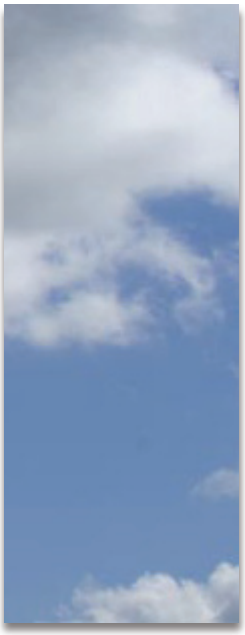
PHYTO2ENERGY

Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier

January 2018

Project Resume Book



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Content

About the Phyto2Energy project

The goal and consortium

Phyto2Energy was a four year effort with a goal to develop and validate in field conditions an innovative, complex approach combining phytoremediation of heavy metal contaminated sites with energy crops production and their conversion to energy using gasification. Six organisations from the scientific sector represented by:

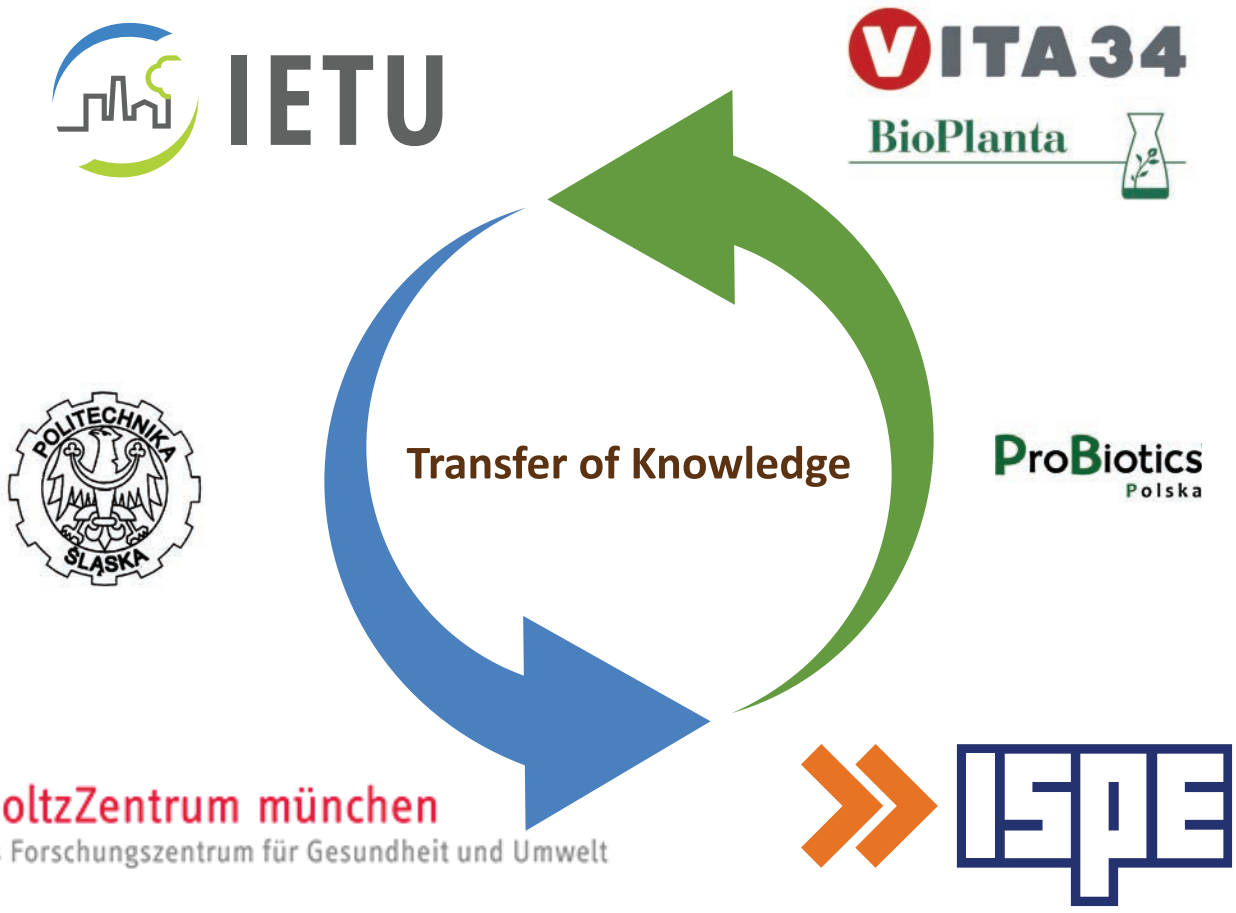
- Institute for Ecology of Industrial Areas (IETU) from Poland,
- Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt- (HMGU) from Germany
- Institute of Thermal Technology of the Silesian University of Technology – (SUT) from Poland

and commercial sector represented by:

- VITA 34 Bioplanta from Germany – an SME dealing with land management and phytremediation engineering,
- ProBiotics from Poland – an SME – producer of biosurfactants for plant growth stimulation
- Institute for Studies and Power Engineering national leader in the field of power consulting and engineering from Romania

established a strategic partnership aimed at transfer of knowledge, exchange of practices and training to advance the proposed approach as a promising, near-to-market solution.

Acedemia | **Industry**



Phyto2Energy start point: concept and assumptions

The development and validation of the approach involved research addressing three specific aspects:

- **the use of energy crops for phytoremediation purposes**
- **the development of microbiological methods to enhance and monitor the phytoremediation effect and increase the biomass production**
- **the conversion of the produced biomass into energy by a gasification process.**

How an energy crops make a change?

It is estimated that across the Europe about 800 000 km^2 are identified as contaminated or potentially contaminated. The share of heavy metal contaminated areas is about 30%. Despite that fact, little has been investigated on combining the production of energy crops on the contaminated areas with phytoremediation of these sites. Whereas heavy metal contaminated soils are unsuitable for food production, energy crops may allow the commercial exploitation of these soils by establishing biofuel feedstock production systems. In addition, the cultivation of the plants offers opportunities for site stabilization and phytoremediation of contaminated soils.

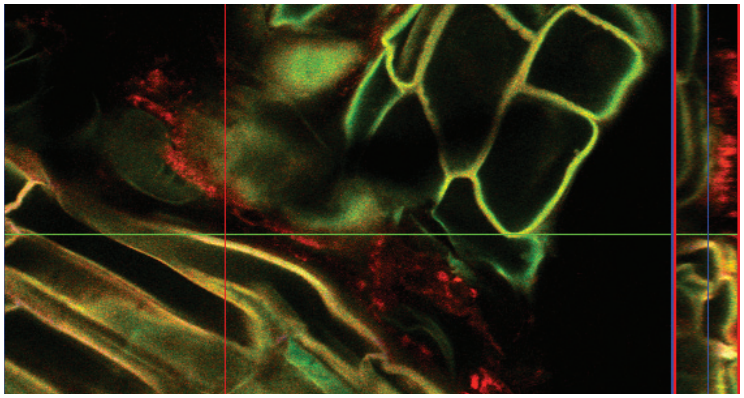
Miscanthus x giganteus *© foxhollowfarmga.com*

While energy from biomass is promoted by current EU law, mainly in order to deliver greenhouse gas emission savings, the use of land for energy crops production in the EU has become the subject of considerable debate. What rises the biggest concerns is the competition of between using land either for food or energy crops production. Already now solutions are available to reconcile these priorities without harming food crops production while addressing environmental challenges. The potential to be taken advantage from is in waste land: either idle arable land or post-industrial sites. Across the EU, land remains out of cultivation for a variety of reasons. These include: economic and market forces; topographic, bioclimatic and edaphic considerations; contamination or pollution factors; and a variety of institutional factors. At the same time remediation of polluted soils is still a challenge not only in scientific and technical terms but also as a societal challenge (rehabilitation of former industrial sites, restoration of ecosystem services) and an economic issue (markets of soil rehabilitation; production of plant biomass for feedstock on contaminated soils integrated in the biobased-knowledge for bioeconomy). In that context finding a proper way for managing the use of heavy metal contaminated soils in a way that would generate environmental added value and provide economic benefits gains high importance.

What is the role of miroorganisms in the process?

The interactions between plants and microbes play a crucial role, especially at sites where plant growth is affected by contaminants like heavy metals. Plant growth promoting microorganisms and the beneficial partnership between plants and their associated microorganisms may become a key in developing a strategy to accelerate plant biomass production and clean-up of the contaminated areas.

To properly explore this potential in-depth knowledge involving some basic research was needed to understand what happens in the plant-soil environment and how the growth processes can be stimulated and the phytoremediation affect successfully achieved. In particular knowledge was needed on the functional diversity of the rhizobacteria and bacterial endophytes to define strategies to enhance the abundance and activity of plant beneficial microbes *in situ*. In this aspect, the changes in the composition of the microbial diversity needed to be investigated to reveal the response of keyplayers to the heavy metals and adaptations to stress conditions in the habitat. It would



Endophytes - bacteria in plant cells

provide new knowledge that can be used for improving isolation strategies for potential plant growth promoting (PGP) rhizosphere bacteria. Based on that new bacterial strains were to be isolated from the rhizosphere of the respective plant species to design new and more targeted bioinoculum formula with a function to stimulate the biomass growth and thus enhance the phytoremediation effect together with a set of robust indicators enabling to monitor the achieved soil quality improvements.

Energy from heavy metal contaminated biomass as a challenging opportunity

Biomass, which has been used in soil remediation process, due to the higher content of pollutants must be treated in a special way. Thermal transformation is one of the options offering recovery of the energy content.

For the Phyto2Energy project the gasification process was selected as it allows to generate a high quality gas which can then be used in a wide range of equipment in order to produce energy. From the installation viewpoint, the project focuses in particular on small scale installations as they represent a considerable potential for market penetration especially in Central and Eastern Europe which on one hand demonstrates high demand for biomass resources and on the other has many chemically degraded, postindustrial sites which require efficient management. The project assumed research into the analysis and evaluation of the impact of the composition of the produced biomass on the quality and composition of the gasification products: the end gas as well as ash and char. The gasification tests and the analysis of the end products would provide new knowledge necessary to understand which char and ash fractions are formed, how heavy metals behave during this process and if and which mineral components used as agrotechnical measures to stimulate the biomass growth may affect the gasification process. This knowledge is crucial to in order to optimize the gasification process parameters from the viewpoint of the produced gas, ash and char so as to maximise their applications. Beside environmental gains, not without importance are the economic aspects of the gasification. Therefore analysis of the costs and benefits of the processes is needed to demonstrate the feasibility and economic viability of the Phyto2Energy approach.

Phyto2Energy challenges: key scientific and technological objectives

The joint effort was aimed to address the following scientific and technological challenges related to establish a scientifically sound basis for demonstrating that the Phyto2Energy concept is innovative and can possibly work as a comprehensive solution:

- Which of the preselected and tested energy crop species: *Miscanthus* x *giganteus, Sida hermaphrodita*, *Spartina pectinata* and *Panicum virgatum* delivers the best results in terms of the biomass production and the phytoremediation effect?
- Which conditions determine the efficiency of these processes?
- How to increase the biomass yield and the phytoremediation effect using microbiological methods promoting plants growth?
- How to convert the produced biomass into energy in a small scale gasification installation taking into account the specific properties of the fuel resulting from its production, the technical performance of the installation as well as the environmental and economic considerations?

Miscanthus x *giganteus*

Spartina pectinata

Panicum virgatum

Sida hermaphrodita

Selected energy crop spiecies

The approach was to be developed and tested for two phytoremediation scenarios, respectively of the land management objective:

- phytostabilisation to enable production of "clean" biomass dedicated to an economic use of idle, heavy metal contaminated sites
- phytoextraction towards restoring the use options of a heavy metal contaminated arable land for agricultural production including food crops.

Where we arrived after four years: The Phyto2Energy results

Energy crops can make a change

The basis for the project was a 4-year field experiment that was established at two heavy metal contaminated sites: arable land (Bytom, Poland) and a postindustrial area – a former sewage sludge disposal site (Leipzig, Germany) with a selection of 4 preselected energy crop species: *M.* x *giganteus*, *S. hermaphrodita*, *S. pectinata* and *P. virgatum* and involvement of N, P, K fertlisation as well as a commercial plant biostimulator EmFarma Plus™. The experiment allowed to make an in depth characteristics of the tested species in terms of biomass production, behavior in the conditions of an environmental stress and allowed to assess their heavy metal uptake ability respectively to the phytoextraction or phytostabilisation purpose. The fellows also worked to define which key factors affect the process and how the agrotechnical measures (N, P, K fertilization, biostimulator treatment) influence the efficiency of the process and the parameters of the produced biomass as fuel. The results of the experiment allowed to establish that *P. virgatum* demonstrated the most promising potential for phytoextraction at sites contaminated with Pb as the main contaminant, whereas *S. hermaphrodita* for Cd contaminated sites while both *M.* x *giganteus* and *P. virgatum* turned out to be promising Zn extractors. Due to low accumulation of heavy metals in the aboveground parts *Spartina pectinata* was identified as the most promising species for metal phytostabilization, at the same time producing high yield of a relatively "clean" biomass for energy production. Very low lead extraction by *M.* x *giganteus* and *S. hermaphrodita* from the postindustrial site suggest, that these species could be used for non-contaminated or slightly contaminated biomass yield production. Analyses also showed that the treatment of plants with EmFarma Plus™ stimulated the uptake of Cd (*S. hermaphrodita*) and Zn (*M.* x *giganteus*). In terms of factors influencing biomass production, the results after the 2nd and 3rd growing season confirmed that soil compaction and high content of organic matter which hamper water and nutrients availability for plants were critical in affecting the biomass yield. That indicates that in order to determine the efficiency of implementing a phytoremediation driven energy crops production, the physical and chemical properties of the soil must be checked in particular for these parameters at the planning stage.

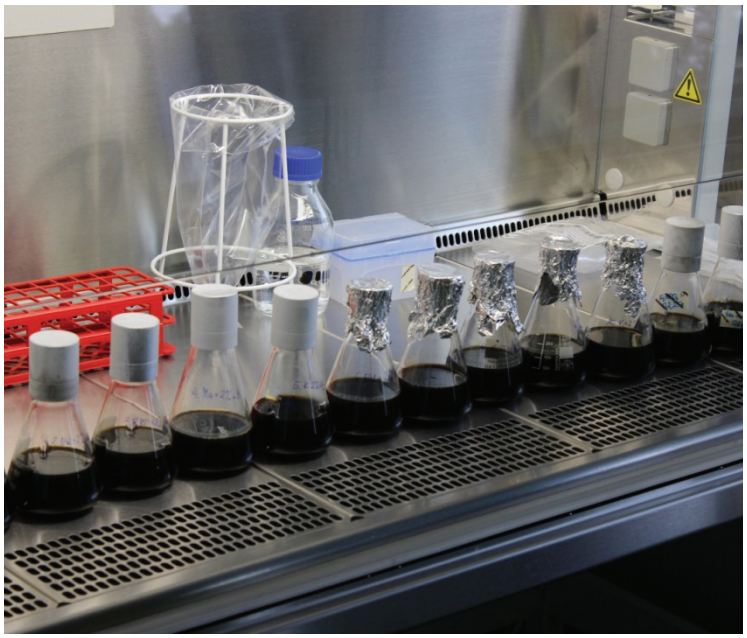
S. pectinata experimental plot in Bytom, Poland

Microorganisms are small but can play a big role

Within Phyto2Energy an attempt was made to develop methods for improving the biomass production and remediation effect which are based on the power of soil microbes to improve plant performance and health on heavy metal contaminated and marginal sites. This includes aspects of general plant growth promotion, improved inert immunity of plants, improved plant fitness towards biotic and abiotic stressors as well as nutrient mobilization and transport. The investigations involved a commercial plant biostimulator EmFarma Plus™ provided by PrioBiotics and applied in field conditions and development of a new formula based on 3 *Pseudomonas putida* strains selected out of 144 rhizobacteria strains isolated from rhizosphere soil of the tested plants: E41, E42 and R85). Studies involved some basic research dedicated, among others to a taxsonomic assessment of the isolated bacterial strains including a complete sequence of genomes. Furthermore, in the case of one of the isolates E41 it was possible to confirm no content of pathogenic genes the remaining two require further studies to eliminate that risk. In order to assess transcriptional response of the *Ps. putida* isolates under metal and antibiotic stress, minimum inhibitory concentrations (MIC) of Pb, Cd and Zn as

Evaluation of the bacteria growth in 5L – bioreactor scale

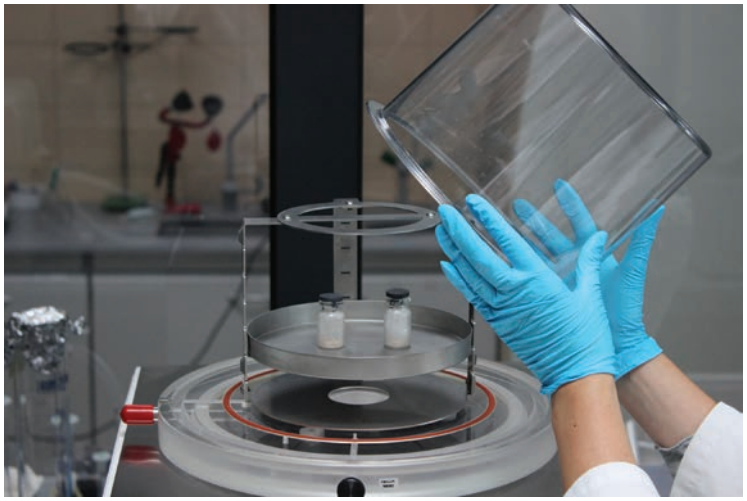
well as eleven selected antibiotics used in veterinary treatments and therefore present in soil, were assessed. The studies showed that the selected strains contained genes promoting the growth of the plants as well as heavy metals resistance genes. Based on the results a prototype composition of the bioinoculum which should be recognised as plant biostimulator has been proposed. The quality and stability of the formula was monitored by measuring the optical density of the liquid, cytometer analysis and classical microbiological cultures. In view of potential development of a market product, for the prototype plant biostimulator formula a dry-freezing procedure was developed and validated. The investigations involved both the mixture of the strains and each strain alone and two lypoprotectants: trehalose and inulin. The influence of dry-freezing on the biocontrol agent properties of the strains was investigated. The antifungal properties of the strains



The culture of the bacteria in batch experiment

before and after liophilization were evaluated. Moreover strains E41 and E42 were identified to produce the rhamnolipid – a biosurfactant. The dry-freeze validation demonstrated that lyophilization is a process which causes the reduction of survival rate of freeze-dried *Ps. putida* strains (survival rates after 180 and 360 days were 70% and 58%, respectively), change the FAME profiles, but no change the enzyme and antifungal activities. This means that dry-freezing can be potentially considered as an option for storage and preservation of strains.

A framework of methods based on a hierarchical concept to assess the impacts of bioremediation strategies on soil quality has been developed that can be used for the assessment of soil quality depending on the respective on site situation As significant improvements of soil quality of HM contaminated sites by bioremediation strategies take longer than



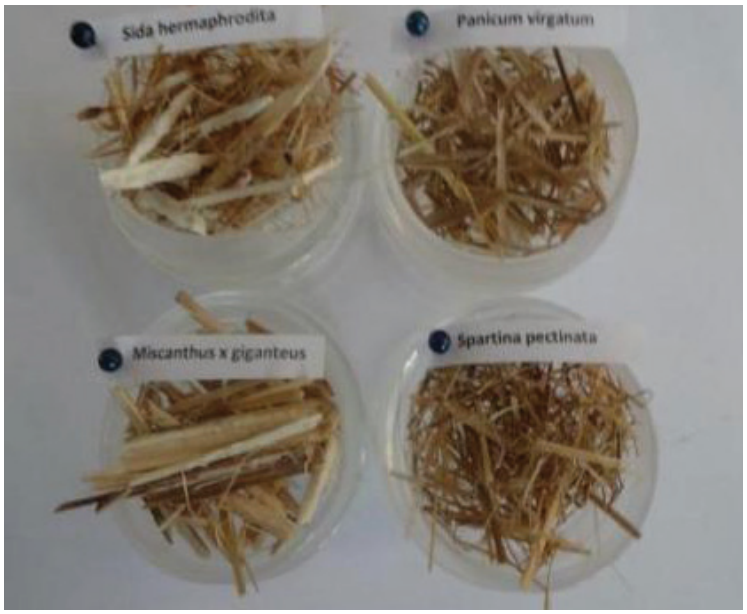
Freeze-dried process of bacteria in the lyophilisate

the project period, the proposed indicator system was not tested under field conditions, but important steps forward towards the detection of important indicator species were made in greenhouse trials.

Heavy metal contaminated biomass can be safely converted into energy

The investigations on the ways to convert the biomass produced from the 4 tested energy crops into energy using gasification involved gasification tests at a lab scale fixed bed gasification installation and thermogravimetry (TG) installation were performed. They allowed to provide new knowledge on the characteristics of a gasification process of a heavy metal contaminated biomass in terms of the properties of the biomass produced from the tested energy crop species as gasification feedstock, the influence of these parameters on the efficiency of the gasification process

Biomass harvesting



Biomass samples for TGA/FTIR analysis

and the quality of the end products as well as the fate of contaminants during the gasification process. Particularly promising results were obtained for *S. hermaphrodita* which recently gained an increasing interest as a bioenergy plant. *S. hermaphrodita* as a gasification feedstock resulted in the lowest content of ash. The LHV of the produced gas was acceptable taking into consideration the usage of this gas as fuel in engines, gas turbines (as a part of the CHP systems) and boilers. The best air ratio of gasification gas was found for $\lambda = 0.18$. In terms of other process parameters, the content of volatile matter and moisture were similar for all 4 tested energy crop species, similarly was the percentage of carbon, hydrogen and oxygen. Considering the parameters of the feedstock resulting from the agrotechnical measures, the test data showed that the gas obtained from N, P, K fertilized biomass had the highest LHV. The tests also confirmed that the effect can be enlarged by catalyst addition to the fuel e.g. halloysite. Moreover, the produced gasification gas is characterized by higher content of hydrogen and the amount of tar is significantly lower compared with non-catalytic gasification process of biomass. The implications obtained from the investigations allowed

Ash samples collected for analysis

Fixed bed installation during work at SUT

to elaborate a set of recommendations concerning the gasification processes of heavy metal contaminated biomass as well as gasification installations that would improve the performance of the process and the quality of the gas while minimizing the generation of by-products. They also allowed to develop tools enabling assessment of the economic feasibility of the gasification and its environmental added value which may find further application for making assessments for small scale power generation projects including agroenergy.

The tests on the gasification of the "difficult" biomass that has not been used so far for energy purposes allowed the partners to advance their knowledge that may find application in addressing the gasification challenges related to other refuse derived fuels as well as for commercial services related to design of gasification installations.

Phyto2Energy Achievements

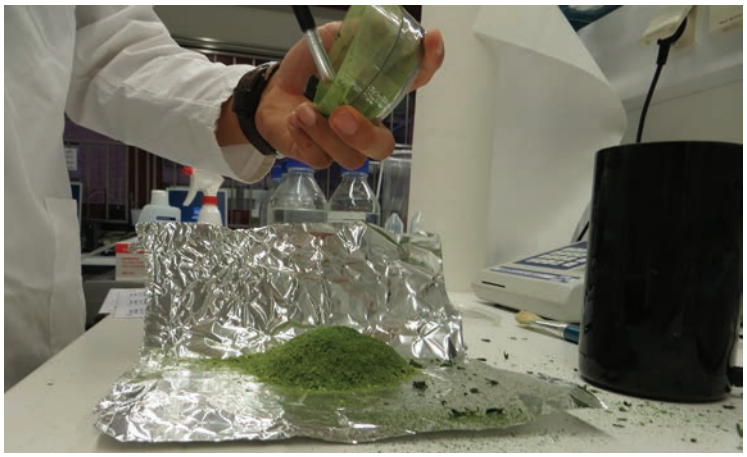
The basis for the project implementation was a 4-year field experiment established at two heavy metal contaminated sites: arable land (Bytom, Poland) and a postindustrial area – a former sewage sludge disposal site (Leipzig, Germany) with a selection of 4 preselected energy crop species: *M.* x *giganteus*, *S. hermaphrodita*, *S. pectinata* and *P. virgatum*.

The experiment allowed to define which of the species deliver the best results in terms of the biomass production and the phytoremediation effect. The information was used to develop **a guidance document on the selection of the tested plants for phytoextraction for heavy metal contaminated arable land and phytostabilisation for post-industrial sites**. *P. virgatum* demonstrated the most promising potential for phytoextraction at sites contaminated with Pb as the main contaminant, whereas *S. hermaphrodita* for Cd contaminated sites while both *M.* x *giganteus* and *P. virgatum* turned out to be promising Zn extractors. Due to low accumulation of heavy metals in the aboveground parts *S. pectinata* was identified as the most promising species for metal phytostabilization, at the same time producing high yield of a relatively "clean" biomass for energy production. Very low lead extraction by *M.* x *giganteus* and *S. hermaphrodita* from the postindustrial site suggest, that these species could be used for non-contaminated or slightly contaminated biomass yield production. Analyses also showed that the treatment of plants with a commercial bioinoculate EmFarma Plus™ stimulated the uptake of Cd (*S. hermaphrodita*) and Zn (*M.* x *giganteus*).

Also conditions that determine the efficiency of these processes were identified and characterized. Physical and chemical properties of the soil (e.g. compaction) and the bioavailability of the heavy metals were identified as the key factors influencing phytoextraction effect. Hight bioavailability significantly reduced the

Field experiment in Bytom, Poland

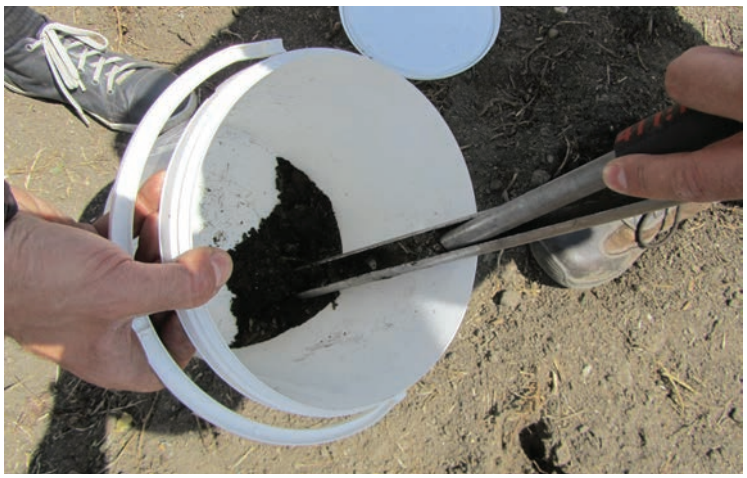
Field experiment in Leipzig, Germany



Preparation of plant material at VITA34 laboratories

contaminants extraction from soil. The results of these investigations advanced the knowledge on the specific properties of energy crop species and their application for the purpose of phytoremediation projects taking into account soil conditions, heavy metal contamination and the desired phytostabilisation or phytoextraction effect respectively of the land management option. These results may find commercial application for **consulting services dedicated to engineering of large scale phytoremediation projects as well as land management projects related to marginal land**. They also create a solid base for new opportunities for the partners in performing application specific research and development of professional carriers in the area of energy crops production combined with remediation which could be implemented in practice for commercial phytoremediation applications.

To improve the biomass production and the phytoremediation effect microbiological methods were investigated which are based on the power of soil microbes to improve plant performance and health on heavy metal contaminated and marginal sites with focus on general plant growth promotion, improved inert immunity of plants, improved plant fitness



Soil sampling

towards biotic and abiotic stressors as well as nutrient mobilization and transport. As a result of the joint work **3 *Pseudomonas putida* strains were selected and characterized as plant growth-promoting bacteria** out of 144 rhizobacteria strains isolated from rhizosphere soil of the tested plants. They were further characterised using genomic techniques including genome sequencing to define the properties of individual strains with respect to pathogens. The characteristics showed that the selected strains contained genes promoting the growth of the plants as well as heavy metals resistance genes. Due to their unique properties they were selected as candidates for the development of **a prototype formula of a plant biostimulator** which could be a good starting point for the continuation of the partnership towards development of a commercial product. For the prototype formula **a dry-freezing procedure** was developed and tested **for the prototype formula** in batch and bioreactor conditions with the use of two lypoprotectants: trehalose and inulin. The influence

Prototype of the bioinoculum

of dry-freezing on the biocontrol agent properties of the strains was carried out that is of importance for determining the function of the potential new plant biostimulant product.

To enable assessment of the impacts of bioremediation strategies on soil quality, **a framework of methods based on a hierarchical concept** has been developed that can be used **for the assessment of soil quality** depending on the respective on site situation. As significant improvements of soil quality of heavy contaminated sites by bioremediation strategies take longer than the project period, the proposed indicator system was not tested under field conditions, but important steps forward towards the detection of important indicator species were made in greenhouse trials.

The investigations on the ways to convert the biomass produced from the 4 tested energy crops into energy using gasification involved gasification tests at a lab scale fixed bed gasification installation and thermogravimetry (TG) installation were performed. They allowed to provide new knowledge on the **characteristics of a gasification process of a heavy metal contaminated biomass** in terms of the properties of the biomass produced from the tested energy crop species as gasification feedstock, the influence of these parameters on the efficiency of the gasification process and the quality of the end products as well

Greenhouse experiment at HMGU

as the fate of contaminants during the gasification process. Particularly promising results were obtained for *S. hermaphrodita* which recently gained an increasing interest as a bioenergy plant. *S. hermaphrodita* as a gasification feedstock resulted in the lowest content of ash. The LHV of the produced gas was acceptable taking into consideration the usage of this gas as fuel in engines, gas turbines (as a part of the CHP systems) and boilers. The best air ratio of gasification gas was found for $\lambda = 0.18$. In terms of other process parameters, the content of volatile matter and moisture were similar for all 4 tested energy crop species, similarly was the percentage of carbon, hydrogen and oxygen.

Preparation of biomass for TG experiment at SUT

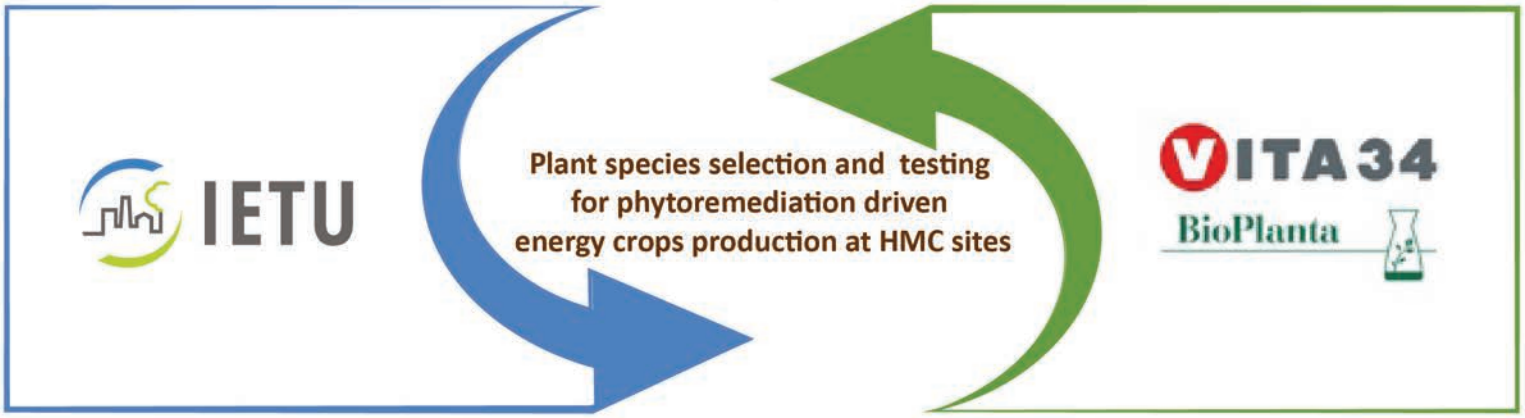
Considering the parameters of the feedstock resulting from the agrotechnical measures, the test data showed that the gas obtained from N, P, K fertilized biomass had the highest LHV. The tests also confirmed that the effect can be enlarged by catalyst addition to the fuel e.g. halloysite. Moreover, the produced gasification gas is characterized by higher content of hydrogen and the amount of tar is significantly lower compared with non-catalytic gasification process of biomass. The implications obtained from the investigations allowed to elaborate **a set of recommendations concerning the gasification processes of heavy**

Pellets of M. x giganteus for gasification tests at SUT

metal contaminated biomass as well as gasification installations that would improve the performance of the process and the quality of the gas while minimizing the generation of by-products. They also allowed to develop **an excel based tool enabling assessment of the economic feasibility of the gasification and its environmental added value** which may find further application for making assessments for small scale power generation projects including agroenergy. The tests on the gasification of the "difficult" biomass that has not been used so far for energy purposes allowed the partners to advance their knowledge that may find application in addressing the gasification challenges related to other refuse derived fuels as well as for commercial services related to design of gasification installations.

Transfer of Knowledge

The Phyto2Energy implementation was based on a multidisciplinary partnership involving different areas of expertise such as biology, chemistry, microbiology, biotechnology, environmental engineering and energy. During the project a cross-sectorial transfer of knowledge for acquiring new skills and knowledge among partner organizations from academia and industry was implemented based on the complementarily of contributions.



IETU contributed with R&D expertise related to characteristics of the energy crop species for their application as phytoremediation crops with special focus on determining heavy metals influence on plant physiological parameters and biomass production, definition of soil conditions determining heavy metal uptake, analysis and assessment of fertilization and microbiological stimulation on soil and biomass quality. IETU provided laboratory facilities for plant samples analysis and infrastructure for the implementation of the field experiment in Poland.

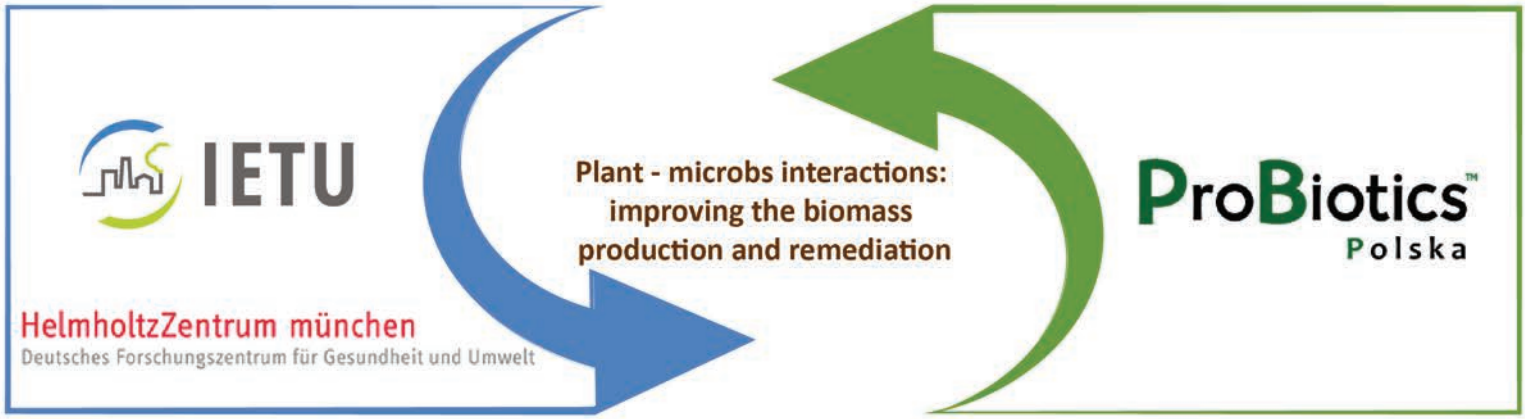
Fellows:
Prof. Grażyna Płaza, Dr. Marta Pogrzeba, Dr. Jacek Krzyżak

Support:
Izabela Ratman-Kłosińska, Dorota Trybała, Szymon Rusinowski, Norbert Słaboń, Marta Fudała, Mateusz Korcz

VITA34 provided engineering expertise on commercial phytoremediation planning, implementation and controlling, investigations on crop management and agronomic practices, design and development of field investigations and plant biotechnology, economic and environmental aspects of remediation projects. VITA 34 provided infrastructure and laboratory facilities for the implementation of the field experiment in Germany.

Fellows:
Anja Hebner, Kristina Ziegler, Kathrin Kopielski, Thomas Fricke, Swantje Prahl

Support:
Andre Gerth, Maria Schöpe, Torsten Harzt



IETU provided R&D expertise in isolation of metal-resistant microorganisms from plant material (endophytes and rhizobacteria), application of the BIOLOG system for characterization of functional diversity of microbial community in the soil samples, analysis of structural changes of the microbial community under phytoremediation in response to the implemented treatments, investigations of the biological control properties of bacterial strains, development of lyophilisation processes and investigations of its efficiency.

Fellows:
Prof. Grażyna Płaza, Irena Biedroń, Dr. Ewa Błaszczyk, Joanna Chojniak-Gronek

HMGU provided R&D expertise and well recognized experimental platforms for genomics, proteomics, metabolomics as well as environmental simulation necessary for performing tests necessary to determine microbiological methods for plant growth promotion. These included taxonomic characterization of the isolated bacterial strains using such methods as Polymerase Chain Reaction (PCR) and random amplified polymorphic DNA Polymerase Chain Reaction (RAPD) and complete genome sequencing, metagenomics mining.

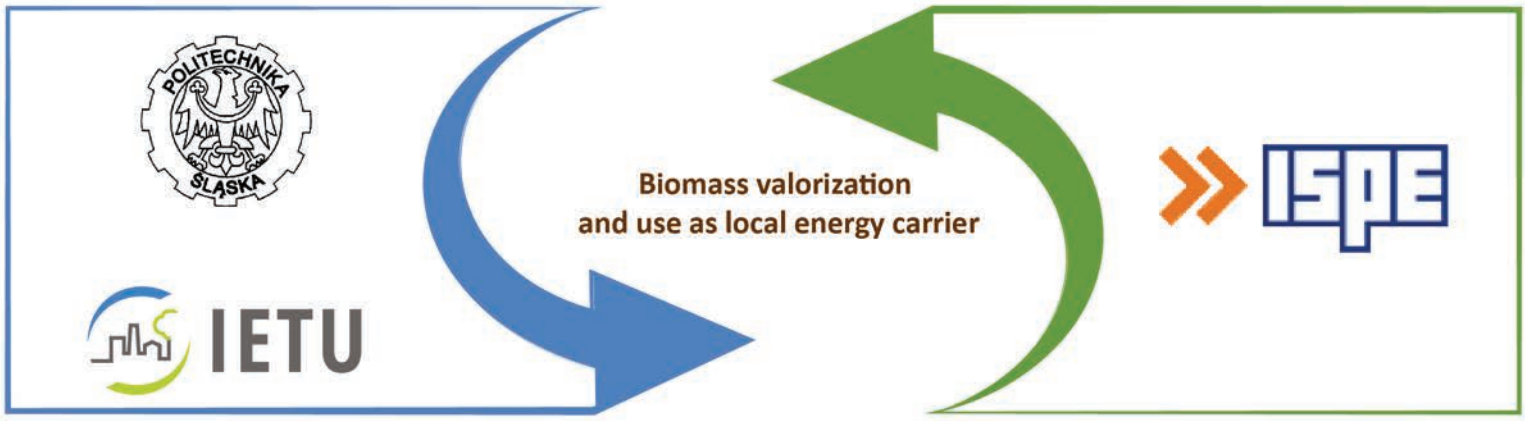
Fellows:
Dr. Gisle Vestergaard, Dr. Joseph Nesme, Urška Zadel

Support:
Prof. Dr. Michael Schloter, Dr. Doreen Fischer

ProBiotics provided practical expertise in isolation of endophytes and characteristic of their properties bioinocula application methods and procedures, techniques for bioinocula manufacturing, knowledge of lyophilisation and fermentation processes of bacterial strains, knowledge of investigating bacterial survival properties, application of different media for biuoinocula composition. ProBiotics also provided an isolated manufacturing room for project purposes and 1000L container for inoculum trials and laboratory facilities including equipment for liophylisation and fermentation experiments, investigations of bacterial strains survival properties.

Fellows:
Dr. Szymon Powałowski, Barbara Cania, Izabela Krzymińska

Support:
Magdalena Górska, Dr. Eng. Bogusław Górski



SUT contributed with extensive knowledge and R&D expertise related to solid and liquid biomass utilization in energy sector, in particular thermochemical conversion of the organic substances in such processes as gasification, pyrolysis, combustion, TG-FTIR analysis, investigations pollutant emission and heavy metal transformations during thermochemical conversion processes of the biomass and the influence of process conditions and fuel composition. SUT provided also laboratory facilities for conducting the gasification tests and thermogravimetric experiments.

Fellows:
Dr. Sebastian Werle, Sylwia Kubicka

Support:
Łukasz Ziółkowski, Paulina Czelok, Dr Anna Katelbach-Woźniak

IETU provided R&D expertise related to the analysis and assessment of fertilizing properties of different types of waste material in view of their land applications. This knowledge was used to investigate the options for the gasification by products such as ash and tar as fertilizers in phytoremediation driven energy crops production.

Fellows:

Dr. Marta Pogrzeba, Dr. Jacek Krzyżak

ISPE contributed with extensive practical experience in bioenergy and RES field including energy generation using biomass, agricultural and non-agricultural residues, studies and analyses for promoting E-RES and H-RES, development of the biomass-coal co-combustion systems). Additionally, based on their experience from commercial projects ISPE contributed also an extensive knowledge on performing the cost-benefit analysis and environmental impact studies of the biomass gasification process that helped define the needed conditions for making the Phyto2Energy approach a competitive option on the market.

Fellows:
Daniel Bisorca, Valentin Rusu, Alexandru Rugiubei, Andreas Alexandru Pahopol, Cristina Tomescu, Iuliana Daniela Cardasol, Ioana Cristina Dima

Support:
Adriana Milandru, Daniela Burnete, Ph.D Marian Dobrin

Awards for Phyto2Energy Fellows

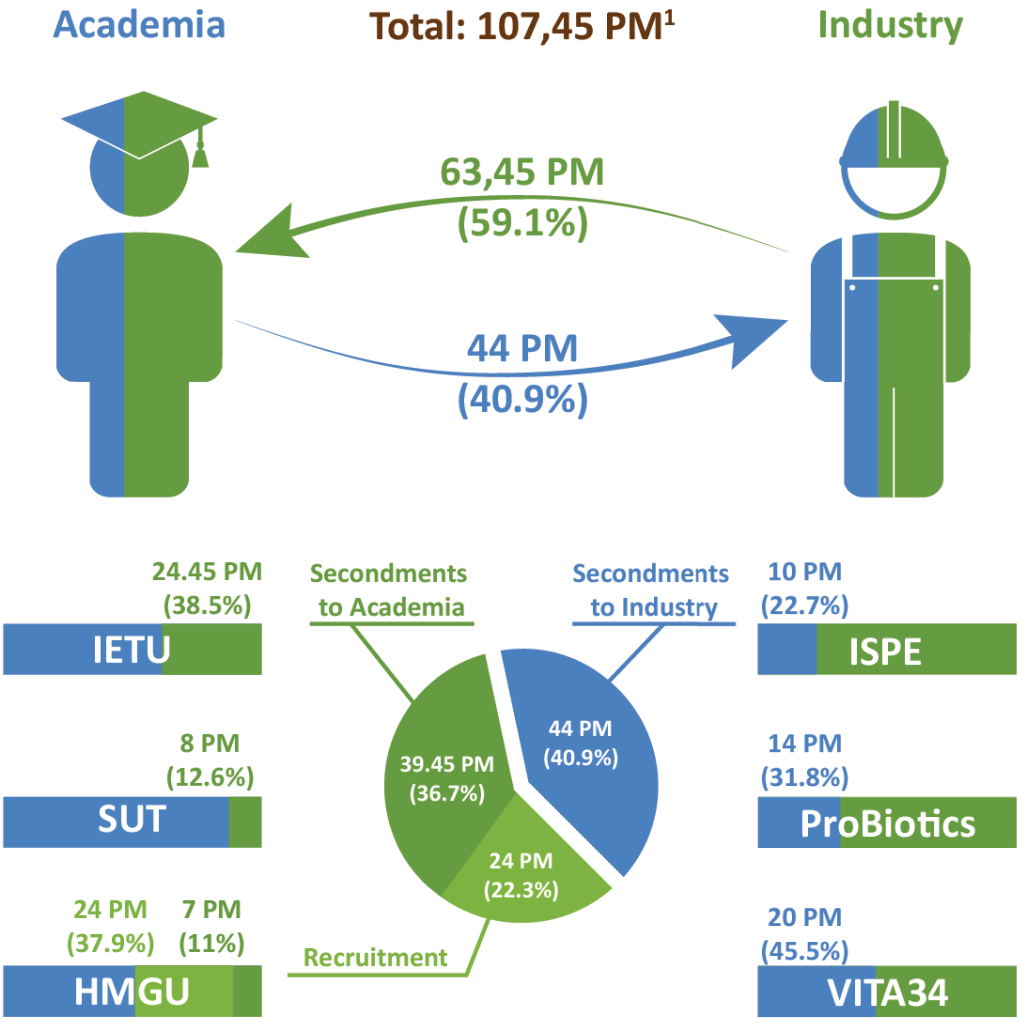
- **The best oral presentation** - Macroelements and heavy metals content in Panicum virgatum cultivated on contaminated soil under different fertilization - Marta Pogrzeba, Jacek Krzyżak and Szymon Rusinowski - VII International Scientific Agriculture Symposium „AGROSYM 2016" hold in Bosnia and Herzegovina.
- **1st prize poster** - The influence of different soil fertilisation on arbuscular mycorrhiza colonisation and heavy metals accumulation by Miscanthus x giganteus - Alicja Szada-Borzyszkowska, Katarzyna Nowak, Jacek Krzyżak, Szymon Rusinowski, Maciej Soja, Marta Pogrzeba - National conference "Current Environmental Issues", Poland.
- **1st prize poster** - Assessment of Plant-Associated Bacterial Community of *Miscanthus* x *giganteus* and its response to metal stress - Urška Zadel, Joseph Nesme, Viviane Radl, Bernhard Michalke, Peter Schröder, Michael Schloter - International Symposium on Biosorption and Biodegradation/ Bioremediation in Prague.

Published peer reviewed scientific articles developed under Phyto2Energy

1. „Phytoremediation as an effective method to remove heavy metals from contaminated area e TG/ FT-IR analysis results of the gasification of heavy metal contaminated energy crops"; „Journal of the Energy Institute"; 04.2016; English;
2. „Evaluation of the potential of the production of electricity and heat using energy crops with phytoremediation features"; Appl. Therm. Eng. 2017 vol. 126, s. 194-203, bibliogr. 47 poz.; 2017; English;
3. „Fixed-bed gasification process - the case of the heavy metal contaminated energy crops"; „Chem. Eng. Trans. 2017 vol. 61, s. 1-6, bibliogr. 21 poz."; 2017; English;
4. „Właściwości fizyczno-chemiczne stałych i ciekłych produktów odpadowych pochodzących z procesu zgazowania roślin energetycznych zanieczyszczonych metalami ciężkimi"; „Inż. Ekol. 2017 vol. 18 nr 1, s. 36-42, bibliogr. 9 poz."; 2017; English;
5. „Relationships between soil parameters and physiological status of Miscanthus x giganteus cultivated on soil contaminated with trace elements under NPK fertilisation vs. microbial inoculation"; „Environmental Pollution, 225, 163-174"; 2017; English;
6. „Macroelements and heavy metals content in Panicum virgatum cultivated on contaminated soil under different fertilization"; „Agriculture and Forestry"; 2017; English;
7. „Complete genome sequences of two plant-associated Pseudomonas putida isolates with increased heavy-metal tolerance"; „Genome Announcements"; 2017; English
8. „Possibility of using energy crops for phytoremediation of heavy metals contaminated land – three years experience"; „Full paper published in the Springer Book after 4th International Conference Renewable Energy Sources"; 2018; English;
9. „Case Study on Phytoremediation Driven Energy Crop Production Using Sida hermaphrodita"; „International Journal of Phytoremediation, in press"; 2018; English.
10. „Macroelements and Heavy Metals Content in Energy Crops Cultivated on Contaminated Soil Under Different Fertilization-Case Studies on Autumn Harvest"; „Environmental Sciences and Pollution Research"; 2018; English

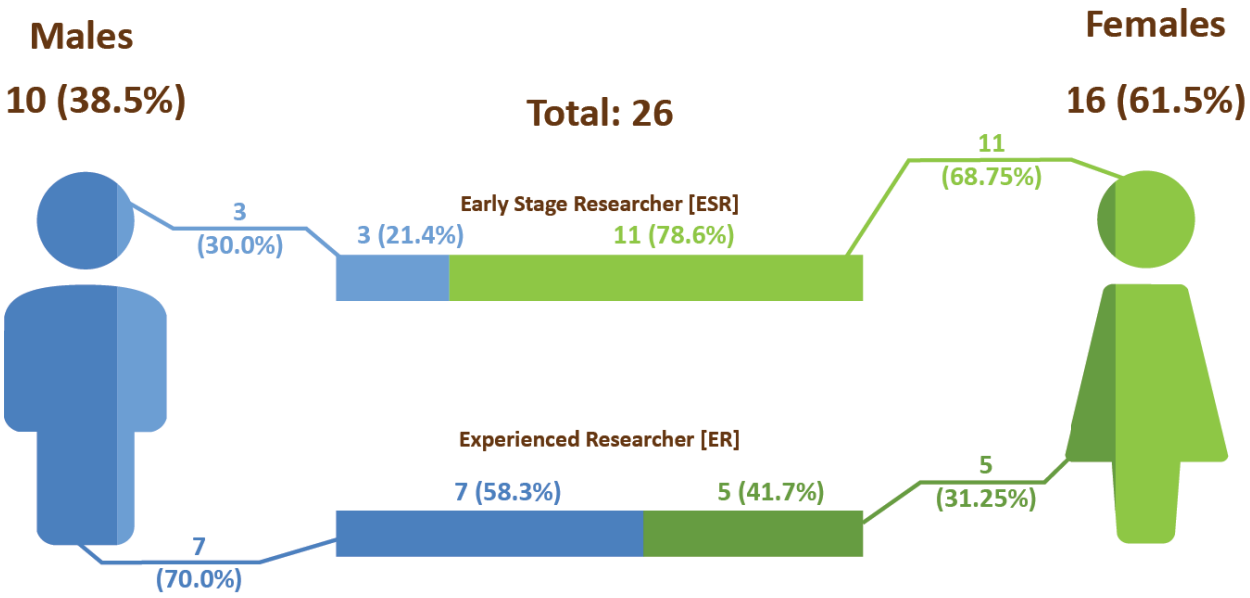
Phyto2Energy in numbers

Secondments and Recruitments

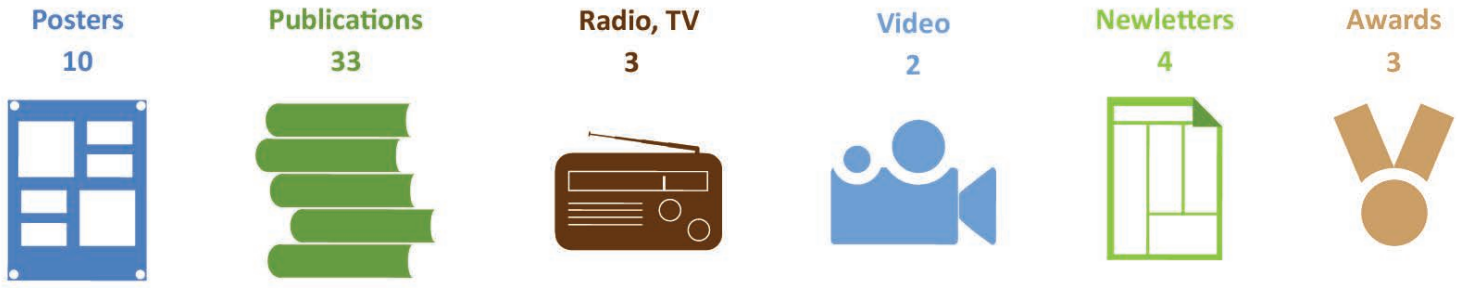


1) Person Months

Phyto2Energy Fellows



Scientific Outreach



Events

51

Seminars and workshops organised for external audiences

30

Conferences and symposia for Phyto2Energy dissemination

66 Internal trainings/seminars

32 delivered by Fellows at Host Organisation

34 delivered for Fellows at Host Organisation

PROJECT FACTS SHEET

PROJECT FULL TITLE:	**Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier**
PROJECT ACRONYM:	**PHYTO2ENERGY**
PROJECT SCHEME:	**Industry-Academia Partnerships and Pathways**
GRANT AGREEMENT NO.:	**610797**
CALL IDENTIFIER:	**FP7-PEOPLE-2013-IAPP**
PROJECT START DATE:	**February 1st, 2014**
DURATION OF THE PROJECT:	**48 months**

Project co-ordinating unit:

Project Co-ordinator
Izabela Ratman-Kłosińska
Institute for Ecology of Industrial Areas; ul. Kossutha 6, 40-844 Katowice, Poland
e-mail: i.ratman-klosinska@ietu.pl; phone no.: +48 322-546-031 ext. 243

PHYTO 2 ENERGY

www.phyto2energy.eu