

## BIOCHAR TESTS & SERVICES



Combustion



Plant Growth Trials



Upgrading



Biochar Production



Technoeconomics



TGA Analysis



PAH Analysis



Feedstock Evaluation



Surface Area



Research  
Collaborations



Biochar  
Analysis



Carbon  
Sequestration

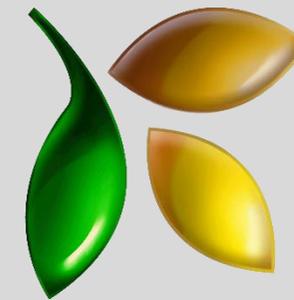
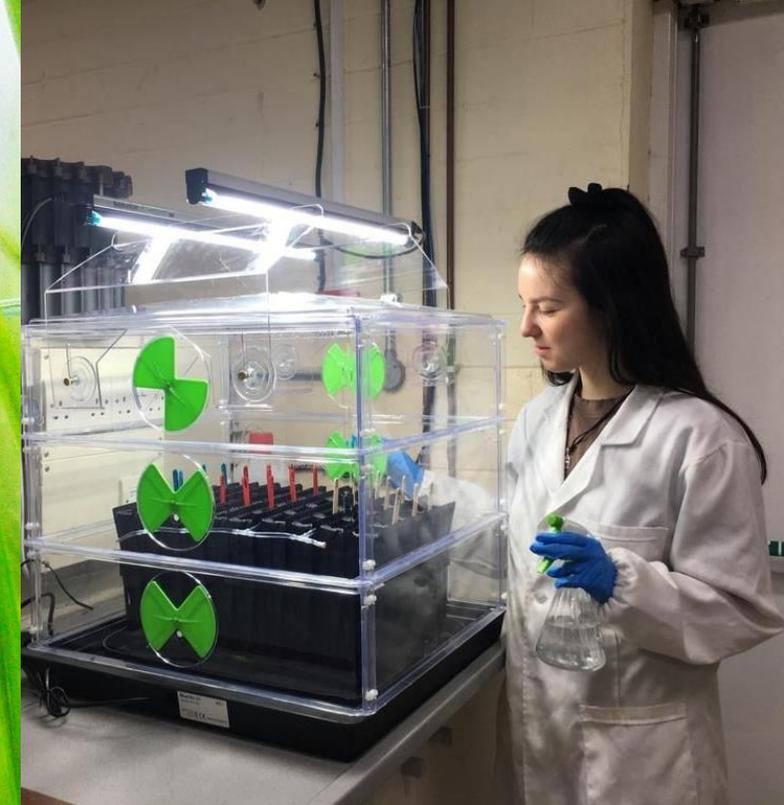
## OUR HISTORY



Celignis launched in 2014 as a spin-out of pioneering research undertaken at the University of Limerick in Ireland. Over the subsequent years we have grown rapidly in size and reputation, with a global client base. We now occupy two sites (Celignis Analytical and Celignis Bioprocess) and offer a full spectrum of services for stakeholders looking to valorise biomass and wastes.

## Celignis Analytical & Bioprocess

- Wide array of analytical services for biomass and seaweed.
- World-renowned expertise in biogas & anaerobic digestion.
- Bioprocess development services for TRLs 1-6.
- Particular expertise in biological processing of biomass and side-streams (e.g. fermentation, enzymatic hydrolysis etc.)
- A global client base of over 1000 customers.
- Team of qualified (PhD) and passionate biomass experts.
- Partners in multiple international research projects.
- Winner of "Innovation of the Year" award in 2021.



# Celignis



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Analysis and Process  
Services for Biochar

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## BIOCHAR ANALYSES



**Compositional:** Comparison of biological polymers before/after pyrolysis, separate analyses for organic and inorganic carbon.



**Thermal:** Thermogravimetric analyses (TGA), Ash melting behaviour, Calorific value, Proximate and ultimate analyses.



**Soil Amendment:** Major and minor elements, Electrical conductivity, Water-Holding capacity, Cation exchange capacity, Plant growth trials, Polycyclic Aromatic Hydrocarbons (PAH), SEM imaging.

## WE CAN ALSO PRODUCE BIOCHAR

Using a wide range of conditions (e.g. temperature, residence time, heating rate). We can target biochar of the desired specifications for your application sector.

## Plant Growth Trials Using Biochar

- Can be run at various scales, ranging from small pots in the lab to large trays in a dedicated greenhouse.
- We consider the effects of various variables, including:
  - Biochar type (from different feedstocks or from one but using different pyrolysis/upgrading conditions).
  - Biochar loading rate.
  - Soil and plat type (e.g. potato, tomato, corn, lettuce).
- Each set of conditions is run in triplicate and compared against a control where no biochar is used.
- Data collected on yield, plant health & soil biology.

## Detailed Reporting & Actionable Data

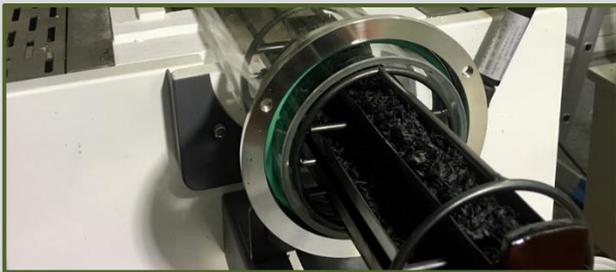
- Data at your fingertips with the Celignis Database!
- Our reports include personally-written interpretations for some analyses and PASS/FAIL tables where results (e.g. PAHs, heavy metals) are compared against limits from the European Biochar Certificate for various end-uses.

EBC Thresholds Comparisons

EBC Cert. Class	Analyte	Units	Value	EBC-Feed	EBC-Agro Organic	EBC-Agro	EBC-Urban	EBC-Consumer Materials	EBC-Basic Materials
Element	H/C <sub>org</sub>		0.51	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Heavy Metals	Pb	g t <sup>-1</sup>	<1	10	45	120	120	120	N/A
	Cd	g t <sup>-1</sup>	<1	0.8	0.7	1.5	1.5	1.5	N/A
	Cu	g t <sup>-1</sup>	14	70	70	100	100	100	N/A
	Ni	g t <sup>-1</sup>	42	25	25	50	50	50	N/A
	Hg	g t <sup>-1</sup>	<1	0.1	0.4	1	1	1	N/A
	Zn	g t <sup>-1</sup>	273	200	200	400	400	400	N/A
	Cr	g t <sup>-1</sup>	74	70	70	90	90	90	N/A
Organic Contam.	16 EPA PAH	g t <sup>-1</sup> DM	2.9070	N/A	4 ± 2	6 ± 2.2	N/A	N/A	N/A
	8 EFSA PAH	g t <sup>-1</sup> DM	<0.0001	1.0	1.0	1.0	1.0	1.0	4

- Data at [www.celignis.com/output/analytical\\_customer\\_view.php?editid1=33297](http://www.celignis.com/output/analytical_customer_view.php?editid1=33297) Lab Manager Signature:  
 - Green = below threshold value; Red = above threshold value; Black = Not

## Our Services



## Services for Biochar Producers and Users

- Screening of biochar feedstocks.
- Data analysis tools link process and analysis data.
- Assess biochar carbon sequestration potential.
- Approaches to reduce levels of PAHs in biochar.
- Technoeconomic analyses of biochar projects, using analysis and experiment data, considering various production scales and scenarios.
- Collaboration in national/international research.
- Advice, based on analytical and application test results, on suitable markets for a given biochar.

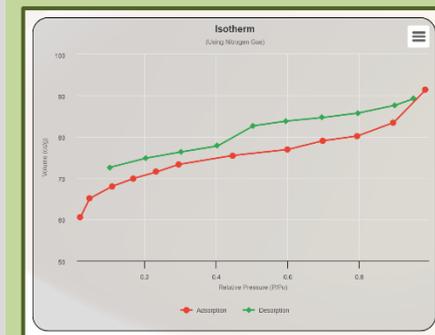


## Upgrading Biochar for High-Value Applications

- Physical (heat-treatment) and chemical activation.
- Washing methods tested for soil amendment is end-use.
- Surface functionalization (chemical and biological).
- Blending biochar to produce high-value composites.
- Our approach for upgrading considers your target application sector and initial properties of your biochar.
- Close iterative feedback between analysis and process data allowing optimized upgrading with less experiments.

## Physical Analyses of Biochar

- Surface area and pore-size distribution. We use nitrogen or carbon dioxide and give recommendations of suitable end-uses for the biochar based on the data.
- Where different pyrolysis and/or upgrading methods are used we can employ data analysis tools to explore the effect on surface area and pore-size distribution.
- Thermogravimetric analysis for screening biochar feedstocks and testing thermal stability of biochar.

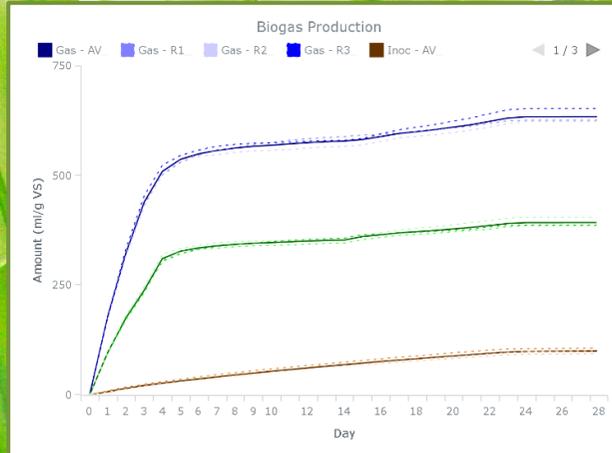


## OUR AREAS OF EXPERTISE



## The Celnigis Database

Our online reporting system provides a level of detail never seen before in the analysis of AD feedstocks. Biogas production data are updated daily and we provide an array of information in tabular and graphical forms regarding feedstock, digestate, and biogas composition as well as statistics on the efficiency of digestion.



# Celnigis Analytical

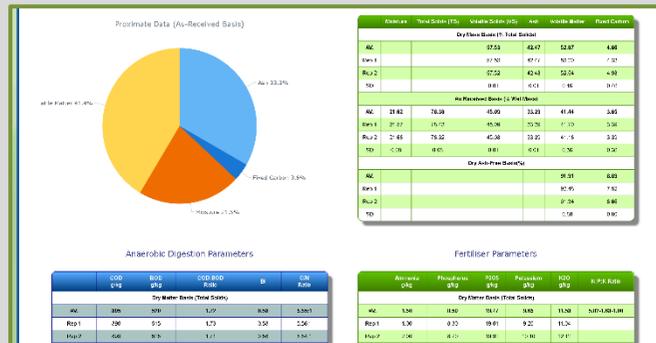


## WHO WE ARE



Dr. Dan Hayes, CEO – Founder

“Celnigis was born from research that targeted replacing fossil-fuels with sustainable biofuels. We found that feedstock composition was crucial, but that literature data could be highly misleading. We are driven to provide the most accurate analysis and want to play our part in the development of the bioeconomy.”



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## Analysis Services for Anaerobic Digestion

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## BIOMETHANE POTENTIAL



BMP is the maximum potential of the feedstock to produce methane when anaerobically digested under ideal conditions.



It is the starting point for biogas plant design and to process the selected feedstock with maximum efficiency.



It can be used to test: combinations of feedstocks; rates of degradation of high organic-content waste streams; maximum organic loadings; and inhibition factors.

## WHY CHOOSE CELIGNIS?

Our team of analytical experts is committed to provide high-quality data and detailed reports on the biomass feedstocks of customers.

### Testimonials

"Celignis has characterised a large number of our complex biomass samples using their NIR method and chemical analysis methods. We have been impressed with both the quality generated of data and the attention to detail employed in their analysis."

Darragh Gaffney PhD, R&D Manager Monaghan Biosciences

"Arigna Fuels has been working in conjunction with Dan and the team at Celignis for a number of years. Alone and as part of a larger consortium that are members of the International Biomass Torrefaction Council (IBTC), we have been characterising thermally processed biomass and their corresponding raw materials for the purposes of producing a domestic heating fuel. We receive a professional, amiable and rapid service from Celignis and wouldn't hesitate to recommend them to others."

Robert Johnson PhD, R&D Manager at Arigna Fuels

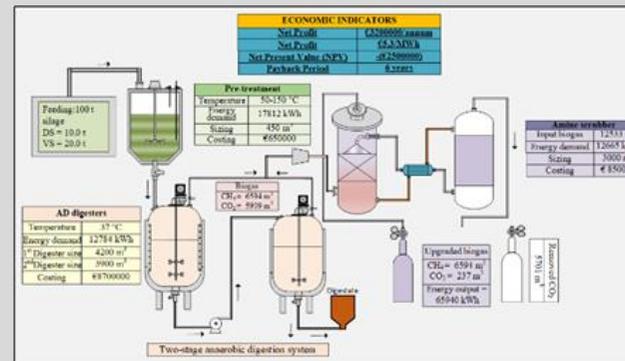
The members of the Celignis team are available by phone/email to discuss results and provide advice on the next steps in feedstock valorisation and process optimisation.

## Our Analysis



### Standard & Deluxe BMP Analysis

Sample incubation time is 14, 21, 28, or 40 days. We analyse the biogas for its composition ( $\text{CH}_4$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{NH}_4$ ,  $\text{O}_2$ ). We report the Total Biogas Volume and the BMP on the basis of ml per g Volatile Solids (VS), Total Solids (TS) and fresh weight. The Deluxe packages also include the Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Phosphorus, Potassium, Ammonia, Carbon, Hydrogen, Nitrogen and Sulphur contents for the feedstock and the digestate, allowing us to give insights on the efficiency of digestion.



### Process Modelling & Techno-Economic Analysis

We provide technical expertise on process modelling of various bioprocess technologies such as anaerobic digestion and fermentation of potential biomass feedstock and organic waste streams. This includes high-end software modelling and optimization research coupled with rigorous techno-economic analysis (TEA) to determine cost-effectiveness of potential bioprocess technologies. Our experts are Doctorial graduates with substantial experience in modelling and TEA.

## OTHER RELEVANT ANALYSES

We can analyse feedstocks and digestates for a range of properties, including proximate, ultimate, and chemical compositions. We are experts in biomass chemistry and our data can help understand the efficiencies of digestion of biogenic polymers (e.g. cellulose, hemicellulose, lignin). We can also determine the residual biogas potential (RBP) of digestates from AD facilities.



## AREAS OF EXPERTISE



Extraction



Fermentation



TEA Analyses



TRL7 Scale-Up



Full Project Dev.



Use of Enzymes



Pre-treatment



Biomass Hydrolysis



Lab-Scale Optimisations



Research Collaborations



Downstream



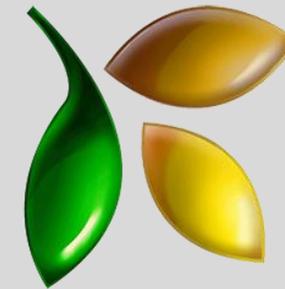
Biobased Chemicals

## Our Bioprocess Background

- Operational for 10 years as an analytical and bioprocess lab.
- A global client base of over 1000 customers.
- Team of qualified (PhD) and passionate biomass experts.
- Multidisciplinary expertise (engineers, chemists, biology experts, technoeconomic analysis, business development).
- Dedicated building for bioprocess development up to TRL7.
- Members of the renowned Biobased Industries Consortium.
- Bioprocess partners in many international research projects.
- Winner of "Innovation of the Year" award in 2021.



## Why Celignis?



**Celignis**  
Bioprocess

We develop and refine processes to efficiently valorise biomass. We can work on individual process stages or can develop a bespoke vertically-integrated process based on your feedstock or desired product. This can be done from lab-scale to the 1m<sup>3</sup> level. Our understanding of biomass chemistry, our extensive array of bioprocessing equipment, and the biological, engineering, and commercial experience of our team, all ensure that our projects are well-designed and focused on our clients' end-goals.



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Bioprocess Development  
Services

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## HOW OUR BIOPROCESS SERVICES WORK



**Understand Your Requirements:** This includes an audit of the existing process and detailed analysis of feedstock and process streams.



**Lab-Scale Development of Bioprocess:** We follow a science-based Design of Experiments approach for process optimization.



**Validation at Higher TRLs:** We run the optimized bioprocess at enhanced scales (up to 1m<sup>3</sup>). The process is adapted to respond to any scale-up issues. There follows a detailed techno-economic analysis of the process.

## TECHNOECONOMIC VIABILITY IS CRUCIAL

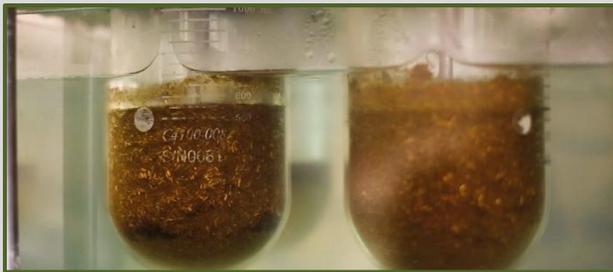
We evaluate bioprocesses, considering various scale, tech, and feedstock options. We use costing models to determine CAPEX/OPEX of simulated processes, then used to find key economic indicators (e.g. IRR, NPV).

### Case Studies

- **Bioethanol from Palm Residues:** This was a lab-scale vertically-integrated project covering pretreatment, and separate hydrolysis and fermentation (SHF). The project involved a series of lab-scale experiments focused on optimising the pretreatment conditions so that the yields and commercial viability of the process as a whole could be improved. The next stage involved optimising the type and dosage of enzymes, as well as other factors (e.g. solid-loading), to maximise ethanol yields from the targeted biomass components.

- **Glycerol from Industry Side-Streams:** This project focused on the hydrolysis of cellulosic side-streams from an industrial process, followed by the fermentation of the liberated sugars into a variety of products, including glycerol, ethanol, and organic acids. Following the lab-scale work, we worked on a TEA analysis of the bioprocess, considering several different scenarios. The outputs of this TEA informed a follow-on bioprocess development project, incorporating the changes deemed to give greatest impact to the process in terms of commercial and environmental sustainability. The final stages of this project will involve scaling up the developed approach to the 100-litre level.
- **Production of Propionic Acid.**
- **Biomaterials from Caribbean Seaweed.**
- **Sugars from Paper Side-Streams.**
- **Oligomers of Targeted Chain Lengths from Biomass.**
- **Bioactives from Tropical Hardwoods.**
- **Sustainable Downstream Purification Process Developed.**

## Our Services



### Optimising Pretreatment and Hydrolysis

- Removal of biomass extractives and recovery of valuable bioactives from these fractions.
- Steam and hydrothermal pretreatments.
- Use of acids, alkalis, and solvents in pretreatments.
- Acid hydrolysis of biomass (concentrated & dilute).
- Enzymatic hydrolysis process development (Separate Hydrolysis and Fermentation (SHF), Simultaneous Saccharification and Fermentation (SSF), Simultaneous Saccharification and Co-Fermentation (SSCF).



### Development and Optimisation of Fermentations

- We're fermentation experts & understand crucial factors (biomass, microbes, nutrient media, conditions). We can optimize yields of an array of fermentation products.
- Bacterial fermentations - Lactic Acid, Propionic Acid, Butyric Acid, Butanol, 1,3-PDO, PHAs Production.
- Yeast and Fungal Fermentations - Ethanol, Glycerol, Single Cell Oils, Emulsifiers.
- Microalgal Fermentation.

### Downstream Processing

- This can account for a large portion (sometimes up to 80%) of the total production costs, particularly in processes dealing with dilute concentrations of the target product or complex mixtures. Hence, optimising this stage is vital for a commercially-viable process.
- We have an array of downstream equipment that can operate up to TRL7 (tangential flow filtration, filter press, filter-dryer, supercritical CO<sub>2</sub>, distillation).



More information available at the Celignis Bioprocess Hub:

[www.celignis.com/bioprocess-development](http://www.celignis.com/bioprocess-development)

## OUR AREAS OF EXPERTISE



## Celignis Analytical & Bioprocess

- Wide array of analytical services for biomass and seaweed.
- A leading bioeconomy lab for the last 10 years.
- Two separate locations (Celignis Analytical & Bioprocess).
- World-renowned experts in biomass chemistry & processes.
- Bioprocess development services for TRLs 1-7.
- A global client base of over 1000 customers.
- Team of qualified (PhD) and passionate biomass experts.
- Partners in multiple international research projects.
- Won "Innovation of the Year 2021" (for seaweed process).



## Why Celignis?



We launched in 2014 as a spin-out of pioneering research from the Uni. of Limerick in Ireland. Over the years we've grown rapidly in size and reputation, with a global client base. We now occupy two sites and offer a full spectrum of services for stakeholders looking to valorise biomass and waste. We see huge potential for biomass to sustainably meet global energy and material needs. Through innovation, passion, and determination, we strive to make a difference in the development of the bioeconomy



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Seaweed Analysis  
Services

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## TYPES OF SEAWEED ANALYSED



**Brown Seaweed:** Thousands of samples analysed, including many kelp varieties, *Sargassum*, *Undaria*, *Laminaria* and others.



**Green Seaweed:** Hundreds of samples analysed, including *Ulva*, *Caulerpa*, *Cladophora*, and others.



**Red Seaweed:** Hundreds of samples analysed, including *Porphyra*, *Gracilaria*, and others.

**Seaweed Fractions:** We have analysed isolated fractions (e.g. alginate, fucoidan) for composition, molecular weight, and purity.

## Our Seaweed Services

## WE HAVE CUSTOMS EXEMPTIONS

We also have customs exemptions for samples sent to us for analysis and research, allowing us to quickly get to work no matter where our clients are based.

### Custom Analysis Method Development

- Sajna KV (PhD) has developed new and customised analysis methods, according to our clients' needs, for seaweeds and other biomass. Sajna also participated in the NIST Quality Assurance Program (Seaweed).



## Seaweed Bioprocess Project Case Study

- Isolation of Seaweed Polymers for Production of Sustainable Biomaterials:** This project concerned the development of a new sustainable process for the extraction, and subsequent modification, of alginate from seaweed. The process, developed by Celignis for our client, allowed for alginate extraction without the use of harsh chemicals (e.g. bleaches) and also considered the valorisation of process side-streams (e.g. fucoidan, cellulose etc.).
- The target of the project was polymers of improved properties for application in a variety of different biomaterials applications. We found that tweaks in the extraction and modification stages of the bioprocess could influence the physicochemical properties of the resulting alginate, allowing the process to be tailored for producing different types of materials for different end-uses.



## Seaweed Analysis Packages

- P71 - Seaweed Carbohydrates:** Fucose, Mannitol, Glucose, Xylose, Mannose, Arabinose, Galactose, Rhamnose, Total Sugars, Glucuronic Acid, Galacturonic Acid, Mannuronic Acid, Guluronic Acid
- P72 - Amino Acids:** Alanine, Arginine, Aspartic Acid, Cystine, Glutamic, Glycine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Proline, Serine, Threonine, Tyrosine, Valine.
- P33 - Ultimate (Elemental) Analysis:** Carbon, Hydrogen, Nitrogen, Sulphur, Oxygen, Ash.

- P38 - Major and Minor Elements:** Aluminium, Calcium, Iron, Magnesium, Phosphorus, Potassium, Silicon, Sodium, Titanium, Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Molybdenum, Nickel, Vanadium, Zinc.
- P73 - Seaweed Lipids as Fatty Acids:** Arachidic Acid, Behenic Acid, Decanoic Acid, Erucic Acid, Lauric Acid, Linoleic Acid, Linolenic Acid, Myristic Acid, Caprylic Acid, Oleic Acid, Palmitic Acid, Palmitoleic Acid, Stearic Acid.
- P74 - Pigments in Seaweed:** Fucoxanthin, Astaxanthin, Chlorophyll-c, Chlorophyll-a, Chlorophyll-b, Lutein, beta-Carotene, Neoxanthin, Antheraxanthin, Violaxanthin.
- P75 - Seaweed Phytohormones:** Gibberellic Acid, Indole-3-Acetic Acid, Indole-3-Propionic Acid, Indole-3-Butyric Acid, 6-Benzylamino-Purine, Kinetin-Riboside, Abscisic Acid, Salicylic Acid, Zeatin.
- P76 - Vitamins (Fat-Soluble) in Seaweed:** Phyloquinone, Tocopherol, beta-Carotene
- P77 - Vitamins (Water-Soluble) in Seaweed:** Thiamine, Niacin, Nicotinamide, Pyridoxine, Folic Acid, Riboflavin, Pantothenic Acid, Ascorbic Acid, Biotin.

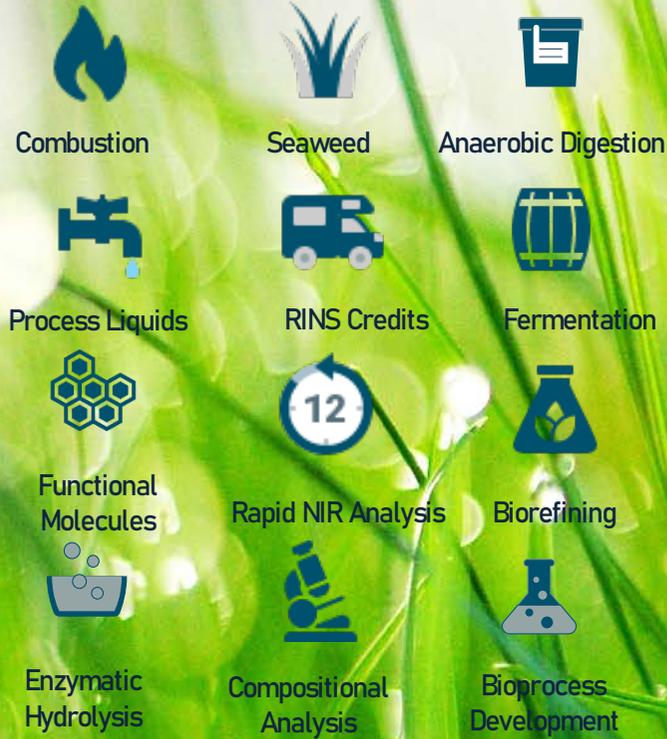
- P78 - Total Phenolics in Seaweed.**
- P79 - Seaweed Phenolics Profiling:** Acids (Gallic, Caffeic, Chlorogenic, Ferulic, Coumaric, Protocatechuic), Catechin.
- P155 - Polyamines:** Dopamine, Histamine, Serotonin, Phenylethylamine, Putrescine, Cadaverine, Norspermidine, Spermidine, Spermine, Tyramine, Agmatine.
- P170 - Total Tannins in Seaweed.**
- P171 - Molecular Weight Analysis: Alginate.**



More information available at the Celignis Seaweed Hub:

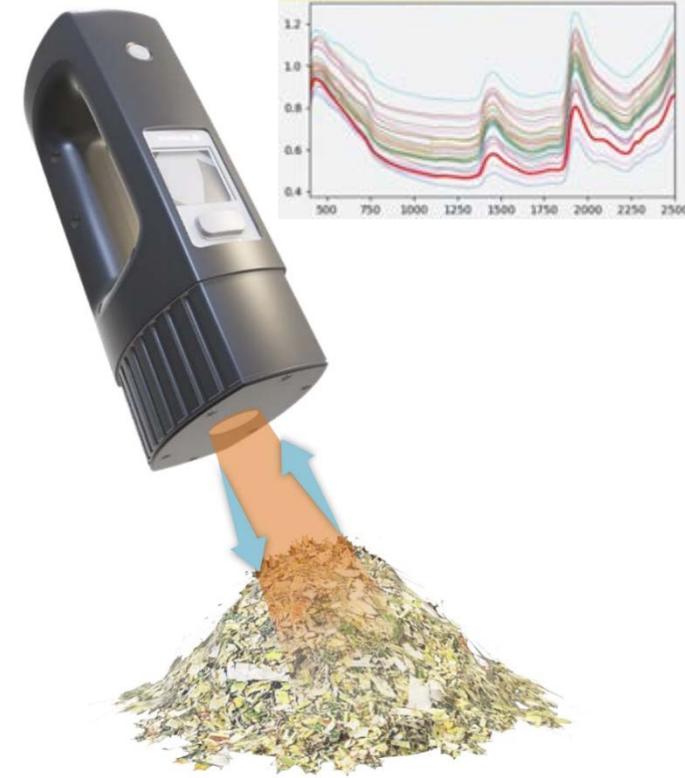
[www.celignis.com/seaweed-analysis](http://www.celignis.com/seaweed-analysis)

## OUR AREAS OF EXPERTISE



## Advantages of On-Site Analysis

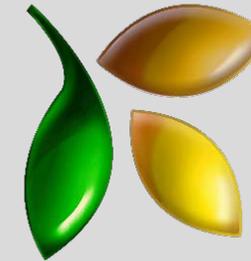
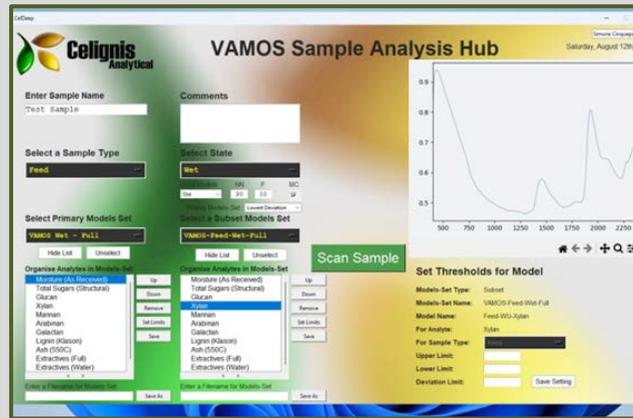
- Samples can be analysed in seconds.
- No chemical or statistical expertise required for operators.
- Actionable data can allow for informed process decisions.
- Cost of annual contract significantly less than employing a dedicated chemical analyst. Can be divided across thousands of NIR scans allowing for minimal per-sample analysis costs.
- Equipment and NIR models are updated by Celignis.
- Email and phone support from Celignis biomass experts.
- Models can be adapted to process and feedstock changes.



## Why Celignis?



We are biomass experts that have been developing NIR models for cellulosic feedstocks and side-streams since 2014. Our models are highly accurate, for both wet and dry samples, and have been demonstrated for a number of different biorefining technologies. This includes most recently for the multinational VAMOS project which saw the deployment of the CelDeep tool at a demo-scale biorefinery. Our developed approach and serviced models are highly replicable to many different types of biorefining processes.



# Celignis Analytical



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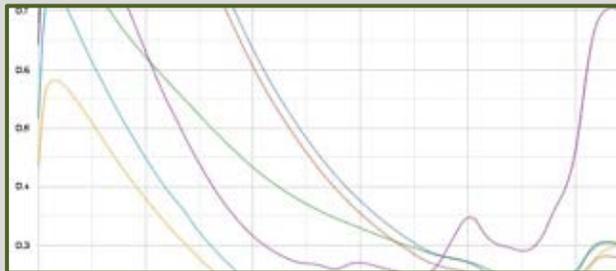
## Rapid Biomass Analysis at Your Facility

[www.celignis.com](http://www.celignis.com)

## BACKGROUND: CELIGNIS NIR MODELS

- Celignis has offered Near Infrared (NIR) predictions of the lignocellulosic composition of biomass since 2014. This reduces analysis time from weeks to seconds.
- We're the only company with robust models for cellulosic feedstocks, covering thousands of samples.
- Until recently, clients' samples were analysed within Celignis's labs and the results then delivered by email.
- Recent technological advancements have greatly reduced the cost of suitable NIR hardware.
- Celignis is now able to offer a combined package of equipment leasing and NIR-model development, enabling clients to use Celignis models on-site.

## Rapid On-Site



## Predicted Compositional Parameters

- Structural sugars (glucan, xylan, mannan, arabinan, galactan).
- Klason lignin content.
- Extractives, ash, and moisture contents.
- Additional parameters possible.
- For each parameter the models provide two values – the predicted amount and the estimated error (deviation) in prediction. High deviation samples are less-well predicted by the models and should be retained for chemical analysis at Celignis

## SUITABLE SAMPLE TYPES

Solid biomass, slurries, pre-treated samples, enzymatic hydrolysis residues, process side-streams. Models can be developed for wet and/or dry samples.

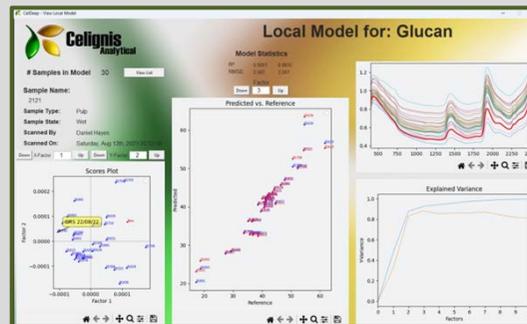
## How it Works

- **Stage 1: Custom Model Development** – NIR models require the development of algorithms that relate spectral data to compositional data, determined via reference (i.e. chemical analysis) methods. Due to the variation in feedstocks and technologies between biorefineries, bespoke algorithms need to be developed for each facility. This is done by the client posting around 200 samples to Celignis's labs where the analysis is undertaken, the results uploaded to the Celignis Database, and the Stage 1 models developed.

- **Stage 2: Routine Analysis and Model Revisions** – After Stage 1 the client is able to use the handheld NIR scanner on-site and gain access to the bespoke NIR models developed by Celignis. Data are provided via the CelDeep software and are accessible online on the CelDeep Process Control website. We understand that cellulosic technologies are constantly being developed and improved and that this can lead to new types of samples being produced over time. It's therefore important that the NIR models adapt to these changes. As part of the annual contract, Celignis will analyse up to 15 samples per month in its laboratories and will use the obtained data to iteratively update the models so that their accuracy and robustness improves. The CelDeep software can provide suggestions to the user regarding which samples should be retained for chemical analysis at the Celignis labs.
- **Stage 3: Contract Renewal** – The contract renews annually, allowing for continued access to the models and hardware.

## Annual Contract

- €65,000 per annum.
- Covers the chemical analysis of up to 200 samples in Yr 1, to develop the first iterations of the bespoke models.
- Covers the subsequent chemical analysis of up to 15 samples per month and associated updating of models.
- Includes unlimited scans on-site and access to models.
- Renewal for subsequent years allows for continued access to the models and monthly model servicing.



## CelDeep Software Tool

- A powerful tool for viewing the outputs of the NIR models.
- Provides the user with great flexibility regarding which models are applied for each type of sample.
- Allows the user to set threshold values for each property.
- Results can be directly emailed to contacts from CelDeep.
- There is also an associated website (CelDeep Process Control) where control plots can be viewed for selected sample types and compositional parameters.

