million tonnes [1] meaning greenhouse gas emissions of around 5.7 million t CO_2 equivalent. Using liquid and gaseous biofuels, as well as regenerative electrical energy, can reduce diesel requirement and thus the emission of greenhouse gases from agriculture and forestry. The process chains for providing the alternative fuels and the necessary drive concepts remain, however, in part not yet available for practical application. Many are still under various stages of development. To expedite energy transition through diesel fuel substitution in agriculture and forestry, new fuels and drive concepts for this sector presented so far by industry must be compared and assessed for their environmental impact, economic viability, development potential and practical applicability.

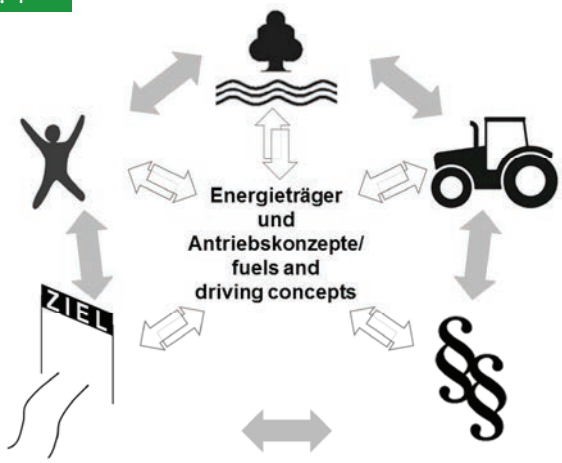
Specialist conference and expert opinion

To demonstrate, discuss and evaluate the status quo in different regenerative fuels and drive systems according to various criteria, the Association for Technology and Structures in Agriculture (KTBL) and the Technology and Support Centre (TFZ) initiated a specialist conference [2] involving representatives from industry, science and applicable associations. Around 50 experts took part, whereby the development stage of regenerative fuels and drive systems was first of all detailed through presentations and statements. In conclusion, the participants were asked to assess on a questionnaire 14 given criteria on a scale from 1 (of little importance) to 3 (of great importance) and to also assess six drive systems according to the individual criteria on a scale from 0 (unsuitable) to 4 (very suitable). In total, 24 questionnaires from conference participants were evaluated. For a final comparison of the alternative fuels and drive systems – including all criteria taken into account – the individual values were multiplied with a specific weighting factor, that was based on a assessed relevance, added up and divided by the number of assessment criteria. The results presented below give the opinions of the 24 experts. In a final discussion, the participants made their conclusions and set out requirements for suitable action.

Evaluation criteria

Evaluation criteria for the fuels and drive systems (**Figure 1**) can be deduced from the requirements of individuals, society, environment, the legal framework, the specific application in agriculture and forestry ("off road"), as well as temporal applicability.

Fig. 1



Demands on fuels and driving concepts for agriculture and forestry and their interactions

The following essential criteria concerning supply and utilisation of fuels were applied for evaluation of the systems:

- (Raw material) potential and availability
- Technology available for production of the fuel
- Stage of technical development (maturity), level of research and development or market introduction
- Standardisation and quality assurance
- Infrastructure of fuel supply and refueling
- Energy efficiency
- Greenhouse gas emissions
- Avoidance of air pollution
- Soil and water protection
- Costs: direct, indirect and specific
- Self-sufficiency, autarky
- Participation of the agriculture and forestry sectors
- Practical timeframe
- Acceptance

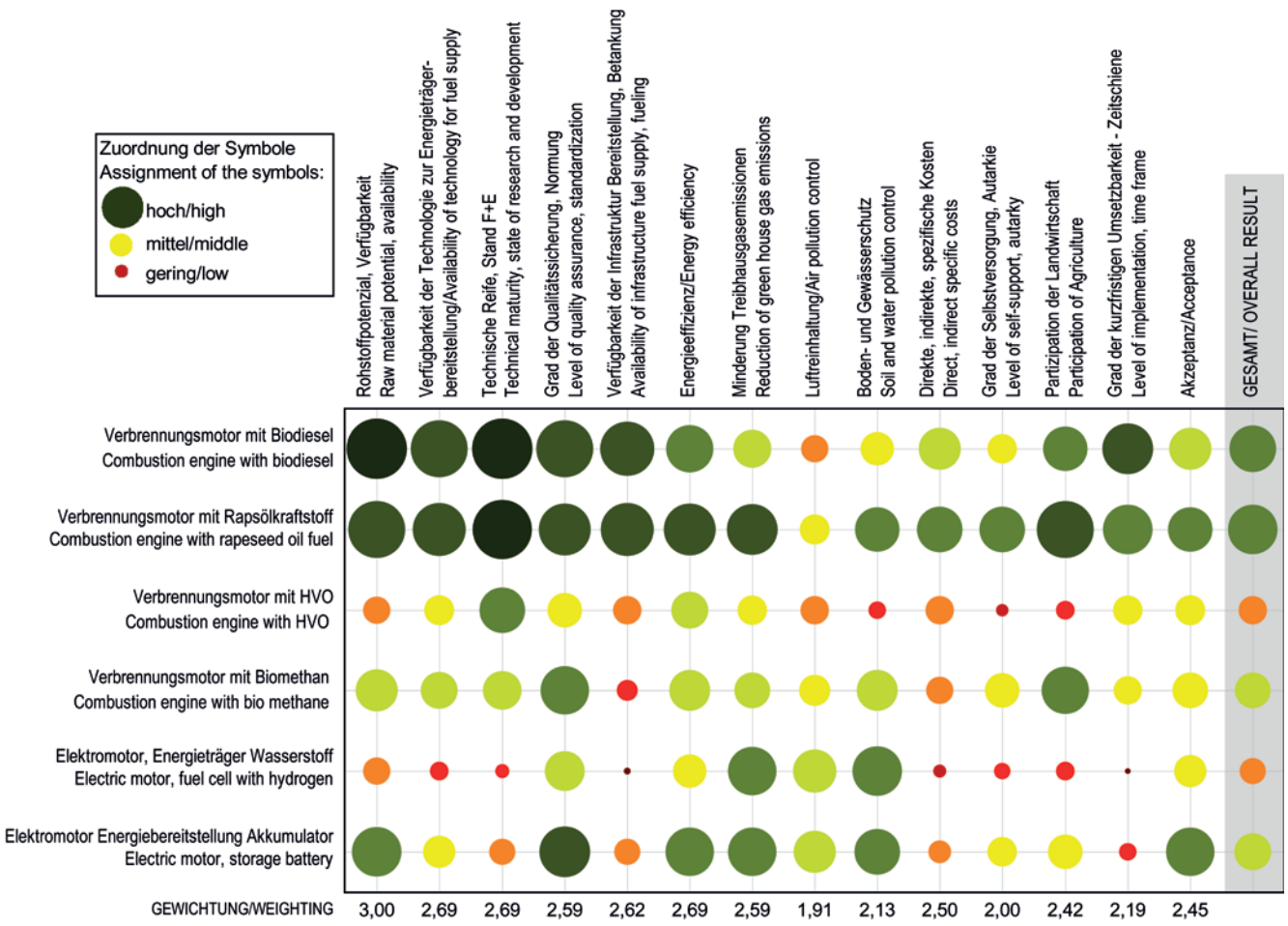
Alternative fuel and drive concepts

The alternative fuel and drive concepts discussed in the specialist conference have already been presented by industry for application in agriculture and forestry. On the one hand, this involves concepts with internal combustion engines and the fuels fatty acid methyl ester (FAME) "biodiesel", rapeseed oil/other vegetable oils, hydrogenated vegetable oil "HVO" and biomethane. Involved on the other hand are electrical drive (electric motors) with energy supply via fuel cells with hydrogen or from accumulators.

Expert evaluation of the alternative fuel and drive concepts

The potential of the raw material and availability of the fuel, the energy efficiency and the production technology, as well as technical maturity or stage of research and development, were all identified as most important evaluation criteria for assess-

Fig. 2



Evaluation of alternative fuels and drive concepts for agriculture and forestry machinery within a range from 0 to 4 with weighting of the criteria as high/middle/low (3/2/1) in the opinion of the participants of the specialist conference (n = 24)

ment of alternative fuels and drive concepts. **Figure 2** gives an overview of the weighting of the criteria and classification of drive concepts. The raw material potential and availability of the fuel were assessed as best for biodiesel. Also the technology of biodiesel production, as well as the fuel's technical maturity and stage of research and development, were seen as the most advanced. Against this, the manufacture and utilisation of rapeseed oil fuel was seen as having comparatively better energy efficiency and the highest greenhouse gas emission reduction potential. Additionally, with regard to participation of agriculture when applying the technology, the greatest opportunities were assessed for rapeseed oil fuel. With regard to nearly all the criteria, rapeseed oil fuel was rated throughout as advantageous to very advantageous. Thus, rapeseed oil fuel and biodiesel were evaluated as best alternatives to diesel fuel in agriculture and forestry. Assessed as least advantageous, marked down by high costs, poor technical maturity and through missing infrastructure, was electrical drive with hydrogen fuel cells. With electrical drive the research and development currently concentrates mainly on the drive of auxiliary units. Hydrogenated vegetable oils were assessed as comparatively poor as fuel for internal combustion engines in agriculture and forestry, particularly regarding the aspect of self-sufficiency. Seen as obstacle to practicability for biogas fuel in agricultural machinery is the small working range because of limited fuel tank capacities.

Conclusions

System analyses are necessary for the evaluation of alternative fuel and drive concepts because individual aspects are insufficient for accurate characterisation of requirements and interactions. To achieve more climate protection and resource savings regarding fuel use in agriculture and forestry, currently the use of rapeseed oil fuel and biodiesel in internal combustion engines offers the most advantages. Engines with the appropriate approvals are, in part, already available in the field, purchasable on the market, or scheduled for production in the shorter term. All other options should, however, be followed-up further within the framework of research and development because, based on the knowledge so far, none of the systems can be completely excluded. Achievable in the short term are de-

central concepts for coupled production of fuels (rapeseed oil fuel, in part also biodiesel) and feed. Because of the framework conditions, especially the price difference between agricultural diesel and agricultural biofuels, there is currently no steady demand for biofuels and the machines suitable for using them.

The application of rapeseed oil fuels and biodiesel could offer a more efficient and rapidly applicable contribution with comparatively low greenhouse gas avoidance costs towards increasing protection of climate and resources in the agriculture and forestry sectors. For this, however, agriculture and forestry must itself set the targets for substitution of diesel fuel. Politics must define long-term reliable framework conditions so that agriculture and forestry can apply rapeseed oil fuel and biodiesel without economic losses. Under such conditions the agricultural machinery industry can develop climate and resource protecting machinery that will also then achieve continual sales.

References

[1] Mineralölwirtschaftsverband e.V. (2012): MWV Mineralölzahlen als Excel-Datei mit Daten zu Kapazitäten, zur Mineralölein- und -ausfuhr, zum Mineralölverbrauch, zu Preisen und zum Weltölmarkt (2012). http://www.mwv.de/upload/statistiken/info/MWV2012_5g7y0W5DKQ4R5L7.zip, Zugriff am 2.6.2014

[2] Remmele, E.; Eckel, H.; Widmann, B. (2013): Alternative Energieträger und Antriebskonzepte für mobile Maschinen in der Land- und Forstwirtschaft. Zusammenfassung der Ergebnisse. KTBL/TFZ-Fachgespräch, 20. und 21. März, Straubing, https://www.ktbl.de/inhalte/themen/energie/themen/alternative-energietraeger/, Zugriff am 16.6.2014

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