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Phy2Climate

NEWSLETTER PHY2CLIMATE PROJECT

Clean biofuel production and phytoremediation solutions from contaminated lands worldwide

We are pleased to share the first issue of Phy2Climate newsletter, keeping you up to date with all the latest news and developments from the project. Phy2Climate is a project funded by Horizon 2020 EU's Research and Innovation programme. The overall objective of the Phy2Climate project is to build the bridge between the phytoremediation of contaminated sites with the production of clean drop-in biofuels and bio-coke.

CONTENTS

Introduction to the project: Phy2Climate presented at EUBCE 2021

"Do you think there is a way to increase the share of biofuels by increasing the demand of land without impacting on the ILUC? Or let's formulate it in this way: do you think it is possible on the one hand to reduce the pressure on the global arable land and on the other hand to increase the market share of biofuels?", considering also that "there is a huge demand and competition for land". "Global land use cannot increase much more, and there is a significant area of land which is contaminated and therefore unusable for any purpose. Even worse, the exploration, registration as "contaminated site" as well as the management are very cost-intensive. Soil pollution degrades major ecosystem services provided by soils. This directly affects human and environmental health, and it reduces food and water safety. Soil pollution is omnipresent and according to several studies and available official numbers, a large number of contaminated sites are existing. In Europe alone there about 2.5 Mio suspected sites, of which about 600,000 sites are officially registered. In the USA it is estimated that contaminated sites cover about 9 Mio hectare and in China between 13 to 20 Mio", said Markus Ortner, ITS, coordinator of Phy2Climate, opening his project's activities and objectives presentation at the **29th EUBCE 2021**

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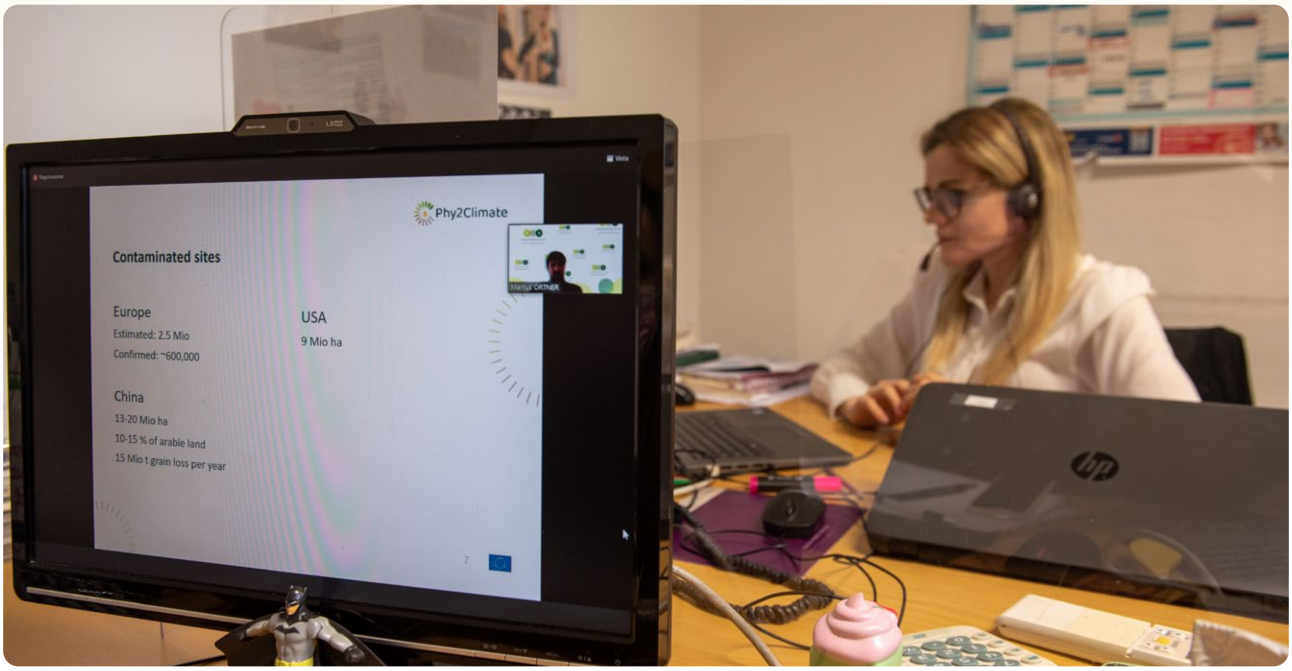
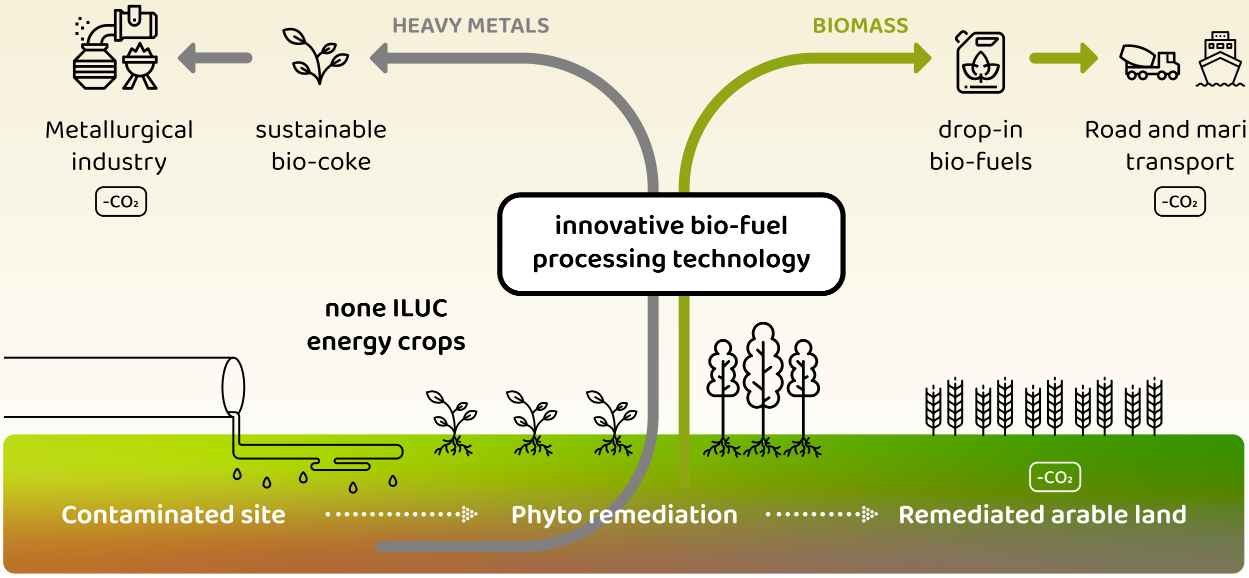
The method of phytoremediation consists of the use of plants and their associated microbes to stabilize, degrade, volatilize and extract soil pollutants. While it is considered a cost-effective and environmentally friendly method, there has been still no significant commercial application of phytoremediation and related produced crops. One of the most important remaining hurdles for commercial implementation of phytoextraction of heavy metals is the disposal of large amounts of the produced contaminated biomass. Currently, contaminated crops are treated as waste and end up in incineration plants or disposed in landfills. For both options gate fees incur and valorisation of the contaminated biomass is not given, making these options not economically attractive. The lack of innovation in the contaminated biomass conversion to added value products is evident and needs to be addressed.In line with the strategy for EU international co-



Markus Ortner presentation.
Credit: ETA Florence.

operation in research and innovation, "the Phy2Climate approach synergistically interlinks the remediation of contaminated soil with the production of added value products as bio-based fuels and bio-coke" stated Ortner. The Phy2Climate approach consists of the phytoremediation using energy crops of contaminated sites in 5 regions all over the world (S-America, Europe and Asia) with different characteristics (type of contamination, type of soil, climate, and legislation) and combines it with innovative cascadic biomass converting technologies to produce added value products such as drop-in biofuels for the road and shipping transport as well as bio-coke as substitution of petroleum coke (pet-coke) in the metallurgical industry. In case of heavy metal contamination of the soil, the extracted metals and metalloids will be also valorised in the metal smelting process.
EUBCE is the largest biomass conference and exhibition in the world. Each year, EUBCE brings together the greatest minds and latest advancements in biomass, with the aim of accelerating research and market uptake across the globe. EUBCE's 29th Conference and Exhibition took place exclusively online with an engaging, interactive, and catalytic platform. Phy2Climate project



The Phy2Climate concept.
Credit: Phy2Climate project.

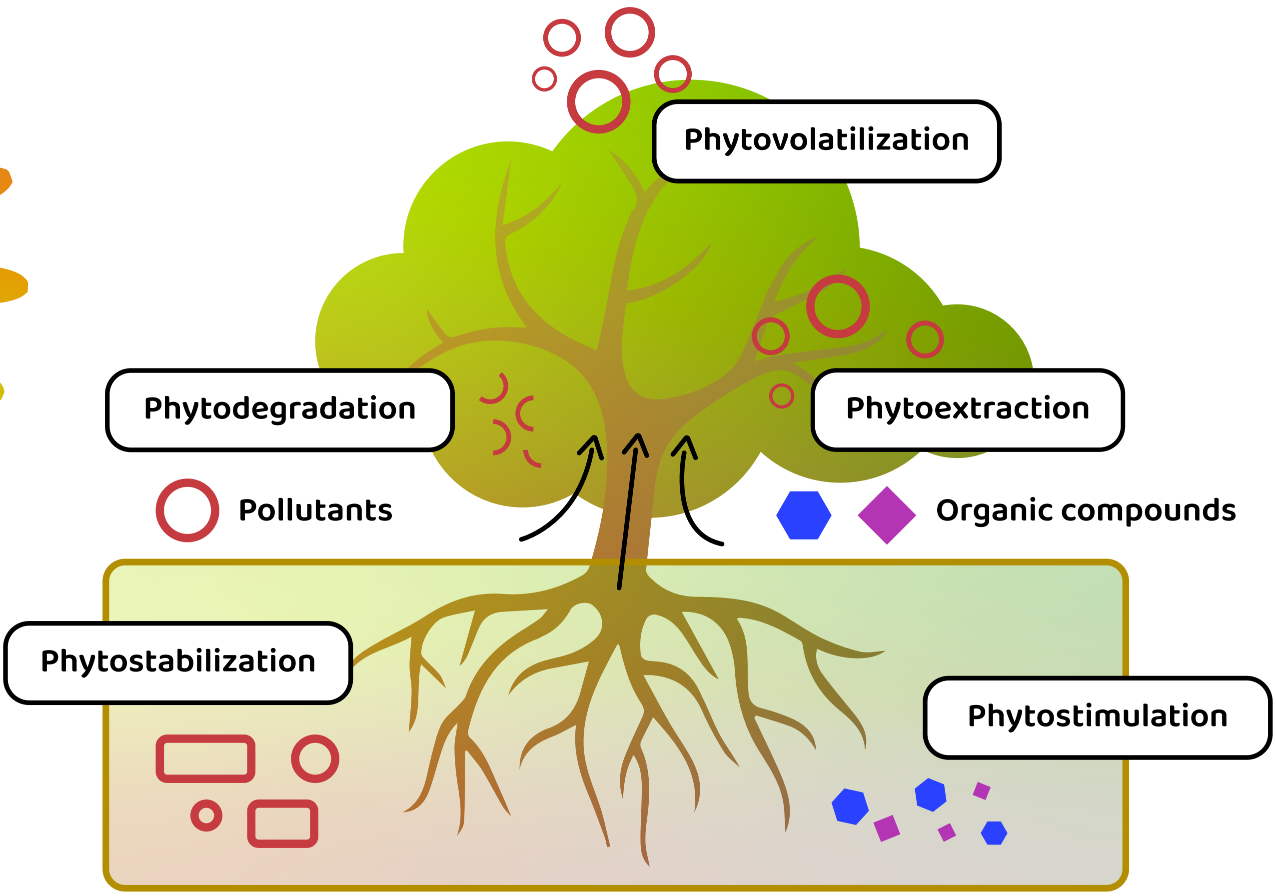
was presented by the coordinator in a dedicated stand of the Exhibit Hall and in the Speakers' Corner. Free registration as visitor of the Exhibit Hall and the Speakers' Corner is open for 1-year access to all exhibit content and to rewatch this project presentation.

Phytoremediation pilots

Pilot sites where phytoremediation using energy crops is applied to contaminated soil
As reported by the EC JRC, soil contamination is the occurrence of pollutants in soil above a certain level causing a deterioration or loss of one or more soil functions. Also, soil contamination can be considered as the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage.
The use of energy crops as phytoremediation species is an incipient approach that is gaining interest in Europe and worldwide as an option to valorise the harvest. A high number of energy crop species that show a good phytoremediation capacity have been identified. Most of the investigated energy crops are oleaginous and lignocellulosic species such as jatropha curcas, ricinus communis, miscanthus sinensis or populus varieties. Less common are starch or sugar producing species such as maize.
Phy2Climate will go beyond the State of the Art by building an optimised phytoremediation strategy coupled with biofuel production, which is adapted to different pedoclimatic areas. Phy2Climate will contribute to increase knowledge on how to increase the phytoremediation capacity and biomass production by testing a set of energy crops and different soil additives that will provide information on the best combination of those, thus linking phytoremediation,

biofuel production and circular economy principles. By using this approach, each Phy2Climate pilot site will define an holistic phytoremediation plan adapted to each site characteristics with the further objective of remediating the soil to agricultural quality, thus recovering contaminated soil for arable purposes. Furthermore, Phy2Climate will study the relationship between the characteristics of the plant growing conditions (soil characteristics, contaminant presence, soil additives, etc.), with the quality of the produced biofuel, and link this to the final economic revenue that the phytoremediation strategy brings.

One of the pilot sites is located in Tarragona, Spain. The contaminated site is an oil storage facility, and the main soil contaminants are hydrocarbons. Initially, an exhaustive soil characterization was conducted to determine the starting contaminant concentration, as well as contamination homogeneity through the site. Furthermore, four plant species with phytoremediation capacity, which are optimal for biofuel production, were selected according to bibliography. Once the soil was characterized, and plant species selected, a pot experiment under real conditions will be performed. The phytoremediation capacity of the four plant species, as well as the capacity of three soil additives (compost, biochar and PGPR) to increase both biomass or soil decontamination capacity will be assessed during a 6-months period, where the plant growth will be monitored. At the end of the experiment, an analysis of soil, aerial plant biomass and root biomass will be analysed to determine the Bioaccumulation Factors (BAF), Translocation Factors (TF) and the effect on biomass production and soil decontamination. By evaluating these



Schematic representation of phytoremediation strategies.
Credit: Phy2Climate project.

aspects and the trade-offs between biomass for biofuel production and the phytoremediation capacity of plants, one or the combination of two plant species, together with the best-performing soil additive will be used to enhance the specific phytoremediation strategy with the aim of removing organic pollutants from the soil of the oil storage plant.

Sampling phase at the Spanish pilot site.
Credit: LEITAT.

Sampling phase at the Lithuanian pilot site.
Credit: BIOVALA.

Sampling phase at the Serbian pilot site.
Credit: IFVCNS.

Argentinian pilot site.
Credit: INTA.

The phytoremediation technology development will be driven by the leaders of each of the five phytoremediation pilot sites in Spain (South Europe), in Serbia (Balkan region), in Lithuania (Baltic region), in Argentina (South America) and in India (South Asia). In order to guarantee a wholesome approach, the pilot sites will cover different types of contaminants, climate regions in five latitudes, different political contexts, financial and regulation schemes.

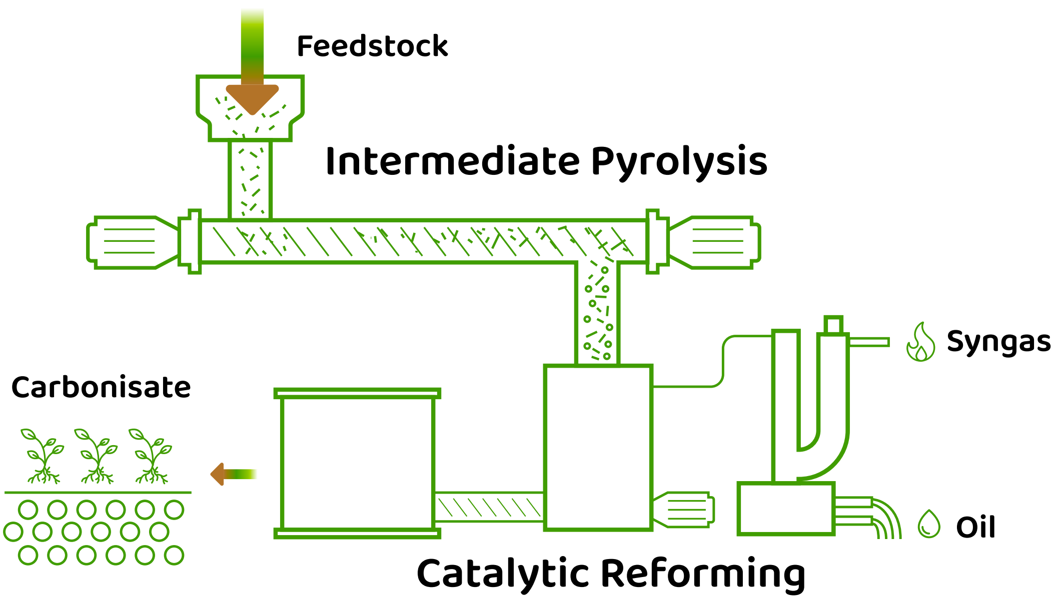
One of the biggest hurdles to produce biofuels from phytoremediation energy crops is the handling of the contaminated biomass. Fermentation processes for 1st and 2nd generation bioethanol and biogas production present the problem of contaminant spreading in high volume by-product streams such as fermentation residues or vinasse. Similarly, in state of the art 1G biodiesel, the contaminants can also end up in the products and by-products such as glycerine and press cake. Otherwise, the thermo-chemical processes offer a better alternative to handle the contaminants present in the energy crops. By using technologies such as pyrolysis or gasification, most of the organic contaminants will be cracked and converted into simpler less hazardous or more useful molecules.

Biorefinery pilot

Purification strategy for the aqueous phase from biomass pyrolysis

The aqueous phase from biomass pyrolysis is until today mostly seen as worthless by-product and has to be costly disposed as waste. However, it can be a valuable resource for the recovery of products. For this, the composition of the aqueous phase must be known and a suitable purification strategy, adjusted to the pyrolysis feedstock, has to be developed. As Christopher Kick from Fraunhofer UMSICHT explained during his poster presentation at the EUBCE 2021, the aim of the investigation performed till now was to introduce a multi-level purification strategy for the aqueous phase gained from the thermo-catalytic reforming of sewage sludge, which allows also the recovery of products. The purification strategy consists out of an electrooxidation step, the decarbonisation of the aqueous phase and the stripping of ammonia by air. In the medium term, purification strategies like this will lead to a reduction of the overall pyrolysis process costs and decrease the specific costs of targeted pyrolysis products like char, bio oil and syngas.

The composition and the amount of the aqueous phase depends on the type of biomass and its moisture content, respectively. Using sewage sludge as feedstock, high levels of organic and inorganic carbon can be found in the aqueous phase. Furthermore, due to the high nitrogen content of sewage sludge, high concentrations of ammonia will be present in the aqueous phase. Until today, the purification of this by-product or the recovery of valuable products thereof has not gained lots of attention in literature. Nevertheless, it will play an intensive part in the overall economy of the biomass pyrolysis processes in industrial scale as the aqueous phase accounts for 20 – 30 m% of the products. The aim of the current research is to demonstrate that there are alternatives to classical disposal ways like incineration and that a recovery of valuable products is possible. Exemplarily, the aqueous phase gained from the thermo-catalytic reforming process (TCR®) of sewage sludge is chosen to prove this statement. The thermo-catalytic reforming technology was developed at the Fraunhofer Institute UMSICHT, the principle function of the technology is schematically shown in the figure.



Schematic principle of the TCR® process.
Credit: Phy2Climate project & Fraunhofer UMSICHT.

The process is based on an intermediate pyrolysis process followed by a catalytic reforming step, valorising the generated pyrolysis products. The aqueous phases used in the experiments with sewage sludge were gained from the lab-scale plant TCR® 2 at pyrolysis temperatures of 400°C and reforming temperatures between 500°C and 700°C. This plant has an input capacity of 2 kg/h.

The lab-scale plant TCR® 2 at the Fraunhofer Institute UMSICHT.
Credit: Fraunhofer UMSICHT.

Concerning the Phy2Climate project, the thermo-chemical conversion of the harvested energy crops from the phytoremediation pilots will be performed and tested, and the electrooxidation pilot plant will be dimensioned according to the related TCR®-water production.
For more information on methods, experimental setup and results of this investigation, the paper "Development of a Purification Strategy for the Aqueous Phase from Biomass Pyrolysis - Recovery of Valuable Products" has been released in the 29th EUBCE 2021 Online Conference Proceedings and freely accessible and available for instant download.

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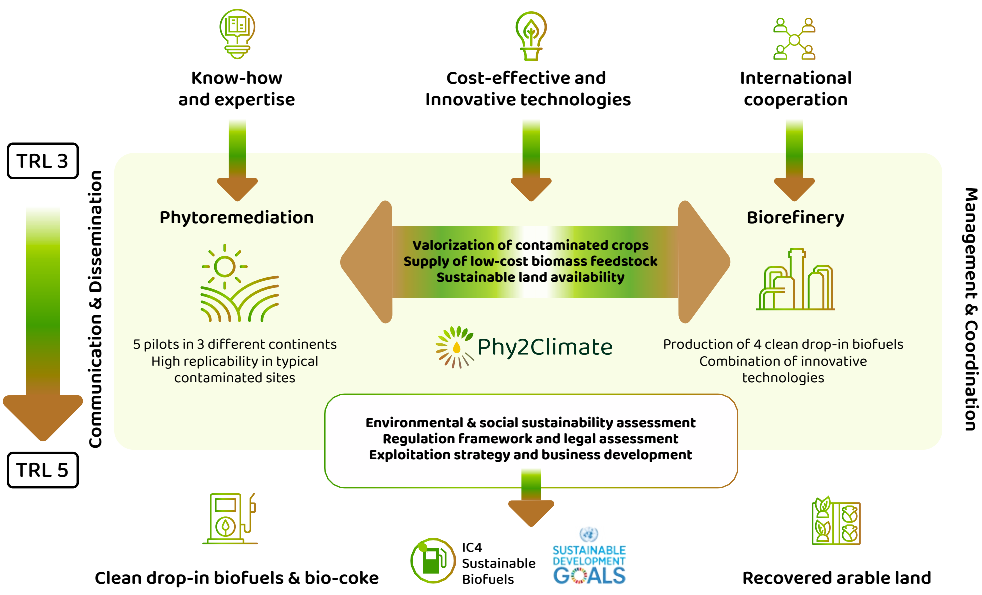
Regulatory and legal issues

The complex and innovative processes deployed by Phy2Climate brings about several important legal and regulatory issues that arise on every step down the chain. Thus, Phy2Climate will develop legal expertise in order to allow for a smooth realization of the overall project and inform future policy-making in the EU and elsewhere. WP6 appraises all legal bottlenecks arising throughout the implementation of the project by first cataloguing potential legal and regulatory issues throughout the entire value-chain in different legal systems (within and outside the EU in a selection of countries) and by mapping potential edges de lege lata and de lege ferenda. Following this mapping exercise, a legal analysis will be carried out to duly assess the impact that the identified legal hurdles might pose to phytoremediation activities and activities related to recovery of output materials. Last, tailored policy recommendations will be devised to advance the development of the current legislative framework governing phytoremediation and related recovery of materials.

The research work carried out thus far under WP6 has allowed to achieve the first milestone of the WP as related to the mapping of relevant areas of law to be further investigated in every jurisdiction covered by the project (Argentina, the EU, India, Lithuania, Serbia, and Spain). This exercise has been supported by all Pilot Site leaders under WP2 (with regard to phytoremediation techniques) and by Fraunhofer Institute UMSICHT as WP3 leader (with regard to the deployment and management of the biorefinery). Despite the several differences existing among the legal systems covered by the research, a set of relevant policy and legal areas have been ultimately identified, including the following:

- **Health policy on endocrine disrupters and antibiotics**
- **Invasive alien species**
- **GMOs, fertilisers and pesticides**
- **Soil quality legislation**
- **Water quality legislation**
- **Waste legislation**
- **Chemicals legislation**
- **Bioenergy (biofuels and biomass)**
- **Industrial emissions**

The project will thus analyse the interplays among the identified relevant fields of law to pinpoint the relevant legal issues arising in connection to every step of the value chain while enshrining also potential legal and regulatory best practices and solutions as implemented in the domestic legal setups analysed.



The overall approach of Phy2Climate.
Credit: Phy2Climate project.

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info@phy2climate.eu

@phy2climate

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The project consortium has put together 17 partners from 10 countries with long-term expertise in soil remediation, phytoremediation, biofuel technologies and energy processes, environmental and social sustainability, legislative analysis, communication and dissemination as well as business development for innovative technologies.

Phy2Climate is a H2020 project with title "A global approach for recovery of arable land through improved phytoremediation coupled with advanced liquid biofuel production and climate friendly copper smelting process

info@phy2climate.eu

@phy2climate

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