D2.3. deliverable title:

Biochar policy supporting report, concerning the absence of potential risks for the different environmental compartments, for the plants and for human health through the food chain resulting from the use of these materials in agricultural soils

This document is an summary abstract of the EU policy support report in 2013.

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Contents

1. Summary

The REFERTIL advanced biochar results achieved so far are based on and active continuation of several EU Commission part financed biochar TRL6 and TRL7 research projects since 2002, which have been coordinated and key technology designed/executed by the Terra Humana Ltd.

This REFERTIL biochar policy support documentation has been developed between October 1, 2011 – September 30, 2013 and then v1.0 submitted to the Commission. Between October 1, 2013 and December 20, 2013 the REFERTIL biochar policy support concept abstract has been open access public consulted in Europe and global worldwide. After careful and extensive public consultation, this REFERTIL biochar policy support documentation is an upgraded and more detailed v2.0. version, but in all major elements are unchanged from the original version.

All in order to have wide range, comprehensive and coherently integrated scientific, technical, economical, environmental and social aspects and approach from other biochar stakeholders the REFERTIL global level public consultation and international networking will be continued during and after the project life time as well. Biochar publications have also been carefully studied, whereas only past decade over 3500 open access biochar publications made by hundreds of biochar scientific projects. The quantity, quality and breadth of research connected to biochar have grown rapidly since 2010 when a number of books and reviews were published and only in 2012 almost 300 biochar research publications made. The numbers of additional biochar studies are also significant. The extensive research resulted clear understanding from all relevant soil, environmental and plant science disciplines how biochar additions affect soil properties, processes and functions.

The REFERTIL is stating that so far we have not received and not found any justified, scientifically-technically-environmentally-legally correct and acceptable biochar public consultation responses from any biochar stakeholders that would make us to change the REFERTIL biochar 2013 report content and findings for Commission biochar policy support.

REFERTIL biochar policy support abstract

Intensive farming practice and human activities have disturbed the natural cycles of Nitrogen and Phosphorus. Industrial agriculture relies on continual inputs of mined and non-renewable Phosphorus and energy-intensive Nitrogen supply. Cadmium and Uranium build-up in EU soils due to the use of Phosphorus fertilizer is raising concerns about human health and environmental damage. There is a strong need for increased sustainability and closing the nutrient loop in agriculture with the creation of a virtuous cycle between urban and rural areas. In this context, reducing the use of mineral fertilizers and chemicals in agriculture is key priority objective that can be achieved by recycling and reusing the treated organic waste as stabile carbon biochar products.

There is a strong need for improved sustainability of currently used treatment processing of organic wastes streams and by-products with urban and farm origin and progress towards low carbon and knowledge based bio-economy. One of the safe and economical viable

options is to convert targeted organic waste streams into biochar, as part of the comprehensive solution.

There is no one fit for all biochar solution, but rather advanced strategy need to be developed for sustainable feed supply, selection of best available pyrolysis technology as of recent EU industrial regulations and case by case soil application strategy need be defined. The objective driven biochar results will fully support the offered economical, environmental and climate protection benefits for the interest of SME farmer users and finally the consumers.

In this context, it is important to improve the biochar product quality, safety, use, environmental and economical effectiveness, while increasing the end-users and consumers confidence for food and feed production. The sustainable biochar production input biomass feed material is not competing with human food, animal feed and plant nutrition supply. The biochar technology processing performance and conditions are the most important and the ultimate definition factors for biochar quality and safety. Biochar industrial installations must use the best available techniques to achieve a high general level of protection of the environment as a whole.

Biochar is plant and/or animal biomass by-product based stabile carboniferous substance with well defined and controlled quality, that is processed under reductive thermal conditions, and applied to improve the soil physical and/or chemical and/or biological properties or the soil activity and/or consists of organic materials of biological origin. The safe biochar product is equally importantly environmental, climate protection and economical sustainable. There are two main biomass based types of safe biochar, such as plant based and animal bone based.

The plant based high C content biochar is soil improver, having no direct fertilizer value, but having high water holding and nutrient retention capacity, C sequestration potential and used at high doses, such as 5000 kg/ha and in cases when justified even up to 20,000 kg/ha.

The "ABC" animal bone biochar is full value organic P-fertilizer, also titled as innovative fertilizer, made of food grade category 3 bones, having low carbon content and as high as 30% P_2O_5 nutrient composition with plant uptake optimized slow release fertilization effect. The fully safe ABC is used at low doses, such as 200 – 600 kg/ha and in cases when justified even up to 1,000 kg/ha. The ABC is highly macro porous, which structure is also optimized for significant enhancing of soil microbiological life, having high water holding and macromolecular organic nutrient retention capacity as well.

The steam processed (133ºC/3bar/20min) bone meal direct application certainly does not provide a safe alternative solution for substitution of the phosphate rock based fertilizers, therefore low temperature treated protein content bone meal should be removed from the organic fertilizer positive list and substituted by the fully safe and high temperature (above 600 ºC) treated animal bone biochar ABC product. As of the Cadmium, Uranium and other Potential Toxic Elements (PTEs) content the high risk natural Soft Ground Rock Phosphate should be removed from the positive organic list and substituted with other forms with proven pure Phosphorous source. In this context important to minimize the further build up of the PTEs in soil, most importantly Cadmium, and remove the ground water pollution risk by minimizing the PAH loads in the substances.

Complex strategy need to further be developed to decrease the EU dependence on P and N fertilizer import by substitution recycling and added value reuse of the organics, nutrients and energy from large volumes of organic waste streams generated in the EU28.

The Fertiliser Regulation (EC No. 2003/2003) is only regulating the mineral fertilizers and in current form is not applicable for biochar products. **One of the key objectives of the REFERTIL project was providing a strong policy support for the EU Commission in revision and full harmonization of the Fertiliser Regulation with inclusion of biochar - as safe organic fertiliser and soil additive. The aim is to ensure that the applied biochar quality and safety criteria are fully consistent with EU-wide Directives, Regulations and MS law harmonized for long term.** In this context, the voluntary biochar certificates having no any legal effects and validity.

The REACH, the CLP and other relevant EU regulation will automatically regulate and control the manufacturing, importing and/or supply of plant based biochar (juridically classified as charcoal CAS 16291-96-6) and ABC animal bone biochar (CAS 8021-99-6) chemically modified substances with high variability of composition, over 1 t/y capacity after 1 June 2018. The EU is towards low carbon economy and the high environmental, climate and human health protection standards are truly supporting the sustainable economical and employment growth, while supporting the development of competitive EU economy for long term.

During the 4 years project lifetime the REFERTIL consortium is integrating the biochar applied scientific research, industrial engineering, environmental, legal and economical aspects, which process is continued for long term even after the project life time by the Terra Humana Ltd and the Wessling Laboratories. All the biochar knowledge and experience generated during the REFERTIL project time and past 30+ years from Terra Humana Ltd. has been united; including several EU financed biochar research projects as well.

The respective EU directives, regulations and also the relevant MS national legislations have been reviewed. Moreover, the **economical sustainability of different types of biochar under market based competitive commercial conditions has been evaluated and developed.**

Harmonized and standardized analytical measurements have been developed for determination of the physic-chemical properties, potentially toxic element content and organic pollutants in the biochar materials.

Based on applied scientific evidence and proven industrial demonstrated practice; biochar quality and safety criterion system has also been set up which is maximizing the Potential Toxic Element and Organic Pollutant content for safe application.

Several workshop meetings have been organized with the EU Commission representatives for joint considerations and also wide range of European biochar science and technology groups have been consulted for knowledge and experience exchange. Detailed policy support reports have been submitted to the European Commission.

Table 1 Proposed safety and quality criteria for Animal Bone bioChar (ABC) as recovered organic P Fertiliser.

Potential Parameters to be fulfilled	**Proposed minimum quality criteria for ABC made from biomass by-products (RECOVERED ORGANIC P-FERTILISER)**
ESSENTIAL AGRONOMIC CRITERIA	
Minimum nutrient content on dry matter (individual values qualifies the product as organic fertiliser) N-P-K (%)	N Total: declaration (a) **P_2O_5 total > 25%** K_2O total: declaration (a)
Plant bioassay (plant growth, germination and phytotoxicity bioassay test)	No germination inhibition, no phytotoxicity
ESSENTIAL SAFETY CRITERIA	
PTEs (c)	
As (mg/kg d.m.)	10
Zn (mg/kg d.m.)	600
Ni (mg/kg d.m.)	50
Cu (mg/kg d.m.)	200
Cd (mg/kg d.m.)	1.5
Pb (mg/kg d.m.)	120
Hg (mg/kg d.m.)	1
Cr (VI) (mg/kg d.m.)	0.5
Cr (total)	100
Organic contaminants	
PAH_{16} (mg/kg d.m.)	6 Maximum allowable dose input per ha area recommended on regional MS level.
PCB_7 (mg/kg d.m.) sum of PCBs 28, 52, 101, 118, 138, 153 and 180	0.2
PCDD/F (ng/kg I-TEQ)	20 mandatory if PCB >0.07 mg/kg
Impurities	
Limited content of macroscopic impurities (glass, metal, plastic)	Zero content of plastic, metal particles and glass
Other criteria (introduction of additional parameters)	
pH value	6.0 - 10.0
Particle size distribution (mm)	Between 1-5 mm, 90% (d)

Table 1: Proposed safety and quality criteria for Animal Bone bioChar (ABC) as recovered organic P Fertiliser (cont.).

Potential Parameters to be fulfilled	**Proposed minimum quality criteria for <u>ABC made from biomass by-products</u> (RECOVERED ORGANIC P-FERTILISER)**
Hygienic aspects - Human pathogens	
Salmonella sp.	No Salmonella sp. in 25 g sample
Escherischia Coli	1000 CFU/g for E. Coli
SAMPLING FREQUENCY	
Sampling frequency	Proposal for <1000, <5000 and >10,000 t/y throughput material processing enclosed.
Labelling information (QUALITY CRITERIA)	
Organic matter content (%)	Labelling
Total nitrogen (%)	Labelling
P soluble in mineral acid (%)	Labelling
Total K (%)	Labelling
Total Mg (%)	Labelling
Total Ca (%)	Labelling
pH	Labelling
Bulk density (kg/m^3)	Labelling
Dry matter (%) minimum 80%	Labelling

(a) ABC is a special performance and high P_2O_5 concentrated organic P fertilizer of biological origin. The input food grade bone meal protein based substance containing high Nitrogen content that is removed from the ABC Animal Bone bioChar during the high temperature processing. In this context, it is avoided that animal protein is exported to soil environment, which is an important safety element. Application in combination with other organic and/or mineral NK fertilizers or as liquid form is recommended. As biochar production is a thermal treatment organic Nitrogen will not remain in the final product. Therefore, the product natural characteristics are the low N+K content. N and K need to be add-on to make full value NPK organic fertilizer, therefore it is suggested not to determine N+K for the ABC.

(**b) The term "heavy metal" has never been defined by any authoritative body such as IUPAC. <u>REFERTIL is recommending</u> that the terminology of the different groups of hazardous substances should be standard harmonized in the different legislations in line with the IUPAC and other chemical authoritative body recommendations.**

(c) Powder form of biochar are not recommended to be used by farmers, due to high risk of uncontrolled dust emissions during transport, storage and field applications.

(d) H/Corg is for optional declaration (recommended ≤0.7, subject to that PAH16s are the key performance indicators).

(e) ABC minimum processing temperature 600°C$^{20\ minutes}$ material core.

Table 2: Proposed labelling for animal bone biochar (ABC) as recovered organic P Fertiliser.

Proposed Labelling for ABC recovered organic P-fertilizer (a)
LEGAL INFORMATION
Brand name
Product category: organic P fertiliser
Product permit number
Legal name, address and VAT number of manufacturer
INPUT MATERIAL TYPE AND INGREDIENTS
Input material type
Ingredients (CAS number)
BIOCHAR QUALITY PARAMETERS QUARANTEED BY THE MANUFACTURER
Organic matter content (%)
Bulk Density (kg/m^3)
Dry matter content (%)
Particle size distribution (mm)
pH
AGRONOMIC PARAMETERS - NUTRIENT CONTENT
Total Nitrogen (%)
P soluble in mineral acid (%)
Total K (%)
Total Mg (%)
Total Ca (%)
IMPURITIES
Declaration: Limited content of macroscopic impurities
APPLICATION RECOMMENDATION
Recommended dose
Recommendation for application/crops
OTHER INFORMATION
total ash content: optional declaration
net weight
date of manufacturing
application expiration date
hazard and fire classification
storage condition
environmental protection instructions (including instruction for utilization or recycling or treatment of unused substance and packaging material)
human health protection instructions (workers health protection instructions and first aid)
fire protection instructions
MSDS availability
GHG balance standard for biochar product to avoid GHG emissions
Reach registration

The agronomical efficiency and “fit for use” suitability need to be guaranteed by the manufacturer.

Table 3: Proposed safety and quality criteria for plant based biochar as Other Soil improver.

Potential Parameters to be fulfilled	Proposed minimum quality criteria for Plant based biochar made from biomass by-products (Other Soil improver)
ESSENTIAL AGRONOMIC CRITERIA	
Minimum organic matter content (expressed on dry matter) (%)	50%
Minimum nutrient content on dry matter (individual values qualifies the product as organic fertiliser) N-P-K (%)	N total: declaration P_2O_5 total: declaration K_2O total : declaration
Plant bioassay (plant growth, germination and phytotoxicity bioassay test)	No germination inhibition, no phytotoxicity
ESSENTIAL SAFETY CRITERIA	
PTEs (b)	
As (mg/kg d.m.)	10
Zn (mg/kg d.m.)	600
Ni (mg/kg d.m.)	50
Cu (mg/kg d.m.)	200
Cd (mg/kg d.m.)	1.5
Pb (mg/kg d.m.)	120
Hg (mg/kg d.m.)	1.0
Cr (VI) (mg/kg d.m.)	0.5
Cr (total)	100
Organic contaminants	
PAH_{16} (mg/kg d.m.)	6 Maximum allowable dose input per ha area recommended on regional MS level.
PCB_7 (mg/kg d.m.) sum of PCBs 28, 52, 101, 118, 138, 153 and 180	0.2
PCDD/F (ng/kg I-TEQ)	20 MANDATORY if PCB >0.07 mg/kg
Impurities	
Limited content of macroscopic impurities (glass, metal, plastic)	Zero content of plastic, metal particles and glass
Other criteria	
pH value	6.5 - 10.0

Table 3: Proposed safety and quality criteria for plant based biochar as Other Soil improver (cont.).

Potential Parameters to be fulfilled	**Proposed minimum quality criteria for <u>Plant based biochar made from biomass by-products</u> (Other Soil improver)** (a)
Particle size distribution (mm)	Between 1-20 mm, 90% (c)
Hygienic aspects - Human pathogens	
Salmonella sp.	No Salmonella sp. in 25 g sample
Escherischia Coli	1000 CFU/g for E. Coli
SAMPLING FREQUENCY	
Sampling frequency	Proposal for <1000, <5000 and >10,000 t/y throughput material processing enclosed.
Labelling information (QUALITY CRITERIA)	
Organic matter content (%)	Labelling
Total nitrogen (%)	Labelling
Total phosphorus (%)	Labelling
Total K (%)	Labelling
pH	Labelling
Bulk density (kg/m^3)	Labelling
Dry matter content (%) minimum 60%	Labelling
Electric conductivity (mS/m)	Labelling

(a) The term “heavy metal” has never been defined by any authoritative body such as IUPAC**. <u>REFERTIL is recommending</u> that the terminology of the different groups of hazardous substances should be standard harmonized in the different legislations in line with the IUPAC and other chemical authoritative body recommendations.**

(b) Powder form of biochar are not recommended to be used by farmers, due to high risk of uncontrolled dust emissions during transport, storage and field applications.

(c) H/Corg is for optional declaration (recommended ≤0.7, subject to that PAH16s are the key performance indicators).

(d) Due to the potential ignition and fire risk of the plant based biochar the moisture content recommended is ≥40%.

(e) Plant based biochar minimum processing temperature 450°C$^{20\ minutes}$ material core.

Table 4: Proposed labelling for plant based biochar as Other Soil Improver.

Proposed Labelling for Plant based biochar Other Soil Improver	
LEGAL INFORMATION	
Brand name	
Product category: organic fertiliser	
Product permit number	
Legal name, address and VAT number of manufacturer	
INPUT MATERIAL TYPE AND INGREDIENTS	
Input material type	
Ingredients (CAS number)	
BIOCHAR QUALITY PARAMETERS QUARANTEED BY THE MANUFACTURER	
Organic matter content (%)	
Bulk Density (kg/m^3)	
Dry matter content (%)	
Particle size distribution (mm)	
pH	
Electrical conductivity (mS/m)	
AGRONOMIC PARAMETERS - NUTRIENT CONTENT	
Total Nitrogen (%)	
Total P (%)	
Total K (%)	
IMPURITIES	
Declaration: Limited content of macroscopic impurities	
APPLICATION RECOMMENDATION	
Recommended dose	
Recommendation for application/crops	
OTHER INFORMATION	
total ash content: optional declaration	
net weight	
date of manufacturing	
application expiration date	
hazard and fire classification	
storage condition	
environmental protection instructions (including instruction for utilization or recycling or treatment of unused substance and packaging material)	
human health protection instructions (workers health protection instructions and first aid)	
fire protection instructions	
MSDS availability	
GHG balance standard for biochar product to avoid GHG emissions	
Reach registration	

The agronomical efficiency and “fit for use” suitability need to be guaranteed by the manufacturer.

PCB_7 and PCDD/F are not target contaminations in animal bone biochar and in the plant based biochar. However, PCB_7 (as low laboratory cost measurement item) may be used as indicator of PCDD/F contamination (that is an expensive and complex laboratory measurement item).

PAH_{16} are target contamination and total PAH_{16} is biochar product quality performance key indicator. Although PAHs' are low water soluble, but the leached out pollution concentration form the PAHs low water solubility process is still high enough to make the subsurface ground water, - including drinking and irrigation water, - polluted above the water regulation limits in a scale of microgram/litre limit level.

In line with precautionary soil protection and limitation of PTEs potential discharges from biochar application there is need for setting up a safe application rate (t/ha dosage) for biochar. The regional specific soil background PTEs concentration and the soil-plant-groundwater system must also be taken into consideration at Member State level by local authorities.

Both plant based and animal biochar products meeting the European Ecolabel criteria system for soil improver and organic fertilizer product and could be registered as Ecolabel product.

REFERTIL proposals and recommendations:

1. Full harmonisation for biochar with specified REFERTIL criteria as listed made from biomass by-products, including MS full mutual recognition.

2. Biochar made from waste streams under Waste Framework Directive End-of-Waste to be regulated by the MS.

3. Plant based biochar is a soil improver at max. 20 t/ha recommended doses. However, case by case considerations to be made at MS level for higher dose between 5 t/ha and 20 t/ha at maximum.

4. ABC animal bone biochar is a recovered organic P-fertilizer up to max. 1000 kg/ha recommended doses.

5. Recommendation for minimizing of toxic contaminants' by biochar use: setting up a safe application rate mg/kg on EU level and specific targeted area kg/ha dosage and background contamination determination is based on MS level for minimizing the risk from PTEs in soil and PAHs loads with water pollution potential.

6. For setting up safe limit value for Potentially Toxic Elements (PTEs) and PAH_{16} content of all type of biochar (both plant and animal based) a limit value (as Reg.(EC) No 1881/2006) of metals, organics and other contaminants in foodstuffs should be also taken account as the growing plants may absorb and/or accumulate the PTEs and organic contaminants from soil through their roots.

7. PCB_7 and PCDD/F are not target contamination in any type of biochar, but PCB_7 are contamination indicator.

8. PAH_{16} is target contamination and biochar quality key indicators.

9. The biochar technology design and processing performance are the most important ultimate definition factors for biochar quality and safety. Low tech biochar technology processing performance and conditions resulting low quality carbon product with high PAH_{16} load.

10. There is need for tight policy and regulations in respect to sustainable biochar feed material supply – biochar production – biochar import - handling – application.

11. The non toxic biochar produced from materials listed in the Annex 9. positive list can be used as an additives for composting - up to 15% of the composting feedstock, expressed in fresh weight – in order to improve the composting process.

12. The REFERTIL consortium is not recommending the nutrient recovery as biochar from any sewage sludge. **In the case of pyrolysis of waste material streams with high and/or variating PTEs input concentrations there is a high risk** that PTEs in final biochar products may exceed the proposed safety criteria limits.

13. The animal protein based rendering by-product organic materials, such as protein content bone meal, direct use as fertilizer for any in vivo application is highly risky. Due to the high recontamination - cross contamination potential of the protein content bone meal by human and animal pathogens (Salmonella, Anthrax, foot and mouth disease, TBC) along the transport, storage and agricultural application routes the use of such materials highly risky and beyond any practical control possibility. The > 133°C 20 min 3 bar sterilized bone meal and any rendering by-products are potential microbiological high risk materials at direct in-vivo applications, therefore sterilized only animal by-products not recommended as organic fertilizer and should be excluded from the positive list.

14. The direct application of natural rock phosphate with variable levels of Cadmium, Uranium and other PTEs content is not recommended for organic farming application and should be excluded from the positive list. This restriction is to avoid further accumulation of the PTEs in agricultural soil, but also important to inform and ensure the organic food Consumers, that the food product is fully safe. If organic food Consumers recognize, that natural rock phosphate with Cadmium, Uranium and other PTEs content is used at crop production level, this might significantly negative impact the organic food EU28 market.

15. Bone biochar recommended to be added to the Annex I. of Regulation (EC) No 889/2008 as organic Phosphorus fertilizer. Plant biochar recommended to be added to the Annex I. of Regulation (EC) No 889/2008 as organic soil improver.

16. All biochar that meets the REFERTIL criteria, also fully meet the European Ecolabel criteria system and can be registered as Ecolabel product.

17. All biochar material, if is manufactured or imported or used in quantities of 1 t/year or more, has to be registered under Article 6 of the REACH Regulation, which is to be applied together with the other EU regulations and REFERTIL specifications..

2. Mandatory biochar permits and commercial certification in the EU

2.1. Mandatory biochar authority permits

Manufacturing/ import/ placing on the market and using of all types of biochar products in the EU require mandatory Authority permits and certificates:

1. **Member State Authority permits for biochar production.**
2. **Member State Authority permit for biochar applications.**
    - Valid for issuing MS only.
    - Mutual Recognition (EC 764/2008) procedure needs to be extended to other MS.
    - Note: EC 2003/2003 Fertilizer Regulation revision is under progress to include biochar, EC BIOCHAR valid for EU28.
3. **REACH registration** (from 2018 >1 t/y).
4. **Extended Producer Responsibility** certificate. Biochar producers having extended responsibility for both production and product quality. As biochar production is generating large amounts of potentially toxic pyro-oil/gas products and the production application is irrevocable, therefore producers full responsibility is key legal element above 1 t/y biochar import, manufacturing and placing on the market capacity.

2.2. Modelling and true value demonstration of the authority permits for REFERTIL industrial production for legal and technical reference to the Commission

All in order to demonstrate in the REFERTIL a true value industrial biochar permit case and provide full value official reference in the demonstration of the REFERTIL project true value legal efforts, the most important elements are the Member state official Authority permit references and accredited legal models to the DG Grow Fertilizer Regulation revision process.

This is a challenging legal and technical work part in REFERTIL, and the way to go through an real permitting procedure cannot be substituted with anything else and the only true value legal demonstration in the EC2003/2003 Fertilizer Regulation revision complex procedure the Commission can take as true value legal reference.

In this context, comprehensive and detailed biochar industrial permits has been worked out, designed, negotiated and made for industrial biochar installation and ABC product applications. This is also an **important and critical element to demonstrate REFERTIL BIOCHAR system complete and qualified status at high maturity research level TRL8 according to the Commission Decision C(2013)8631** for confirmation of a research result technology readiness level. This is the only way to make credible and authorized EU reference about biochar Authority permits.

Biochar production permit procedure is started up at one Authority with comprehensive application that is split up into different subsections, that is further submitted to the advising Authorities.

Each of the permit application sections must contain specific, relevant and detailed site-technology-operational condition description, identified technical standards and documentation, including environmental and health risk elimination requirements that comply with all MS legislations, EC Regulations and relevant industrial norms/standards, that section is controlled by each relevant Authority.

When the permit documentation is evaluated, negotiated and accepted, than the competent Authorities make joint site inspection(s) during and after the construction is completed, furthermore frequently during operations.

In this context, industrial production Authority permits worked out and applied for Kajaszo Hungary installation according to the EU/MS regulations, with involvement of the following Authorities:

1) **Industrial Safety Inspection (main Authority)**
    a. General permit, terms and conditions for biochar industrial installation safety, including coordination of the terms and conditions of the advising Authrities.
    b. Permit for storage of hazardous liquids (pyrolysis oils)
    c. Permit for processing of hazardous gases (pyrolysis gas)
    d. Permit for storage of hazardous liquids (pyrolysis oils)
    e. Permit for Integrated electric installation
    f. Permit for accredited measurements and certificates.

The main Authority: **Industrial Safety Authority**, who will issue the final construction and operational permit, including annex of the approved permits from the advising eleven Authorities with 17 permit structures. **Final permit is issued only after all advising Authorities approved all relevant sections and elements.** (In the waste treatment cases, comprehensive and detailed environmental assessment is required also local public acceptance to set a project, additionally only short time temporary permit is issued at first time, under which period extra frequent Authority inspections and accredited laboratory evaluation made for all material streams, most importantly from Environmental and Water Protection Authority, Fire Protection Authority and Workers Safety Inspection.)

ADVISING AUTHORITIES:

2) Environmental Protection Agency
3) Water Protection Authority
4) Human Health Protection Inspection
5) Worker Safety Inspection
6) Soil and Plant Protection Inspection
7) Fire Protection Inspection
8) Local Building Construction Office
9) Chimney Authority
10) Road inspection
11) Utility suppliers: Electric Works, Gas Works and Water Works including sewage water processing.

REFERTIL Biochar Permit Status: the industrial permit schedules worked out, designed and negotiated in 2013 under REFERTIL work schedule. REFERTIL BIOCHAR validated Authority permits will be demonstrated before project end as part of the high research maturity.

The Wessling chemical and ecotox accredited analytics have been based on the REACH registration annex VII. to demonstrate the REFERIL legal understanding on REACH viability for the project results. The **REACH,** the **CLP** and other relevant EU regulations regulate and control the manufacturing, importing and/or supply of ABC animal bone biochar (CAS 8021-99-6).

Authority permit status of ABC (Animal Bone bioChar) product

When biochar is irrevocable applied to open and complex soil ecological system, there is also a direct interlink to subsurface water systems, therefore only qualified and safe biochar must be applied.

For this reason manufacturing, placing on the market and application of all types of biochar products in the European Union **require mandatory EU/MS Authority permits, same as for all soil improver and other soil products**.

The use of secondary substances in open ecological soil application needs to be permitted by competent MS Authority, usually Soil and Plant Protection Authority. Biochar is such a secondary substance. However, many MS is not yet officially recognized the biochar product as no biochar commercial/industrial production with economical importance is started up in the EU yet.

The first European biochar national Authority permit has been issued in Hungary in 2009 under protocol number 02.5/67/7/2009 (applicant: Terra Humana Ltd./Edward Someus). This specific biochar product is classified as yield enhancing substance.

The biochar product was authorised in Hungary according to the Ministerial Decree 36/2006 (V.18) FVM (Ministry of agriculture and rural development) on the authorisation, storage, marketing and use of yield enhancing substances.

The permit and test procedure has been executed in the accredited test fields and accredited laboratories of the Government Authority between 2005 and 2009. The reason for the four years extensive tests was that there has been no any prior Authority reference in Europe for biochar accredited permitting and definition of biochar safety, quality and application conditions. Terra's biochar S&T works since 1980's and biochar pilot operations with wood and straw carbonisation in the 1990's has been informative only to the Authorities, as no accredited biochar tests has been made at that time.

Table 5: ABC biochar quality and safety parameters according to the 36/2006 FVM decree, Hungary.

ABC biohar quality and safety parameters in the permit	
Limit value for toxic elements (36/2006 (V.18.) FVM decree, HU)	
As (mg/kg)	10
Cd (mg/kg)	2
Co (mg/kg)	50
Cr (mg/kg)	100
Cu (mg/kg)	100
Pb (mg/kg)	100
Hg (mg/kg)	1
Se (mg/kg)	5
Limit value for organic pollutants: PAH[19] (mg/kg)	1
Quality parameters	
Particle size distribution	Below 3.2 mm (100%)
Dry matter content	>80%
pH	8
N and K total	declaration
Total P (P2O5)	>29 %
Total Ca	>25
Germination inhibition assay	No inhibition
Phytotoxicity	No phytotoxicity
Agronomic efficiency	Proved

The REFERTIL ABC BIOCHAR has been comprehensive and detailed evaluated by the Authority (National Food Chain Safety Office Directorate of Plant Protection, Soil Conservation and Agri-Environment) according to all the new and recent EU regulations after 2010, such as CLP Regulation (EC 1272/2008). The Authority consolidated and harmonized permit meet the past 5 years EU regulation changes and in line with the EU Fertilizer Regulation revision mandatory biochar standardization and law harmonization. **The REFERTIL BIOCHAR permit is key technical and legal EU case**, and is a real technical, legal and market break though for the biochar case in the EU. The biochar permit sets the requirements for high quality and safety conditions including minimum nutrient content, maximum level of contaminants and product labelling conditions. This is important to highlight that the Hungarian biochar permit is based on a comprehensive and detailed efficiency tests in the accredited Authority laboratories and tests fields in two different Authority regions. This permit procedure is far more comprehensive than most Member States simplified product registration. However, as biochar is a new product it was necessary.

The achieved REFERTIL BIOCHAR standardization results to support the EU DG Grow Fertilizer Regulation revision works are based on and continuation of the past three decades of extensive scientific RTD and industrial engineering efforts of Terra Humana Ltd in several EU Commission co-financed research projects. Since 2002 several large scale biochar specific RTD EU FP programmes has been executed, for which projects Edward Someus has been the coordinator, biochar key S&T designer and original source.

Extension of the permit to other MS

The EU Fertilizer Regulation revision is rapidly developing towards the mandatory biochar law harmonization on EU level. At the same time and from now on the 02.5/67/7/2009 permit can be extended to other EU Member States based on the EU Mutual Recognition Regulation (according to Reg. EC 764/2008). This means that specific biochar product can be authorized and applied in other EU Member States. Works also under progress on the biochar/pyrolysis oil REACH registration, that is truly challenging for all biochar cases. However, it should be noticed:

a) The analysis of the existing national regulatory frameworks revealed large differences between Member States.
b) Further harmonisation efforts concerns about 25% of the market value of the fertiliser sector, including mainly organic fertilisers and soil improvers. – Limit values for chemical contaminants should serve as safeguard tools but are not enough per se and should be complemented by guidelines on application rates to be enforced at local level. Full risk assessment should apply to 'new' products.
c) Existing EU legislations address risk and safety issues of fertiliser materials (e.g REACH, CLP, Plant Protection Products Regulation, Animal By-Products legislation, Waste Framework Directive, Quarantine legislation,) – As to agronomic efficacy criteria, 13 Member States have declared using such parameters to estimate the quality of the products that are placed on the market. However the criteria set by the Member States are rather different as they depend mainly on the local soil and climatic conditions.

2.3. Material Safety Datasheet

Introduction

The provision of a Safety Data Sheet (also called a Material Safety Data Sheet or MSDS) is a mandatory requirement for substances and preparations which are classified as "dangerous" according to the Dangerous Substances Directive (67/548/EEC) and the Dangerous Preparations Directive (99/45/EC). An MSDS is also mandatory for preparations which are not classified as dangerous but contain at least one substance at a level of >1% posing a health or environmental hazard, that is, a substance classified as dangerous, or a substance which has workplace exposure limits. The MSDS must be provided to the recipient by the person responsible for placing the substance or preparation on the market (the manufacturer, importer or distributor). An MSDS is principally intended for use by professional users. The MSDS providing information on the hazards to health, safety and the environment inherent in a chemical substance or preparation. It also gives guidance on how the substance or preparation should be handled, stored and disposed of as well as what to do in case of an accident. The Material Safety Data Sheets have been prepared on the basis of the Regulation EC No. 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH regulation) and the European Directive on Safety Data Sheets (2001/58/EC). The information provided by the MSDS also meets the requirements set out in Directive 98/24/EC on the protection of the health and safety of workers. The European Directive on Safety Data Sheets (2001/58/EC) entered into force on July 30, 2002. The

Annex of the Directive provides in-depth guidance on the compilation of an MSDS and aims to ensure consistency and accuracy in the content of each of the mandatory 16 sections under the following headings:

- identification of the substance/preparation and of the company/undertaking
- composition/information on ingredients
- hazard identification
- first-aid measures
- fire-fighting measures
- accidental release measures
- handling and storage
- exposure controls/personal protection
- physical and chemical properties
- stability and reactivity
- toxicological information
- ecological information
- disposal considerations
- regulatory information
- other information The Authorities in the European Member States monitor the availability of Material Safety Data Sheets in the trade.

3. INPUT MATERIAL SELECTION

3.1. Input material selection criteria for biochar production

Raw material (feedstock) is, along with pyrolysis conditions, the most important factor controlling the properties of the resulting biochar.

In principle, any organic feedstock can be pyrolysed, although the yield of solid residue (char) respective to liquid and gas yield varies greatly along with physico-chemical properties of the resulting biochar[1].

The chemical and structural composition of the biomass feedstock relates to the chemical and structural composition of the resulting biochar and, therefore, is reflected in its behaviour, function and fate in soils. Secondly, the extent of the physical and chemical alterations undergone by the biomass during pyrolysis (e.g. attrition, cracking, micro structural re-arrangements) is dependent on the processing conditions (mainly temperature and residence times). [2].

Feedstock, along with pyrolysis conditions, is the most important factor controlling the properties of the resulting biochar. The chemical and structural composition of the biomass feedstock relates to the chemical and structural composition of the resulting biochar and, therefore, is reflected in its behaviour, function and fate in soils. Secondly, the extent of the physical and chemical alterations undergone by the biomass during pyrolysis (e.g. attrition, cracking, microstructural rearrangements) is dependent on the processing conditions (mainly temperature and residence times) [3].

To obtain a high quality biochar product, mainly two aspects have to be considered: the input feed material and the performance of the pyrolysis technology design that provides the treatment efficiency.

The composition of feed material has an effect on the nutrient and also on the potential toxic element (PTE) content of the biochar product. So feed material streams from agriculture and the food industry are not always appropriate for being feed materials of the pyrolysis process to produce biochars. Therefore, we have to select the targeted input feed material streams strictly, we have to obtain information about their chemical and physical properties, and compile a unified system of materials suitable for the production of environmentally safe chars.

Plant based biochar is having multi feed option; **ABC animal bone biochar is based on mono feed**, e.g. only single and well defined input option from the Authority permitted and continually controlled rendering industry.

For plant based biochar the usual weakness is the lack of a uniform, clear and compelling financial justification versus short/medium termed and direct benefits from end-user SME farmer point of view. The feedstock, feedstock condition and feedstock availability varies

[1] F. Verheijen, S. Jeffery, A.C. Bastos, M. van der Velde, I. Diafas, Biochar Application to Soils, A Critical Scientific Review of Effects on Soil Properties, Processes and Functions, JRC 2010).
[2] F. Verheijen, S. Jeffery, A.C. Bastos, M. van der Velde, I. Diafas, Biochar Application to Soils, A Critical Scientific Review of Effects on Soil Properties, Processes and Functions, JRC 2010).
[3] F. Verheijen, S. Jeffery, A.C. Bastos, M. van der Velde, I. Diafas, Biochar Application to Soils, A Critical Scientific Review of Effects on Soil Properties, Processes and Functions, JRC 2010).

significantly, soils vary significantly, crops vary significantly, gross income per hectare varies significantly, and the productivity benefit also varies; and each of those variables affects the bottom line. When financial outcomes are difficult to predict and risky for the plant based biochar, than industrial investments are less attractive. Usually the overall plant based commercial biochar making cost in Europe is as high as approx. >€750/t.

3.2. Sustainability criteria for feedstock selection

For selecting of biomass for sustainable biochar production, the following criteria should be applied:

1. Only the listed (**positive list**) **organic feed** materials (organic waste, product, by-products) can be used for biochar production.
2. **Recorded clean feedstock source**. Evidence of **complete feedstock documentation including origin** need according to the EU and Member State law.
3. **Consistence feedstock quality**. The quality characteristics of biomass feedstock are not to be variable and inconsistent. Production of biochar from low grade biomass brings potential environmental and human health risks and biochar quality problem.
4. **Consistence feedstock quality.** The quality characteristics of biomass feedstock are not to be variable and inconsistent.
5. **Feedstock quality parameters and physical/chemical properties to be considered:**
    a. **Particle size distribution** (any sizes, but material sizing is extra cost many treatments can not afford)
    b. **Bulk density**. Low mass density is causing logistical problem and extra cost tons vs. m3 for collection, transport and storage.
    c. **Moisture content, requirement: <20% w/w**.
        i. The moisture content is critical for storage stability (biological stability).
        ii. Storage and pre-treatment strategies should be developed for high-moisture biomass.
        iii. Many feedstocks will need to be dried before pyrolysis, but for most biochar cases such action is economically not viable. Moisture removal is necessary and critical important for the thermochemical conversion. Pyrolysis technology is particularly well-suited to low moisture content organic by-products <20% w/w. Energy for drying could be recycled from the pyrolysis process.
    d. Ash content.
    e. pH.
    f. Potential nutrient value and availability of the feed material.
        i. **Does not compete with biological treatments** (composting, anaerobic digestion) for organic fertilizer production. The potential nutrient value lost during the thermal conversion in the plant based biochar production cases versus biological conversion and producing compost. This is the case for green residuals and manure.

ii. **The nutrient composition of the final biochar** (the amount of carbon, nitrogen, potassium, calcium) **depends on the feedstock used, the processing conditions, duration and temperature of pyrolysis.**

g. **The Potentially Toxic Elements (PTEs) and organic contaminats (POPs) should be minimized. Priority elements: As, Cd, Cr Total, CrVI, Cu, Pb, Hg, Ni, Zn.** The PTEs concentration of input material should be regularly monitored**.** **Requirement: If the concentration of any PTEs in the feed material are exceeding the 20 percent of the REFERTIL recommended limit value, those feedstock should be excluded from the biochar production for agriculture applications.**

h. **The organic contaminants (PAHs, PBC) should be minimized.** However PAHs are regenerated during treatments, therefore it is important to apply high end pyrolysis technology.

i. **Must be free from non-organic waste (plastics, stone, metals, glass) and hazardous waste.**

6. **Sustainable feed supply, only the sustainable use of biomass should be promoted (product and by-products feedstocks)**:
   a. Biochar feed materials does **not compete with human food, animal feed and plant nutrition supply.** Production biochar from low economical value by-product biomass should not create competition for land use for human and animal food production.
   b. **Feedstock production**: costs and inputs need to minimize for the growing and harvesting of the crop grown for biochar supply. *Should be meet to the sustainable agricultural production and the environmental cross-compliance requirements in the Common Agricultural Policy (CAP).*
   c. **Forbid the use of biomass from land converted from forest, and other high carbon stock areas, as well as highly biodiverse areas.** Increased demand for forestry or agricultural residues can lead to reduction of land carbon stock in the soil, for instance, if too few residues are left on the land. There are large quantities of carbon in soil organic matter, which can increase or decrease depending on the crops or trees planted and the management regime, such as the application of fertiliser.
7. **Feedstock availability:** seasonal and yearly round availability of the feedstock should be carefully evaluated. Feedstock availability can vary year to year and within years.
8. **Environmentally sustainable feed material logistics.** The environmental and human health impact of logistics (long way transport, dust, gaseous emissions during transport, storage and pre-treatment, safety of workers, fire hazards) should be minimized. The potential flammability of dry, stored material will require mitigation strategies to reduce the potential for fire. When biomass, especially materials with low mass density characteristics, should be transported over a long distance the transportation costs and environmental impact can be very high.

9. **Effect of sustainable soil management**. Removal of crop residues for use as a feedstock for biochar production should be eliminated. can forego incorporation of the crop residue into the soil, potentially leading to multiple negative effects on soils.
10. **Economically sustainable feed material availability:** price and long term supply contract and logistical cost.
    a. The choice of feedstock will be affected by the distance of biomass resources.
    b. Feedstock price.
    c. Long term and continuous availability: long term supply contract. As pyrolysis process in economical industrial scale is 8000 h/y continuous process, therefore continuous availability of the feeds are critically important.
    d. Logistical costs: Collection, transport, storage and pre-treatment costs. The logistical costs often make the most economic sense to use local feedstock.

3.3. Setting up input material positive list for biochar production

The following table shows the different categories of potential biomass sources for production of biochar and linked legislations.

Table 6: Summary table for the categories of potential biomass sources for production of biochar and linked legislations.

INPUT MATERIALS	LEGAL FRAMEWORK	BIOCHAR
WASTE BIOMASS		
WASTE biomass	• **as defined and regulated by Directive 2008/98/EC - Waste Framework Directive (WFD).** • '**waste**' means any substance or object which the holder discards or intends or is required to discard (Article 3 of WFD) ; • '**bio-waste'** means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants • If biochar is made from waste according to the WFD it will be classified as a waste until End-of-Waste status is given. as **Article 6 of Directive 2008/98/EC.** • Waste Categories as listed in **List of Wastes (2000/532/EC).** • **non-waste biomass mixed waste biomass to be considered as waste material which is regulated by WFD.**	**Biochar from waste.***
NON-WASTE BIOMASS		
PRODUCT biomass "biomass produced on land"	• In Europe, sustainable agricultural production is regulated through the environmental cross-compliance requirements in the **Common Agricultural Policy.** • Forest management is regulated at national level, with policy guidance through the **EU Forestry Strategy** and international processes such as the Ministerial	**Plant based biochar (PBC)**

	Conference for the Protection of Forests in Europe (MCPFE).	
ANIMAL BY-PRODUCTS category 2 and 3 **	**As excluded by Article Article 2(2b) of Directive 2008/98/EC.** Animal by-products category 2 and 3 are regulated by Regulation (EC) No 1774/2002 - ABP regulation.	**Animal Bone bioChar (ABC)**
BY-PRODUCTS Food processing by-products	**as defined in Article 5 of Directive 2008/98/EC**	**Plant based biochar (PBC)**
Natural non-hazardous **AGRICULTURAL OR FORESTRY MATERIAL** used in farming***	**as excluded by Article 2(1f) of Directive 2008/98/EC**	**Plant based biochar (PBC) Manure based biochar**

Remarks:

* At the EU level for end-of-waste criteria and methodology for biochar product from waste is not established even at draft proposal level so this might be regulated at Member State level only according to the Article 6 (4) of WFD.

**Category 2 and 3 food grade bone grist (animal by-product). All in order to improve environmental and product safety high temperature treatment conditions required, e.g. not the usual 133 0C/30bars/20 min, but rather material core processing temperature above 600C for further and certain use of the substance.

*** Examples for materials from agriculture or forestry that could be considered natural non-hazardous materials are: faecal matter, Straw from grain and other crops; Cut grass; 'Natural' wood, wood off-cuts, wood chips, saw-dust, etc.

Table 7: The list of potential waste material for biochar production, specified according to the List of Wastes (2000/532/EC).

List of wastes (2000/532/EC)[4]	
02 Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	
02 01	Primary production waste
02 01 01	sludges from washing and cleaning
02 01 02	animal-tissue waste
02 01 03	plant-tissue waste
02 01 06	animal faeces, urine and manure (including spoiled straw), effluent, collected separately and treated off-site
02 01 07	wastes from forestry
02.02	Wastes from the preparation and processing of meat, fish
02 02 02	animal-tissue waste
02 02 03	materials unsuitable for consumption or processing
02 02 99	wastes not otherwise specified
02 03	wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation
02 03 01	sludges from washing, cleaning, peeling, centrifuging and separation

[4] http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!CELEXnumdoc&numdoc=32000D0532&lg=en

02 03 04	materials unsuitable for consumption or processing
02 03 05	sludges from on-site effluent treatment
02 03 99	wastes not otherwise specified
02 04*	wastes from sugar processing
02 04 99	wastes not otherwise specified
02 05*	wastes from the dairy products industry
02 05 01	materials unsuitable for consumption or processing
02 06	wastes from the baking and confectionery industry
02 06 01	materials unsuitable for consumption or processing
02 06 03	sludges from on-site effluent treatment
02 07	wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)
02 07 02	wastes from spirits distillation
02 07 04	materials unsuitable for consumption or processing
02 07 05	sludges from on-site effluent treatment
02 07 99	wastes not otherwise specified

Table 8: The list of potential waste material for biochar production, specified according to the List of Wastes (2000/532/EC) cont.

03	Wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard
03 01**	wastes from wood processing and the production of panels and furniture
03 01 01	waste bark and cork
03 01 02	Sawdust
03 01 03	shavings, cuttings, wood, particle board and veneer containing hazardous substances
03 01 99	wastes not otherwise specified
03 03	wastes from pulp, paper and cardboard production and processing
03 03 01	waste bark and wood
03 03 06	Fibre and paper sludge
03 03 99	wastes not otherwise specified
19	Wastes from waste management facilities,off-site waste water treatment plants and the preparation of water indeed for human consumption and water for industrial use
19 05	wastes from aerobic treatment of solid wastes
19 05 99	wastes not otherwise specified
19 06	wastes from anaerobic treatment of waste
19 06 99	wastes not otherwise specified
20	Municipal wastes(household) waste and similar commercial, industrial and institutional waste including separately collected fractions COLLECTED FRACTIONS
20 01	separately collected fractions (except 15 01)
20 01 08	Biodegradable kitchen and canteen waste
20 02	garden and park wastes (including cemetery waste)
20 02 01	Biodegradable waste
20 03	Other municipal wastes
20 03 02	waste from markets

* as a potential additive

** only untreated, not containing hazardous substances

3.4. Specific consideration on biochar produced from waste

The by-product and waste stream thermal treatment options having two very different (environmental, processing, human health, product quality, aso...) risk profiles, different treatment conditions, different integrated pollution prevention and control, different safety,

different production performance and different Authority control/reporting performances. The key definition factor which direction the permit is applied is based on the feed material classification, if the input is a by-product or waste classified. For any biochar quality/safety/user criteria determination strict specification and titled responsibility is required, as because biochar soil application is irrevocable and from that point of view the SME farmers must know for total sure what they put in into soil they own.

To obtain a high quality biochar product, mainly two aspects have to be considered: the input feed material and the performance of the pyrolysis technology design that provides the treatment efficiency.

3.4.1. Consideration related to the Potential Toxic element content of biochar from waste

The composition of feed material has an effect on the nutrient and also on the potential toxic element (PTE) content of the biochar product. So feed material streams from agriculture and the food industry are not always appropriate for being feed materials of the pyrolysis process to produce biochars. Therefore, we have to select the targeted input feed material streams strictly, we have to obtain information about their chemical and physical properties, and compile a unified system of materials suitable for the production of environmentally safe chars.

Biochar quality, safety and performance produced from waste streams having very different criteria VERSUS biochar produced from agricultural, food and forest industrial by-products.

When diverse waste streams are processed than wide range of new PTE potential toxic element inputs coming up with highly variable concentration and composition. These variable PTE's than will be concentrated into the char residual solid phase that supposed to be applied in open ecological soil environment. Application of diverse waste streams in the production of biochar is highly risky, not transparent and the precautionary principle cannot be applied. The Potential Toxic Elements (PTEs) of the input raw material are concentring in the final biochar products and cannot be removed by the pyrolysis treatment or by any other treatments that is economical. Therefore all biochar feed materials must be low PTE level at biochar thermal processing input end.

In practice it is experienced, that the overall technical and public acceptance risk is higher in the case of waste derived biochar product versus by-product derived one. Therefore Member States are expected to differentiate the Mutual Recognition of the biochar produced from waste material.

In the case of waste materials with high PTEs concentrations there is a risk that PTEs in final biochar products may reach the REFERTIL recommended safety criteria limits. The PTEs concentration of input waste material should be regularly monitored. If the concentration of any PTEs in the feed material are exceeding the 25 percent of the REFERTIL recommended limit value, those feedstock should be excluded from the biochar production for agriculture applications.

It is important to highlight that biochar is a specific quality substance for soil improvement and/or organic fertilizer agricultural application specific product only, that continuous

quality/safety/performance is fully and with full legal/economical responsibility guaranteed by the producer, importer and the commercialization trading unit, as joint responsibility by the production and/or trade market chain actors. In most cases the waste materials having variable chemical composition and concentration (PTEs content and organic pollutants). The increased concentration of the PTE's and the risk is very high that it will result variating composition and concentration of output char with high PTEs. Waste streams usually having highly variating in composition and concentration of components which different materials will reflect differently for thermal treatment in the same batch. The industrial practice is indicating, that in many cases waste titled materials often handled with low care, as this is "just" waste, this is why often the complex structure and variating composition for the waste streams. The different types and often mixed feed material characteristics with mixed particles in the same input batch providing different responses for heat transfer and gas-out. This will result a mix of outputs that is containing properly treated and low end treated material particles, so no any true value homogenously safe quality can be determined. That is not acceptable for biochar. This is also why so important to have homogenous mono feed materials as it is possible that by WfD/EoW cannot be fully and always guaranteed.

At the EU level for end-of-waste criteria and methodology for biochar production from waste is not established even at draft proposal level so this might be regulated at Member State level only. If a biochar product is produced from waste (as specified in the WFD) according to locally applicable national End-of-Waste criteria (in the MS in which it is manufactured) it cannot then be exported as a product (only as a waste) to other EU countries.

3.4.2. Considerations related to the acceptance of biochar from waste

In practice, there would be no any true value EU/MS Authority control and follow up opportunities for the life cycle and quality over the waste derived biochar products, while would let open a legal backdoor for illegal waste management activities in EU scale.

Additionally, the justified public acceptance would be low, if any, while it would result negative market reflection for the biochar case; that otherwise expected to be natural, pure and organic, made from known and well identified agri - food – forestry industrial by-products with positive and wide public acceptance.

There are other better and safer ways for waste-to-product conversions, which EoW does not impact any risk to open ecological soil and subsurface drinking water, such as the biochar used for. Such biochar soil application is irrevocable; therefore before any use, the biochar producer and user must be fully confident about high biochar quality.

However, Member States are able to implement specific national criteria for EoW biochar in order to adapt to local situations, but such national EoW criteria would not have mutual recognition in other Member States. If a product is produced according to locally applicable National End-of-Waste criteria (in the country in which it is manufactured), it cannot then be exported as a product (only as a waste) to other countries (for example, where no national criteria are defined). In the "biochar product made form waste" case (biochar that feed materials are considered as waste under the Waste Framework Directive) other industrial characteristics PTE's may come up, such as Se and Mo that are beyond the basic seven PTE's. While the agricultural, food industrial and forestry by-product based biochar is expected to be mutually MS recognized biochar product, - the biochar made form waste case require further consultation from the MS and might not be mutually MS recognized

biochar product. If biochar made form waste material supplementary data may be required, including the definition of positive list for input materials and its it specific potential toxic element compositions.

Furthermore, there are several approaches:

1. TECHNICAL: The input material characteristic is always reflected into the output products in one or other way. The Potential Toxic Elements PTE' s in the input material (except Hg, S) will be concentrated in the output char at any carbonization temperature:

    a) In the case of cellulose based feed material 15-30% production yield is expected. This means that majority >85% of the PTEs concentration level will be multiple increased in the char only by factor approx. 3x-5x, and that PTE configuration cannot be removed from the char anymore by any economical process.

    b) In most cases the waste materials having variable chemical composition and concentration (PTEs content and organic pollutants). The increased concentration of the PTE's, and the risk is very high that it will result variating composition and concentration of output char with high PTEs. If such waste derive biochar product put into open ecological soil environment, who will take that high risk and who will take the legal, economical, technical and environmental responsibility? Waste materials are not sustainable feed materials to safe biochar.

    c) There is no any biochar technology in this world which can produce a continuously even quality and safe biochar products with guaranteed performance from input waste material having variable chemical composition and PTE concentration. Even if the waste input is supposed to be homogenized, the industrial reality is that the waste processors will process everything which is not legally restricted and economical. If any waste is legal to EoW process and there is business in it, they will do so.

    d) Waste streams usually having highly variating in composition and concentration of components which different materials will reflect differently for thermal treatment in the same batch. The industrial practice is indicating, that in many cases waste titled materials often handled with low care, as this is "just" waste, this is why often the complex structure and variating composition for the waste streams. The different types and often mixed feed material characteristics with mixed particles in the same input batch providing different responses for heat transfer and gas-out. This will result a mix of outputs that is containing properly treated and low end treated material particles, so no any true value homogenously safe quality can be determined. That is not acceptable for biochar. This is also why so important to have homogenous mono feed materials as it is possible that by WfD/EoW cannot be fully and always guaranteed.

    e) Waste processing industrialists will have not much interest, if any at all, to produce biochar for agri application, as they make high profit on gate-fee and energy only (and that is the name of the game), and when the waste is

"converted" into EoW char, than it is unlikely to have any true market value as "biochar" for such non green and not organic material origin. On the top of that the waste processing industrialists does not need to use advanced (and costly) pyrolysis technology to process char as they already have the high profit on gate-fee and energy even at high PTE and PAH contamination levels.

f) Versus EoW char the biochar is more sensitive for input feed material quality and far higher pyrolysis technology level for higher cost must also be applied to achieve the requested high biochar quality.

g) Legal acceptance to EoW converted waste to biochar is estimated to be highly uncertain, and open a backdoor for the illegal trade and illegal treatment of waste materials in large scale, while the legal documentation versus the industrial/economical/environmental reality will be very different and often opposite.

h) Waste incinerators like any carbonized and char feed materials, as this would decrease their off-gas treatment cost significantly and boost energy efficiency. But this energetic operation has nothing to do with the biochar, so there is no any justified reason from agricultural – safe soil fertilizer point of view to mix energy production and fertilizer issues.

2. LEGAL: It would be very difficult to get, if possible at all, to place such a waste derived carbon product on common EU fertilizer market and make it mutually recognized.

3. PUBLIC: it is estimated and predicted that that public will not support transfer EoW char product to other MS under "biochar" name, not even if they get it free of charge give away. It is also a moral aspect, that people mostly does not want to use waste derived materials from others backyard (maybe except recycled scrap iron, paper and car tire), especially not when it is about food production. Biochar is a agri/food industry by-product processed green/organic product and if this combined with waste derivation that the core market drive and trust is lost.

3.5. Determination of environmental, economic and logistical factors

Summary of barriers of pyrolysis feedstock logistical system:

- Biomass feedstock from agricultural and forest resources have high volume but low mass and low energy density. The low density of these feedstock makes them cost-prohibitive to transport, handle, and store.
- The moisture content of biomass at the time of harvest or collection—whether agricultural, forest, food industrial and manure—is higher than desired and leads to degradation and decreased system efficiency. High moisture content can cause aerobic instability during storage and reduce the efficiency of transportation and pre-processing operations.
- Currently available equipment for biomass feedstock logistics systems is inefficient. Existing equipment has insufficient capacity to efficiently and economically harvest, store, and deliver feedstock for biochar production.

- Quality characteristics of biochar applicable biomass feedstock are variable and inconsistent. Biomass attributes vary with feedstock source and season, creating inefficiencies in handling and conversion systems. To optimize biochar production, it will require feedstock of consistent quality, particle size, and moisture content; There is need for pyrolysis processing are robust for a wide range of feedstock characteristics and producing feedstock with consistent properties. Develop logistics operations that maximize uniformity and consistency of delivered feedstock attributes. Develop quality standards for delivered feedstock and instrumentation to determine feedstock quality quickly at point of sale.
- Transportation of biomass is costly and can strain transportation networks. Currently available technology for biomass transportation involves truck traffic that is costly and environmentally polluting. Both agricultural and forest materials are distributed over large areas, making collection costly. A key determinant for biomass supply is an infrastructure that ensures economically viable feedstock logistics and handling from farm to plant.
- Development of viable domestic biomass feedstock production systems will require combined public and private efforts.
- Ultimately, specific processing and utilization of biomass will depend on the feedstock type; regional and site characteristics; and the goods, services, and values required to develop and maintain reliable biomass logistics supply systems.

4. The biochar specific pyrolysis processes

4.1. General considerations for biochar producing technologies

Biochar is an important strategy to protect ground water and restoration of soil natural life. The plant based biochar provides water/nutrient retention and is a soil improver. The bone based ABC Animal Bone bioChar is controlled release P/Ca fertilizer (that can be formulated to full value NPK-C+Ca+micro nutrient complex organic fertilizer in any needed configuration) and nutrient retention performance of both types of biochar is strongly preventing leach out. Under EU market based and competitive commercial conditions it is estimated that the minimum economical throughput capacity of a biochar plant is from 6500 t/y. The realistic biochar price levels in Europe under commercial conditions estimated from >€750/t.

The REFERTIL project completed and validated the 3R AGROCARBON pyrolysis and biochar specific designed technology at high reserach maturity Technology Readiness Level and prepared for TRL9 level – that is the final stage of the RTD according to the EU Commission Decision C(2013)8631 to demonstrate the viability of the research results under true value industrial conditions. Official and mandatory EU/MS permit models developed and validated for true value legal demonstration.

The most important REFERTIL biochar achievement is that the project removed all major (scientific, technical, technological, economical process scale up, environmental, safety and

legal) barriers for legalized production and economical application of the industrial biochar in a safe and environmentally/climate sustainable way.

However, **market barriers can only be removed once a TRL9 is implemented, that is the only true value and convincing demonstration of the high research maturity RTD results** under market competitive conditions for the interest and benefits of the SME farmer users.

The biochar technology processing performance and conditions are the most important and the ultimate definition factors for biochar quality and safety. There are critically important technical differences between energetic purpose designed pyrolysis VS biochar product specific designed pyrolysis technologies. These are two very different technology designs with two very different product schedules. In this context:

- The input feed material character and quality having less impact on the biochar quality and safety than the thermal processing conditions itself.
- Low tech biochar technology processing performance and conditions resulting low quality carbon product, which is after insufficient reductive thermal processing still remains waste material and not a safe biochar product.
- Traditional and energetic purpose designed carbonization and gasification “energy charcoal maker” technology “energy char” carbon products are not qualified for safe biochar with objective driven applications in open ecological soil environment.
- All biochar manufacturing, importing, placing on the market or use of biochar product is regulated by REACH Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals EC 1907/2006 and corrigendums, which provisions are underpinned by the precautionary principle.
- REACH is not applied to waste but for organic waste converted End of Waste product yes.
- REACH registration and notification requirements apply already above a total quantity of **one tonne** of biochar substance or preparation per year.

4.2. What is a biochar specific pyrolysis process?

The biochar specific pyrolysis process is when all the engineered design elements and the comprehensive construction is specifically designed to legally manufacture specific carbon product (biochar) **for the purpose to legally apply in functioning soil ecosystems.** As biochar application is usually irrevocable, therefore the key value chain stakeholders, such as producers, importers, distributors and users are fully responsible for the product total safety.

Therefore, all biochar specific process must unconditionally meet all the specific requirements to make safe biochar that will be irrevocable applied in soil with no “end of the life cost”. In this context the biochar product need to be Extended Producer Responsibility certified. The “legally manufacture” and “legally apply” criteria means Authority permitted under EU/MS regulations and REACH above 1 t/y capacity. In this context biochar specific pyrolysis process is both technical and legal term together.

a) Plant based biochar is a chemically amended MULTI CONSTITUENT substance (carbon content <80%) or MONO (carbon content >80%) with variable composition, usually originating from MULTI FEED processing.
b) ABC Animal Bone bioChar is a chemically amended MONO CONTITUENT substance, originating from MONO FEED processing.

Usually, the pyrolysis process is thermal energy independent and self sustaining. The system pressure is not constrained by the vapour pressure of water.

The description of the pyrolysis process is particularly challenging because it evolves a great deal of physical and chemical transformations and produces a large number of product species. As a result, existing models aiming to predict the rates or yields of the released pyrolytic volatiles are still supported by empirical data.

Feed material strategies:

A. **MONO CONSTITUENT substance**, (one main constituent >80% w/w) homogenous mono feeds processed, which is easier to operate than multiple feed selections.

B. MULTI CONSTITUENT substance, (each main constituent ≥10% but <80% w/w) several types of feed applied as received for which specific treatment schedule to be organized to follow up variations.

The core elements of the biochar case are the biochar specific processing technology with advanced thermal engineering design and the product itself for resource efficient and added value utilization of the agri/food industrial by-products in an environmental/climate friendly way.

In the context the biochar resource efficiency means smart and sustainable utilization of the European resources, including

a) organic by-products and waste streams for recycling and reuse,
b) human resources for develop and design biochar high tech,
c) environmental and climate resources in a time of changing climate,
d) economical resources to make best value for investment and
e) all and any other elements towards sustainability.

In a world with finite resources there is no infinite development opportunity with sustainability, unless fully cycle circular economy is not implemented for which the case example model is the REFERTIL biochar 3R zero emission biochar processing green technology.

The REFERTIL biochar towards horticultural applications provides major economic opportunities, improve productivity, drive down costs and boost competitiveness and

i. ensure Phosphorus security by recovered P supply as critical raw material resource;
ii. boost economic performance of the horticultural farming while reducing resource use;
iii. provides an opportunity to keep costs under control by reducing material and energy consumption for production of recovered high P_2O_5 concentrated Phosphorus fertilizer and soil improver in economical interesting industrial scale; with special highlight on the interest and benefits of the SME farmers in the low input and organic farming sectors;

iv. identify and create new opportunities for economic growth and boost competitiveness; and
v. fight against climate change and limit the environmental impacts of resource use.

The carbonization heat treatment efficiency down to material core is directly realted to the efficiency of the devolatilization and reflected into the PAH_{16} and PAH_{19} levels in the output product as process and product key indicator.

To obtain a high quality biochar product, mainly two aspects have to be considered: the **input feed material and the performance of the pyrolysis technology design** that provides the treatment efficiency.

During the biochar production performance improvements the following items have been considered:

a) Improvement of the **operating conditions** during pyrolysis (e.g. heat transfer efficiency, heating rate, high treatment temperature, residence time, pressure conditions, flow rate of the inert gas, reactor type and shape) and pre- (e.g. drying) and post- (e.g. sieving, formulation) treatments which can **greatly affect biochar properties and structure.**

b) Evaluation of the carbonisation core temperature, residence time and input **material quality effects on the biochar end-product quality and safety**.

c) Prevention of occupational hazard, **robust qualitative and quantitative assessment of emissions from pyrolysis process**.

Generally the stability of biochar increases as a function of pyrolysis material core temperature whereas the maximum allowable limits of the PAH_{16} and PAH_{19} are key process and biochar product quality/safety indicators. At plant based biochar with carbon strategy, the lower processing temperatures 450 - 550 °C more char is produced, but the high temperatures 550 - 850 °C at plant based biochar favour the higher yield of liquid and gas fuel components. For biochar product applications in open ecological systems risk characterisation need to be made for each exposure scenario and for each target population or compartment.

Table 9: Plant feed material, bulk density and heating value.

Feed	Bulk density (kg/m^3)	Heating value dry basis (MJ/kg)
straw	100	20
woodchips	400	20
Plant based pyro-oil	1100	18
Plant based biochar	300	30

Additional advantages of the well designed advanced pyrolysis systems: feed flexibility with good added value valorisation economical opportunities, wide output product application areas, near zero emissions and safe operations. However, although many development past three decades, very few biochar specific pyrolysis systems are industrially viable, few having

efficient and comprehensive solution. Well performed, efficient and economical - biochar specific pyrolysis technology design is a challenge.

4.3. Setting up criteria for biochar specific pyrolysis process

The biochar specific standard pyrolysis process is characterized by the following criteria:

1) **Comprehensive industrial design for treatment and management of all processed material streams in any form;** including technological, mechanical and thermal engineering, electric and electronic design and instrumentation, mass and energy balances, hazard and risk evaluations, occupational health and safety design, storage and logistics, data collection and storage, auxiliary systems, a.s.o. according to the valid EU/MS industrial and environmental standards and mandatory permit conditions. Energetic, environmental, GHG and economical Life Cycle Assessment of all the system elements and materials recommended. Preparation of sufficient level of training and instructions of the operators, commissioning - operation - maintenance manuals are critically important elements, similarly to the professional standard industrial scale thermal installations.
2) **True reductive environment** thermal processing with self sustaining thermal energy supply or electric power generation and full value surplus energy recovery as standard installation. The true value reductive pyrolysis thermal processing means, that no any air is introduced for the process through technology design. However, there are still sources of oxygen from
    - System sealing, which should be such advanced technological design, that not more than 0.01% of the reactor internal volume equivalent air volume introduced into the reactor per hour through sealing, otherwise the hot carbon material will burn off to ash biochar not generated,
    - Chemically bounded oxygen burn off, which is feed material dependent.
2) **Temperature criteria: material core processing temperature is between 450°C and 850°C**.
    a. Plant based biochar **material core processing final treatment carbonization temperature** is from >450 to <550 °C at minimum 20 minutes residence time.
    b. ABC biochar material core processing final treatment carbonization temperature is from >600 to <850 °C at minimum 20 minutes residence time.
    c. Constant material core temperature and residence time is to be defined and followed by the producer for each mono and multi constituent feed material that will result targeted output biochar commecial product quality.
3) **Towards zero emission performance or even zero emission performance processing** to be designed, most importantly full processing of the pyrolysis-gas-vapors and energy supply units needed to **fully meet relevant industrial emission standards, including the Industrial Emission Directive**, with the difference that biochar – as main product - is not combusted. Full and added value recycling and

reuse of pyrolysis-gas-vapours as higher value organic chemical compounds should optimally be targeted.

4) **Resource efficient and sustainable biomass feed materials selected**.

5) **Fully monitored**, each biochar series identified/labelled data collected and fully documented operations with production records according to the Authority permit specifications. The availability of all records and documents in 5 years. Industrial full process monitoring means that both the **automated process** (such as temperature and pressure differences, residence time, electric and electronic instrumentation data, all material stream weights and volumes, energy balances, production schedules, aso) and the total **environmental** performance data (such as all emissions, storage and handling of hazardous materials, aso) are continuously and measured with validated/Authority permitted instrumentation with validated recording/documentation system.

6) Continuously 7days/24hours operated.

7) **Authority permitted construction and Authrity controlled operation** implemented above 1 t/y capacity (usually 17 Authority permits required with specified terms and conditions)

8) **REACH certification and authorization above 1 t/y biochar production** capacity made, related to biochar and pyrolysis oil manufacturing, and/or importing and/or placing on the market. This authorisation requirement ensures that risks from the use of such substances are either adequately controlled or outweighed by socio-economic benefits, having taken into account the available information on alternative substances or technologies.

9) **Having Extended Producer Responsibility** certificate for the lawful and “fit for purpose” product (full value legal and economical responsibility for the product safety and stated performance).

10) **The biochar minimum quality specification and labelling according to the expected EC2003/2003 Fertilizer Regulation** revision content and format to be applied. For improved quality and in justified environmental case MS may define more strict specification. Product characteristics, physical-chemical properties, degradability, biological effects, safety standards and specifications specified in SDS safety data sheet according to EU Regulation, continuous follow up control to meet REACH and legal status, aso are public information and cannot be classified as confidential business information.

The three standard pyrolysis products are: carbon as main product, gas and pyrolysis oil. The relative proportion distribution carbon-gas-oil is depend very much on the pyrolysis technology design, the characteristics of the biomass and the reaction parameters. There are many different types of conventional biomass pyrolysis processes for energetic charcoal making, still few pyrolysis are suitable for biochar processing with strict requirement for the carbon product environmental and ecological quality.

5. Good practice guide for pyrolysis

5.1. Good practice guide for the pyrolysis technology

The biochar treatment efficiency is most importantly depending on the pyrolysis design. Construction and operation of pyrolysis technology above 1 t/y capacity require EU/MS Authority permits with well specified requirements. In fact a pyrolysis technology in industrial scale is similar to a chemical industry, where beyond the main thermal unit a long list of different auxiliary installations operating for processing of different material streams, solid-liquid-gaseous chemicals and emission controls which all have strict EU/MS regulation defined requirements.

There are different types of pyrolysis technologies for different treatment and production purposes, from which the biochar processing is one of them. The treatment and production objective purposes makes big different between the different designs, such as for ex.

a) designed for **energetic** purpose or
b) designed for **waste treatment** purpose or
c) designed for **carbon refinery purpose,** such as the biochar, where the output carbon quality is the main production and production goal.

The biochar processing specific pyrolysis technologies are designed carbon refinery purpose only, as the only and unconditional engineering design goal in all elements of the construction. Any specific carbon production with specific pyrolysis technology from specific feed materials - resulting specific end-product quality, safety and character, - can be recognized as fingerprint of each specific biochar system. In each cases it is experienced, that the specific knowledge, industrial engineering know-how and design on the few successful pyrolysis technologies possessing confidential information and high business value.

5.2. Good practice guide for the biochar specific pyrolysis technology operators

All in order to support the EU/MS Authority permitted, legalized and **BIOCHAR SPECIFIC PYROLYSIS TECHNOLOGY OPERATIONS** with market competitive and economical industrial scale performance the key elements and concepts of a successful pyrolysis technology operation recommendations are as following:

1) comprehensive follow up and continuous documentation of all the EU/MS Authority **permit requirements** for pyrolysis installation operations, if requested allow Authority real time monitoring access through remote digital system,

2) **organization of continuous operations**, usually 8000 h/y, be careful for feedstock availability and planning of feed material supplies, environmentally sustainable feed material logistics to be selected, input feed material quality is continuously controlled,

3) **training and education** of the workers are critically important, especially in the beginning of the operations, the operations are based on the precautionary principle,

4) **identify biochar productions** for each series, make documentation and labelling,

5) **prevent occupational hazard** and make robust qualitative and quantitative assessment of emissions from pyrolysis process; in addition to the update of SDS EU and labels, employees must also update alternative workplace labelling and hazard communication programs as well as providing additional employee training for newly identified physical or health hazards,

6) make continuous, comprehensive and documented **monitoring** of the operations, including the biochar end-product quality and safety, all feed material inputs and product outputs. The constant material core temperature and residence time is to be defined and followed by the producer for each mono and multi constituent feed materials that will result targeted output biochar commercial product quality,

7) **carefully maintain the storage infrastructure**, with special highlight on the dust explosion risks and fire,

8) all materials streams – input feed output products – are weighted by Authority approved weighting balance, that makes also possible to establish and **document the operations material balance and document material routes,**

9) **prepare for emergency case;** such as explosion, fire and accident, start and stop procedures, aso; make regular training at least one a year for the emergency cases, lead by professionals,

10) attach valid **Extended Producer Responsibility certificate documentation** for each delivery batches from the production (full value legal and economical responsibility for the product safety and stated performance).

6. Recommendations that can be adopted for the use of biochar in agriculture

- When manufacturing biochar, an ideal technology would not produce other organic compounds at all, that are adsorbed on the surface, and since **the purpose of the biochar production is not to produce organic compounds inside the char**. Thus, the optional TEOC characterizes the success of production, mainly by measuring unwanted by-products.
- **Agronomical performance test should be accompanied to chemical, physical and microbiological analysis in order to guarantee farmers that they are using not only a safe products, but also a product with different positive effects on soil and plants.**
- Animal bone char can be considered as a reliable alternative to phosphorus chemical fertilizers, with both short term (nutrients) and long term effects to crops and soil. Consequently, farmers' willingness in the use of animal bone char is expected to be high.
- Lignocelluloses based biochar does not containing economically interesting nutrient add-on inputs to soil, can't be considered as a fertilizer, but only as a soil improver having long term effects. Consequently, farmers' willingness in the use of plant based biochar is expected to be very low if not accompanied by subsidies or other environmental/economical supporting measures.

- Biochar is safe for users, doesn't contain human pathogens, thanks to the high temperatures used for their production.
- **Biochar application to soil is irreversible; therefore, careful consideration and application doses strategy need to be made to avoid PTEs build ups at plant based biochar cases.**
- Plant based biochar does not supply nutrients only at very high doses (<20,000 kg/ha), but in that case the PTEs input will also be high. Animal bone based biochar is high nutrient content with very low PTEs impurities, and the usual application dose is from 200 kg/ha to 1000 kg/ha.
- The additional PTEs pollutants into the soil system should be minimised for minimising the negative environmental, human and animal health.
- PAHs are target contamination and **PAHs are biochar quality performance key indicators.**
- The higher application dosage may result in higher total PAHs loads to the agricultural land and possible contamination of subsurface groundwater above the drinking water limit.
- PCB_7 and PCDD/F are not target contamination in animal bone biochar and in plant based biochar products.
- The application of biochar in field can be easily achieved by the use of common agricultural machines used for the distribution of granulated fertilizers. Localized applications in the rows, near the roots, are recommended in order to reduce dosages and costs for farmers. Standard application dosages of animal bone char in the soil are expected to be 100-1000 kg/ha, according to soil conditions and crop uptakes.
- The use of biochar in growing media and potting mixes is easy to be carried out also by producers of substrates.
- Powder form of biochar are not recommended to be used by farmers, due to high risk of uncontrolled dust emissions.
- Application in combination with other fertilizers or as liquid form is recommended.
- A suppressive effect of biochar can be considered as an added benefit for farmers, but this is not expected in all cases and at all dosages. However, biochar can be used as a substrate for beneficial microorganisms and technological advanced formulations of biochar enriched with microorganisms are expected in the future.

Biochar production with variable and multi-constituent substance biomass by-product feed streams: The variable biomass by-product feed specification means, multi-constituent substance from a several source supply with variable compostions and PTE's, with more variation difference than 20%.

Table 10: Product testing requirements for Biochar production with multi-constituent and variable biomass by-product feed streams.

Annual input (tonne)	Sampling and analysis frequency (number/year)									
	Recognition year					Following years				
	Sampling			Analysis		Sampling			Analysis	
	Total	External	Internal	Full list	Targeted	Total	External	Internal	Full list	Targeted
<1000	2	1	1	2	0	2	1	1	1	1
< 5000	3	2	1	2	0	2	1	1	1	1
<10000	5	3	2	5	0	4	2	2	2	2

Internal sampling: must reach 80% of the external sampling results limit values. If the internal and external sampling results are different more than >20%, than in that case new external sampling to be taken. Each new feed material type should be externally sampled in recognition year.

Biochar production with mono-constituent well defined biomass by-product feed streams: the mono-constituent well defined biomass by-product feed specification means, mono structured materials from controlled industrial production conditions and which are well identified in terms of composition and PTE's, with not more variation difference than 20%.

Table 11: Product testing requirements for Biochar production with mono-constituent well defined biomass by-product feed streams.

Annual input (tonne)	Sampling and analysis frequency (number/year)									
	Recognition year					Following years				
	Sampling			Analysis		Sampling			Analysis	
	Total	External	Internal	Full list	Targeted	Total	External	Internal	Full list	Targeted
<1000	1	1	0	1	0	1	1	0	1	0
< 5000	2	2	0	2	0	2	1	1	2	0
<10000	3	2	1	3	0	2	1	1	2	1

Internal sampling: must reach 80% of the external sampling results limit values. If the internal and external sampling results are different more than >20%, than in that case new external sampling to be taken. Each new feed material type should be externally sampled in recognition year.

7. Standardisation and accreditation of biochar analytical methods in Wessling laboratory

The appearance of the ABC and PBC are very similar, although their composition is greatly different. PCB is stabile carbon content plant origin micro- and meso porous material while ABC is high calcium phosphate apatite mineral and low carbon content macroporous material. However, same analytical test methods are suitable for both. In the REFERTIL project, WESSLING Hungary Ltd. is responsible for detailed and accredited analytical characterization of ABC, PBC and all sample streams.

Biochar is new product; therefore careful and material specific consideration is needed for all analytical items, also which standard to be applied. As the end result of the REFERTIL project, the goal was for the Environmental Testing Laboratory of WESSLING Hungary Kft. to be the first laboratory in Europe to obtain accredited status for different analyses of the biochar sample type.

Accreditation of the analytical activities related to the REFERTIL project is an important step to be able to support the application and legal standardization oriented research work with analytical activities that have a recognized quality management background (Table 1), in addition to the proper professionalism. It is also an important step to **support the legal standardization and mandatory permit process of biochar industrial production**, application and commercialisation.

Quality management acivities of WESSLING Hungary Ltd.:

1. Working under well controlled workplace environmental conditions (temperature, filtered air exchange, humidity, lighting, workplace <10 m2/person)
2. Using validated methods (standards: ISO, EN, EPA, published and validated methods: AOAC, LMBG)
3. Using controlled and maintained equipments
4. Using certified measure etalons (weights)
5. Using certified or calibrated laboratory measuring tools
6. Using laboratory chemicals from assessed supplyers
7. Using certified reference materials (CRMs)
8. Using Control charts to assess our serially measured results
9. Measuring recycled real samples (comparison the relevant results) regularly
10. Carrying out in-house audits regularly

Accreditation is the official recognition that an organization is competent (suitably prepared) to perform certain activities (analysis, certification, control, verification) adhering to specific conditions. The accreditation is performed by national accreditation organizations satisfying requirements prescribed in international standards. The accreditation body is legally authorized (with exclusive powers) by the MS government under EU regulations. There are standardized requirements on the European and international levels that apply to accreditation bodies, and competence, preparedness and proficiency in performing these requirements is recognized by the accreditation. The goal of accreditation is to ensure professional performance of compliance evaluations, and to eliminate multiple analyses and certifications of products and services in order to remove technical obstacles to trade. In other words, to increase trust in organizations that have obtained recognition in accreditation

systems built on uniform European principles, to raise the reliability of analytical, certification and control activities, to promote mutual acceptance of analytical results and certificates, thus eliminating repeat analyses and removing technical obstacles to trade.

The Environmental Testing Laboratory of Wessling Hungary Kft. had already been accredited for hundreds of different analyses of several sample types.

Table 12: Summary about the number of accredited methods after the expansion of scope.

Sample type	***Number of the accredited methods***
Waters (drinking water, mineral water, medicinal water, bath water, groundwater, surface water, waste water, extract water and high purity laboratory water)	96
Wastewater	3
Sewage sludge	40
Soil and sediment	46
Dust	1
Solid and liquid phase wastes (dangerous, industrial wastes and sludge)	59
Solid recovered fuels	17
Air (indoor-air, ambient air, soil-gas)	84
Biogas	2
Asbestos-containing materials	1
Soil improvers and fertilizers (compost, biochar, fertilizer)	31

Most of the standards selected for biochar qualification were chosen from among currently valid CEN/ISO standards. **As biochar is a new product, for a number of parameters it was necessary to adopt soil or waste analytical methods, which were validated** to assess their analytical performance.

Validation methods were developed to check the suitability of not entirely standard methods to be used in laboratory practice. Applicability of the selected analytical methods had to be proven for this new biochar sample type and, when the method had to be modified, the complete analytical process had to undergo a validation procedure. At the end of the validation, applicability of the method was verified by confirmation of the goodness of suitable system parameters.

Confirmation of specificity, selectivity and linearity generally went smoothly with standard methods, there were no problems with repeatability, but for the accuracy of the method (because of the special surface activity of biochar products), and the sample preparation process had to be modified in some cases.

The accreditation procedure was initiated at NAT (National Accreditation Body) after almost two years of continuous work. During this period, WESSLING gained significant experience in this analytical area and maintained the external and internal quality assurance activities as well.

Finally, after years of technical development and gaining experience, and after a one and a half year long legal procedure, within the framework of the REFERTIL project, the Wessling laboratory was awarded the accredited status necessary for the analysis and qualification of biochar products – as the **first biochar accredited laboratory in Europe and global as well**.

The REFERTIL partner - **The Environmental Testing Laboratory of WESSLING - is the first laboratory in Europe who obtained accredited status, under Wessling-NAT-1-1398/2012, for comprehensive analyses of biochar samples.** The accreditation has been developed for the both types of biochar ("PBC" and "ABC") for organic Phosphorus fertiliser, soil improver and growing media applications.

According to the mutual recognition agreements[5] [6], activities of NAT and organizations accredited by NAT are **recognized internationally** by all other signatories. **According to Regulation EC 765/2008, authorities of the member states of the European Union are obligated to accept the results of organizations accredited by NAT.**

This means, that the Environmental Testing Laboratory of WESSLING Hungary Kft. possesses a certification as an independent testing laboratory under reg. no. NAT-1-1398/2012, its management system satisfies the requirements of standard MSZ EN ISO/IEC 17025:2005. **Wessling laboratory biochar accreditation: NAT-1-1398/2012**[7]

Table 13: Detailed area of the accredited methods from Soil improvers and fertilizers.

Soil improvers and fertilizers (compost, biochar)	Dry matter content
	Ash content
	Particle size distribution
	Bulk density
	Iodine number
	pH
	Nitrite
	Nitrate
	Sulphate
	TOC (Total Organic Carbon)
	TC (Total Carbon)
	TN (Total Nitrogen)
	Ammonium-nitrogen
	CEC (Cation Exchange Capacity)
	Nutrient elements (P, K, Ca, Mg, S, Na)
	Micronutrients (Fe, Cu, Zn, Mn, B, Se, Mo, Cu, Al, Si)
	Phosphorous, water soluble
	Phosphorous, citric acid soluble

[5] Multilateral Agreement of the European Cooperation for Accreditation (EA MLA) in the areas of analysis, calibration, control, product certification, management system certification and person certification.

[6] Mutual Recognition Arrangement of the International Laboratory Accreditation Cooperation (ILAC MRA) in the areas of analysis and calibration.

[7] http://nat.hu/okiratok/NAT-1-1398-2012-04BRO1.pdf (page 109-112)

	Phosphorous, ammonium-citrate soluble
	Phosphorus, Olsen-solvent
	Water soluble nutrient elements (K, Mg, Ca, S, Na, P, Si, Fe, B, Mo)
	PTE compounds (Pb, Cr (total), Cr(VI), Cd, Co, Hg, Ni, As, Al, Ba, Ag, Be, Li, Sb, Sn, Sr, V, Tl, Si, Pb)
	PAHs (Polyaromatic Hydrocarbons) (19 compounds) CEN/TS 16181:2013
	PCBs (Polychlorinated Biphenyls) (7 compounds)
	VOC (Volatile Organic Compounds)
	TEOC (Total Extractable Organic Compounds)