In this Issue:

- *Conference summarising three-year research on cultivation of Miscanthus*
- *Workshop, Marginal Land can be useful, 26 September 2018, Katowice, Poland*
- *Integrating Miscanthus into farming systems*
- *Progress so far*

Editorial

Dr. Marta Pogrzeba, Project Coordinator, Institute for Ecology of Industrial Areas, Poland

Dear Readers,

Welcome to the last issue of MISCOMAR newsletter. Our project has been a 3-year journey that allowed researchers and practitioners from 3 research organizations and one commercial gain new practical experiences and scientific knowledge. MISCOMAR is testing the several novel Miscanthus hybrids on marginal and contaminated lands at three locations in Europe. *Miscanthus* for biomass is an alternative non-food land use option. The works implemented jointly by the scientists and practitioners brought the number of interested research advancements that are not only valid as scientific results but maybe further explored in commercial scale.

First of all, thanks to the work of IBERS and UHOH scientists which gained a lot of new knowledge concerning *Miscanthus* cultivation on marginal land. The study is helping to identify options of *Miscanthus* cultivation. It is tested, if *Miscanthus* cultivation improves soil conditions of marginal/contaminated lands. Additionally, the effects of marginal/contaminated soil conditions on biomass is tested, when biomass is used for combustion or anaerobic digestion. The increased heavy metal concentrations in the biomass had no negative effects on the ash melting behavior. For anaerobic digestion, a harvest before winter seems to be favorable, as slightly higher substrate specific methane yields can be achieved. Results show that higher heavy metal contents in biomass do not negatively affect anaerobic digestion.

Main lessons learnt from MISCOMAR shows that *Miscanthus* crop is generally improving the soil fertility, through increase of soil organic matter and activation of soil life. At the same time the increase in soil organic matter and the root and rhizome mass contribute to produce a carbon sink in the soil. There is first evidence that especially the deep roots contribute to produce a long-term carbon sink, since they are deeper than the tillage zone of conventional arable crops. What was a bit surprising, that *Miscanthus* genotypes due to very low concentration of heavy metal in the biomass are not suitable for cleaning up the contaminated soils, as we expected at the stage of proposal preparation. On the other hand, we confirm that *Miscanthus* cultivation could be safe and profitable option for marginal and contaminated lands.

Further research should be concentrated on the disposal of the residues after combustion and anaerobic digestion process, to close the loop of the biomass life. The most probable way of the disposal should be use it as soil fertilizers and soil conditioners. Special attention should be paid to the residues from heavy metal contaminated biomass. Moreover testing the best *Miscanthus* genotypes in the real-scale environment would be also a challenge.

Conference summarising three-year research on cultivation of *Miscanthus*

The International Scientific Conference: Multiple Benefits of Biomass Crops on Marginal Land, held on March 20-21, 2019 at the Institute for Ecology of Industrial Areas in Katowice, brought together a group of leading scientists and practitioners involved in research on energy plants in Poland and Europe.

Among the participants of the conference were representatives of the Aberystwyth University, University of Aberdeen, Terravesta from Great Britain, Hohenheim University from Germany, Groningen University from the Netherlands, University of Jan Evangelista Purkyne from the Czech Republic and National Agricultural University from Kiev, Ukraine, as well as representatives of the West Pomeranian University of Technology from Szczecin, University of Warmia and Mazury in Olsztyn.

This project is carried out under the flag of ERA-NET Cofund FACCE SURPLUS in the frame of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)

FACCEJPI

The European Commission was represented by Nicolas Tinois, coordinator of the FACCE SURPLUS programme: „Sustainable and Resilient Agriculture for Food and Non-Food Systems" which is part of the Joint Programming Initiative „Agriculture, Food Security and Climate Change" (Joint Programming Initiative Agriculture, Food Security and Climate Change – JPI FACCE).

The conference programme consisted of 4 paper sessions:

1. Possibilities of growing perennial energy plants on marginal soils;
2. Experiments in the cultivation of *Miscanthus* on marginal soils;
3. Growing of other species of energy crops on marginal soils;
4. Biomass as a raw material of many applications - panel discussion and poster session.

During the conference the scientists summarised the research on the cultivation of new *Miscanthus* seed genotypes on poor quality soils and soils contaminated with heavy metals, which was carried out in Germany, Poland and Great Britain as part of an international project: ***Miscanthus* Biomass Options for Contaminated and Marginal Land: Quality, Quantity and Soil Interactions (MISCOMAR)**.

This meeting of scientists is not only to summarise the three years' research conducted jointly under the MISCOMAR project, but also to show the importance of growing energy plants for improving the quality of poor soils and energy production - emphasised Dr. Marta Pogrzeba, coordinator of the MISCOMAR project, under which this event was organised, opening the conference debate.

The possibilities of growing *Miscanthus* were also analysed in the context of current and forecasted climate changes and cultivation on soils contaminated with heavy metals.

Researchers from the Aberystwyth University in the UK, which has more than a 100 years' experience in breeding and growing various grass species as well as a great collection of grass from all over the world consisting of more than 100 species, presented the results of research on various aspects of cultivation of *Miscanthus*.

Prof. John Clifton-Brown, an outstanding expert in the field of breeding and cultivation of *Miscanthus* and research on the impact of cultivated crops on soil quality and Dr. Elaine Jensen discussed different aspects of breeding new *Miscanthus* genotypes, cultivating on marginal soils in terms of yield size, as well as maintaining or improving the value of ecosystem services. Another topic addressed by Elaine Jensen were directions of research on the use of various grass species for phytoremediation purposes.

Dr. Astley Hastings from the University of Aberdeen presented the results of research on the cultivation of *Miscanthus* in the context of global warming, with particular focus on the increase of temperature and limited humidity.

Dr. Jacek Krzyżak from the Institute for Ecology of Industrial Areas presented the problem of soil contamination with heavy metals in the Silesian Voivodship based on the research carried out by the Institute since the 1980s. Dr. Marta Pogrzeba discussed the results of a three-year study on the cultivation of *Miscanthus* on soils contaminated with lead, cadmium and zinc at the IETU experimental plot in Bytom. The conducted research confirmed that cultivation of *Miscanthus* was possible on soils contaminated with heavy metals, without the negative impact of contamination on the quantity and quality of biomass produced, and with a positive effect on the quality of poor soils.

Some presentations given during the conference focused on bioeconomy and benefits of growing energy crops not only due to energy production, but also in the context of improving soil quality and supplying raw materials for production of building materials, packaging, etc. Visitors had an opportunity to see examples of building and packaging materials made from *Miscanthus*. The exhibition was organised by Uwe Kühn from the Technical Service Kuehn GmbH from Germany.

Presentation which raised particular interest was the presentation of a *Miscanthus* cultivation system in Great Britain, which was developed by Terravesta Ltd. in cooperation with the University of Aberystwyth. Specialists from Terravesta closely cooperate with farmers, providing new cultivars of *Miscanthus*, specialised planting equipment and agrotechnical consulting. What was strongly emphasised was the impact of cooperation with farmers on the crop quality, which is particularly important for its recipients, as it allows preparation of the crop according to their requirements. Sam Buckby, presenting Terravesta's achievements, pointed out that the main target for future should be to expand the cultivation of *Miscanthus* not only for energy purposes, but also as a raw material for construction materials. He also mentioned that Terravesta had been testing the use of drones to control the development of new plantations and the health status of the crops. The conference participants were interested in the possibility of implementing such a system in other countries. Sam Buckby explained that the company was going to prepare a license that would allow Terravesta to implement solutions in other countries.

The results of the study on the possibilities of growing *Miscanthus* in China were discussed by Bingquan Zhang from the University of Groningen (The Netherlands). Polish research on the cultivation of energy plants was presented by Dr. Marek Bury from the West Pomeranian University of Technology in Szczecin and Prof. Mariusz Stolarski from the University of Warmia and Mazury.

Discussion panel led by Dr. Marta Pogrzeba from IETU concerned the use of poor quality and contaminated soils for biomass production for energy purposes and for bioeconomy. The panel was attended by Prof. John Clifton-Brown from the Aberystwyth University, Dr. Astley Hastings from the University of Aberdeen, Sam Buckby from Terravesta (Great Britain), Andreas Kiesel from the University of Hohenheim (Germany), Prof. Valentina Pidlisnyuk from the University of Jan Evangelista Purkyne (The Czech Republic), Prof. Mariusz Stolarski from the University of Warmia and Mazury and Michał Moś from Energene.

The discussion concerned various aspects of cultivation of *Miscanthus* in Europe, including Poland. The panellists presented examples of good practices in the field of energy crop cultivation in Germany and the United Kingdom, where their area is gradually increasing. Also in Ukraine the area of energy crops is growing, and particular focused is being paid to post-military areas. In Poland, the interest in cultivating *Miscanthus* is low because there are no subsidies and the price of agricultural biomass is not high. It is necessary to build a biomass market for technological purposes, mainly for the production of bioproducts which will replace plastic products. The necessity of wider and more common use of research results and good practices in the European Union countries was emphasised. If there is a demand for raw material from innovative technology companies, then the market will appear and the farmers' confidence in new companies using biomass for the production of biodegradable construction and packaging materials will increase. The participants agreed that the British model explicitly showed that the cooperation with farmers, creating a support system and popularising good practices should be a priority. The use of marginal soils (weak and contaminated) for the production of biomass requires subsidies for farmers, providing energy producers with guaranteed prices and ensuring support for small enterprises which would like to cultivate, e.g. *Miscanthus* on small areas for biodegradable materials. Prof. John Clifton-Brown emphasised an important role which scientists would have to fulfil - based on the conducted research they should demonstrate and promote the benefits of cultivating *Miscanthus*. In his opinion, it is first and foremost the scientists who have arguments which can convince farmers that the biomass market will successfully operate in the future.

On the second day of the conference, a poster session was held, during which eighteen posters presenting the results of research carried out by young scientists from the Czech Republic, Great Britain, Ukraine and Poland were demonstrated.

At the end of the conference, the participants went to Ruda Śląska, where they got acquainted with the outcomes of an international project: "Implementation of Sustainable Land Use in Integrated Environmental Management of Functional Urban Areas" (LUMAT), coordinated by IETU. The participants visited a zinc spoil heap, which was secured to be used for recreational purposes.

Integrating *Miscanthus* into farming systems

Anja Mangold
Department of Biobased Products and Energy Crops, University of Hohenheim, Germany

Andreas Kiesel
Department of Biobased Products and Energy Crops, University of Hohenheim, Germany

Although *Miscanthus* seems to be an ideal bioeconomy crop, it plays only a minor role in the European agriculture. Reasons for this are likely uncertainties (financial returns of *Miscanthus* compared to annual crops), not established markets for biomass or less available practical and objective information for farmers how to cultivate the crop.

Therefore, a concept study was conducted to provide an overview of potential utilization pathways for *Miscanthus* and how it can be integrated into practical farming. Thus, a cost calculation for three different utilization pathways (combustion, anaerobic digestion, animal bedding) was conducted and additionally, labour time aspects for each utilization pathway were investigated.

The three utilization pathways were chosen because of the following:

1. Miscanthus straw as animal bedding material is a lucrative utilisation option, due to the evolving market (especially for domestic animal keeping).
2. The suitability of *Miscanthus* for biogas production was demonstrated by different research studies, which have shown that its methane yields reach up to 5,000 to 6,000 m³ CH_4 ha^{-1} and are therefore comparable to those of maize.
3. Combustion is still the most common utilization pathway for *Miscanthus* up to date.

Independently from the utilization pathway, it was assumed that *Miscanthus* establishment procedure and costs were identical. From the second year onwards, the crop management (harvest date, harvest technique, fertilization) was adapted to the utilization pathways: If *Miscanthus* is used for animal bedding or combustion, it is harvested brown after winter (March), while green harvest before winter (October) was assumed for anaerobic digestion. For animal bedding, *Miscanthus* was first cut on swath and afterwards picked up and baled by bale press. Harvest by a field chopper was assumed for biogas production and combustion.

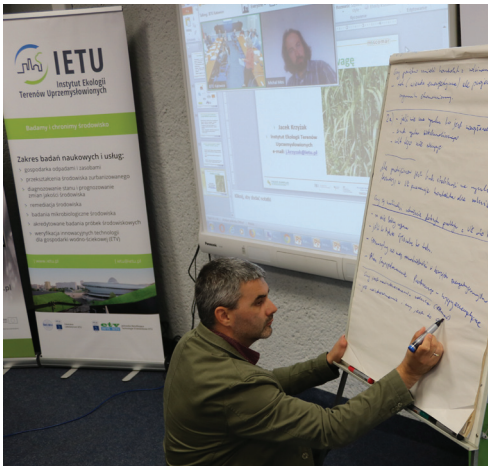
Despite of identical establishment costs for each pathway, the differences in harvest procedure resulted in varying biomass costs to produce 1 t *Miscanthus*: *Miscanthus* used in combustion could be produced at the lowest costs (47 € $(t\ DM)^{-1}$), followed by anaerobic digestion (55 € $(t\ DM)^{-1}$) and animal bedding (64 € $(t\ DM)^{-1}$). Those different production costs in combination with variable selling prices lead to varying cross margins, which were calculated: for combustion the attainable gross margin was up to 800 € ha^{-1}, for anaerobic digestion up to 2,000 € ha^{-1} (if it is sold chopped) and for animal bedding up to 8,100 € ha^{-1}. Following this, animal bedding seems to be the most lucrative utilization option.

With regard to labour requirements of *Miscanthus* cultivation for the three different utilization pathways, combustion has the lowest labour amount (approx. 113 hr ha^{-1}), followed by anaerobic digestion (approximately 178 hr ha^{-1}) and animal bedding (approximately 218 hr ha^{-1}). For each utilization pathway, establishment of *Miscanthus* is most labour intensive, especially rhizome planting (approximately 24 hr ha^{-1}). The high labour amount for animal bedding is mainly due to the transport of bales to the farm. Therefore, from this point of view combustion seems to be the most attractive utilization pathway.

Additionally to the concept study, we investigated, how *Miscanthus* can be efficiently integrated into a crop rotation and how such a reconversion into arable land impacts soil nitrogen content. To address this, a field trial was conducted, where a mature *Miscanthus* stand was ploughed and afterwards different spring crops were sown (barley, ryegrass, rapeseed, maize), with and without fertilization. Additionally, some plots stayed fallow as a control (unfertilized). It was shown that fertilized crops in tendency better supressed resprouting *Miscanthus* compared to unfertilized and that soil mineral nitrogen content increased but was in general on a low level. This leads to the conclusion that nitrogen is mostly fixed in organic matter and thus is not plant-available. However, some nitrogen was supplied by the decomposition of *Miscanthus* residues, which is why we recommend that a subsequent crop after a *Miscanthus* removal requires less fertilization. Maize coped with the prevailing soil conditions best and supressed resprouting *Miscanthus* efficiently, which resulted in satisfying yields. Thus, it seems to be a suitable crop for cultivation after *Miscanthus*.

Why it is worth cultivating energy plants on soils contaminated with heavy metals?

On the 27 of September 2018 at the Institute for Ecology of Industrial Areas scientists and practitioners discussed the possibilities of growing energy crops on soils contaminated with lead, cadmium and zinc and on post-industrial wastelands.



Sustainable production of biofuels and food production requires development of new methods of growing energy crops on poor quality agricultural land, while leaving clean and good quality soils for food production.

During the workshops, we presented the results of our latest studies on the cultivation of new Miscanthus seed genotypes on marginal soils and the impact of cultivation on the improvement of soil structure and quality, which are carried out with partners from Germany and Great Britain.

The selection of the appropriate species of energy plants allows achieving the assumed goals, such as: restoring the soil contaminated with heavy metals and improving the structure and quality of soil, as well as obtaining a high biomass yield with good parameters for processing for energy purposes.

Dr. Michał Moś from Energene presented practical aspects of establishing plantations and growing Miscanthus. He has emphasised that the cultivation of Miscanthus provides soil protection, i.e. prevents soil erosion and spreading of pollutants and improves its quality.

During the discussion, it was emphasised that the introduction of energy crops to marginal soils requires appropriate legal and economic support as well as infrastructure for biomass processing. Practitioners claim that as soon as the demand for Miscanthus biomass appears on the market, there will also appear those who will be ready to grow it.

The workshop included a visit to the IETU testing plot in Bytom. We showed a four-year experimental plantation of innovative Miscanthus genotypes obtained from seeds and Miscanthus giganteus, cultivated on soil contaminated with heavy metals - adds Dr. Jacek Krzyżak.

On the testing plot the visitors could also see other species of energy plants, including *Sida hermaphrodita*, *Panicum virgatum L.* or *Spartina pectinata*.

MISCOMAR at the Silesian Science Festival in Katowice

Researchers from IETU were participants of the Silesian Science Festival, which took place at the International Congress Centre in Katowice on 12-14.01.2019. Under the motto "Plants with energy" the speakers presented how the research on the possibility of growing energy crops (*Miscanthus giganteus*, *Sida hermaphrodita*, *Panicum virgatum* and *Spartina pectinata*) is carried out on contaminated and poor quality soils.

The Silesian Science Festival KATOWICE is one of the biggest events popularising science, organised by the greatest Silesian academic units, in that: University of Silesia, Silesian University of Technology, Medical University of Silesia, Academy of Fine Arts, and the City of Katowice. The main theme of this year's edition was ENERGY.

For more information visit the website: www.slaskifestiwalnauki.pl

Progress so far

German test site

At the harvest in March 2018, all *Miscanthus* hybrids increased their yield compared to 2017. On average, *Miscanthus* had a yield of 13 t DM ha^{-1} a^{-1}, while it was 4.3 t DM lower in spring 2017. The highest yield increase was achieved by Sin55, which quadruplicated its yield to almost 13 t DM ha^{-1} in 2018 compared to 2017. However, the highest average yield was found in GNT3 (14.6 t DM ha^{-1}).

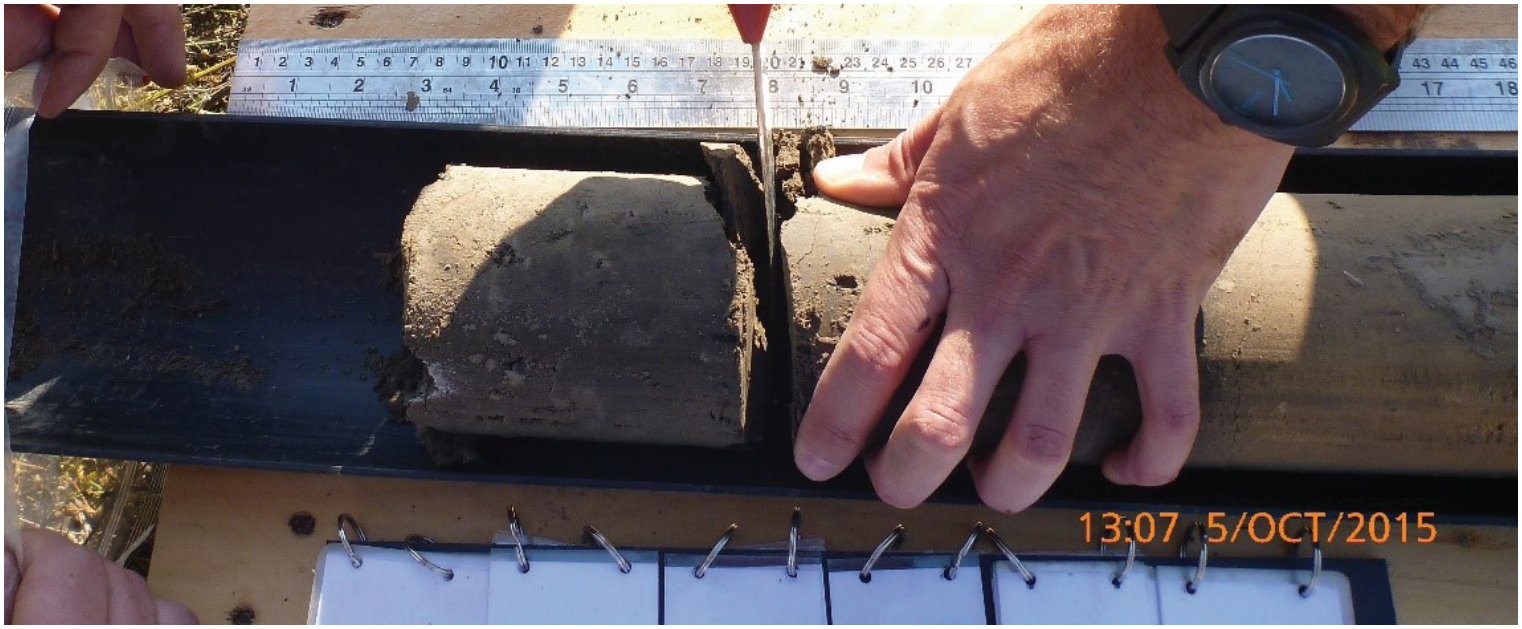
At the German site Unterer Lindenhof, the growth season in 2018 can be characterized as a warm and dry year. Especially in the months July to November less than half of the precipitation occurred in 2018 (235 mm) compared to 2017 (490 mm). At the same time, the average temperature was 1.9°C higher in 2018 than in 2017.

In autumn 2018, the third green harvest of *Miscanthus* was conducted. While the genotypes *M* x *giganteus* and *Sin55* could increase their yield compared to the autumn cut in 2017, the yield in *GNT1* and *GNT3* decreased. On average, *Miscanthus* had a yield of 14.7 t DM ha^{-1} a^{-1} in 2018, which is 0.9 t DM ha^{-1} a^{-1} lower than in 2017. Especially *Sin55*, which already doubled its yield from 2016 to 2017, again increased its yield by further 1.75 t DM ha^{-1} a^{-1}. *GNT3*, however, yielded more than 4 t DM ha^{-1} a^{-1} less than in 2017, probably due to frost damages. Besides *GNT3*, also *GNT1* was damaged by frost, which could be due to lower frost resistance of the rhizomes or due to earlier start of sprouting. While *GNT1* was able to recover from this damage, *GNT3* hardly could and in consequence achieved a much lower yield.

Great Britain test site

In November 2018, a team from IBERS travelled to the three MiscoMar sites in UK, Germany and Poland with the same standardised soil coring equipment used at the start ('time-zero') of the MiscoMar trials. A sampling strategy to take account of the root and rhizome development over the trial lifespan was used: coring the plant centre, plant edge and interrow. A total of 102 cores were taken and divided into depth layers 0-10, 10-20, 20-30, 30-60, 60-100 cm from the soil surface.

Roots and rhizomes were extracted and soils were assessed for their bulk densities. The soil cores were sampled in order to determine changes in soil physical and chemical properties after three years of cultivation of the *Miscanthus* crop, following sampling and analyses done in 2015. As expected, most belowground biomass was found in the surface layer 0 - 10 cm. Chemical analyses of samples of soil and of belowground biomass will provide data on changes in soil organic carbon and in nutrient status and on the uptake of HMs from soil and their translocation and distribution in plant biomass. The areas represented by each core position will be scaled to estimate below ground biomass stock changes.



Polish test site

Work carried out at the Polish test site focused on the assessment of plant growth and biomass productivity in the third growing season. Biomass production and heavy metal uptake were determined twice, at autumn and spring harvests. The main finding of the performed analyses was that seed-based hybrids after the third growing season showed biomass production comparable to that of *M.* x *giganteus*. It was also confirmed that seed-based hybrids were characterized by lower heavy metal uptake to aboveground parts than commercial *M.* x *giganteus*, showing phytostabilisation abilities and giving the opportunity for safe biomass production on contaminated soil. Analyzing plant physiological parameters measurements it was found, that the stomatal response to light of the new hybrids was at least twice as fast as that of *M.* x *giganteus*, a trait that is often associated with increased seasonal water use efficiency. Simplifying, it might be stated that more conservative water use by novel seed-based hybrids resulted in lower metal uptake. In November, together with colleagues from Aberystwyth University, soil cores were resampled and analyzed, among other parameters, for changes in soil organic carbon, soil porosity and and heavy metal concentration. Changes after three years of *Miscanthus* cultivation indicated an overall positive trend in decreasing bulk density values over time, which corresponded with observations of increased porosity, as well as increased soil organic carbon. Detailed assessment will be described in the project final report as well as in forthcoming scientific publications.

Project Facts Sheet

Project acronym:	MISCOMAR
Project full title:	Miscanthus biomass options for contaminated and marginal land: quality, quantity and soil interactions
Project start date:	1st of May 2016
Duration of the project:	36 months
Project website:	www.miscomar.eu

Project partners

Institute for Ecology of Industrial Areas, Poland

Dr. Marta Pogrzeba, Project Coordinator
Phone No.: +48 32 2546031 ext. 252
e-mail: m.pogrzeba@ietu.pl
Dr. Jacek Krzyżak
e-mail: j.krzyzak@ietu.pl
Szymon Rusinowski, M.Sc.
e-mail: s.rusinowski@ietu.pl

University of Hohenheim, Biobased Products and Energy Crops Department, Germany

Andreas Kiesel, M.Sc.
e-mail: a.kiesel@uni-hohenheim.de
Anja Mangold, M.Sc.
e-mail: amangold@uni-hohenheim.de
Prof. Iris Lewandowski
e-mail: iris_lewandowski@uni-hohenheim.de

Aberystwyth University, Institute of Biological, Environmental and Rural Sciences, United Kingdom

Prof. John Clifton-Brown
e-mail: jhc@aber.ac.uk
Dr. Jon Paul McCalmont
e-mail: jpm8@aber.ac.uk
Dr. Elaine Jensen
e-mail: fft@aber.ac.uk

Project Funded by

Polish National Centre for Research and Development

The National Centre for Research and Development

German Federal Ministry of Education and Research

Federal Ministry of Education and Research

UK Department for Environment Food and Rural Affairs

Department for Environment Food & Rural Affairs

Asocciated partner

Terravesta Ltd., United Kingdom

PhysisData Ltd., United Kingdom

This project is carried out under the flag of ERA-NET Cofund FACCE SURPLUS in the frame of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)

FACCEJPI