

Inventory of North-West European algae initiatives

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Author

Joanneke Spruijt, Wageningen UR, NL

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Inventory of North-West European algae initiatives

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Inventory of North-West European algae initiatives

1 Introduction

In 2012 an inventory of North-West European (NWE) algae initiatives was carried out to get an impression of the market and research activities on algae production and refinery, especially for bioenergy purposes. The study was designed to obtain the baseline conditions of algae facilities and pilots in NWE at the start of the 'EnAlgae' INTERREG IVB NWE project.

A questionnaire was developed (Annex 1) that would provide the EnAlgae project with information on the value chains in which algae production was positioned within these initiatives. This information could help us to identify the business cases that the algae industry is targeting and those concepts thought by industry to have the highest potential and feasibility. The questionnaire was developed in Excel and was used by EnAlgae project partners to collect information in Great Britain, Ireland, Germany, Belgium, France, Switzerland, Luxemburg and the Netherlands. Information about algae initiatives originated from networks and from internet searches. Additional information was collected by bilateral contact with contact persons of several initiatives. Not all the required information was available for all the initiatives. The analysis of the results is reported here.

2 Initiatives per country

In total 117 initiatives were reported by the EnAlgae partners. Most initiatives were found in Germany and the Netherlands, followed by France. In the United Kingdom 32 algae initiatives have been reported, although for the purpose of this analysis we include only those that provided extra information in addition to a name (16). Relatively few initiatives were found in Belgium, Ireland and Switzerland (Figure 1).

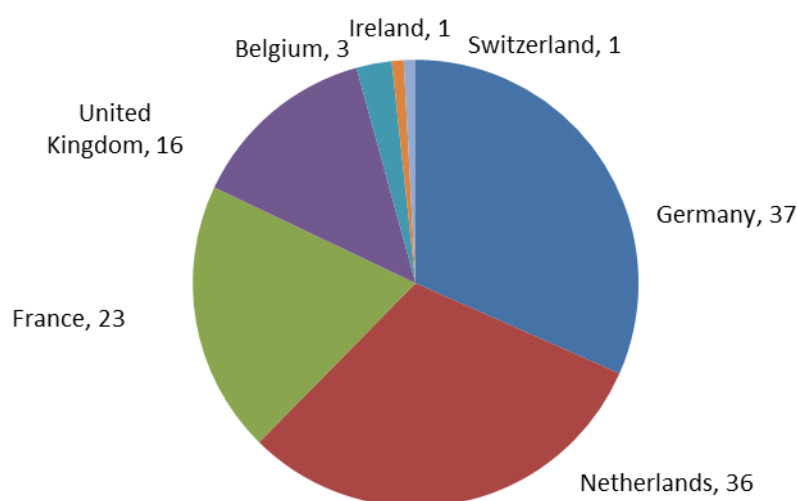


Figure 1: Number of reported algal initiatives per country.

3 Algae type

The main focus of these 117 initiatives is on microalgae, although especially in the UK information on macroalgae initiatives was also captured as shown in Figure 2. There is limited information about the used species. Most frequently mentioned for microalgae were Chlorella (15), cyanobacteria (5), Nanocloropsis (4) and Scenedesmus (4) and unspecified mixtures. Ulva is the most mentioned (3) macroalgae.

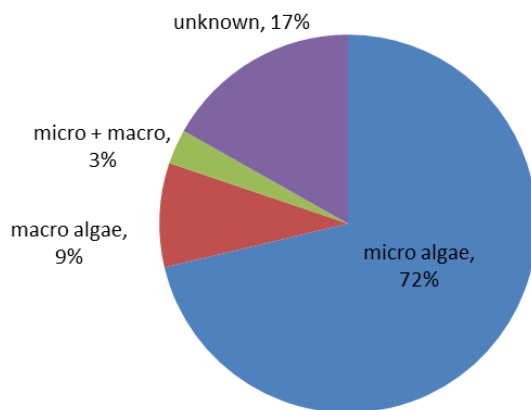


Figure 2: Focus on algal type as a percentage of all the initiatives.

Table 1: Focus on algal type as a percentage of the initiatives per country.

	DE	NL	FR	UK	Total
Microalgae	70%	61%	96%	63%	72%
Macroalgae	3%	6%	0%	38%	9%
Micro- + macroalgae	3%	3%	4%	0%	3%
Unknown	24%	31%	0%	0%	17%
	100%	100%	100%	100%	100%

4 Organisations involved

Most algal facilities across NW Europe are initiated and operated by private organisations (see Figure 3). Germany appears to be the exception, with relatively more operators found in scientific organisations (Table 2).

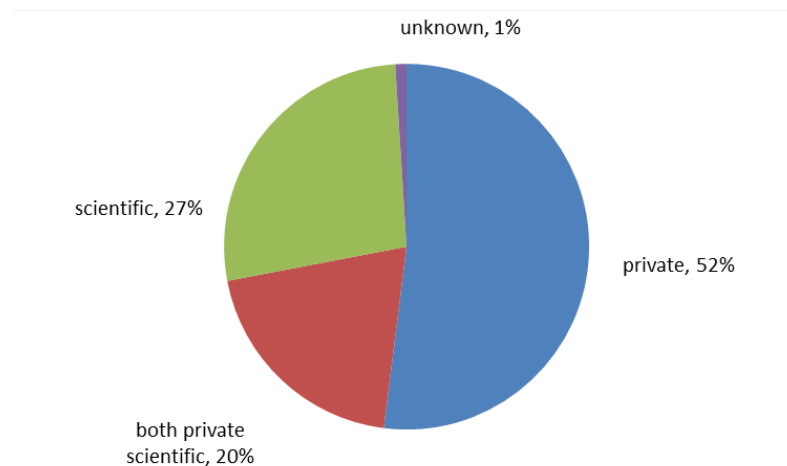


Figure 3: Type of involved organisation as a percentage of all the initiatives.

Table 2: Type of involved organisation as a percentage of the initiatives per country.

	DE	NL	FR	UK	Total
Private	32%	69%	57%	63%	52%
Both private & scientific	30%	19%	0%	25%	20%
Scientific	38%	11%	43%	13%	27%
Unknown	0%	0%	0%	0%	1%
	100%	100%	100%	100%	100%

5 Status and production scale

Most of the initiatives (74%) are either realised in terms of construction and/or are already operational (see Figure 4 and Table 3). A few of the reported initiatives remain in concept phase (9%), meaning that a design has been made or a feasibility study carried out.

Information about the production scale of algae is very limited. A lot of initiatives are at laboratory scale or are only very small research pilots. Some of the largest facilities are found in Germany and The Netherlands, where some initiatives produce algae on a larger area than 250 m² or at a bigger volume than 75 m³.

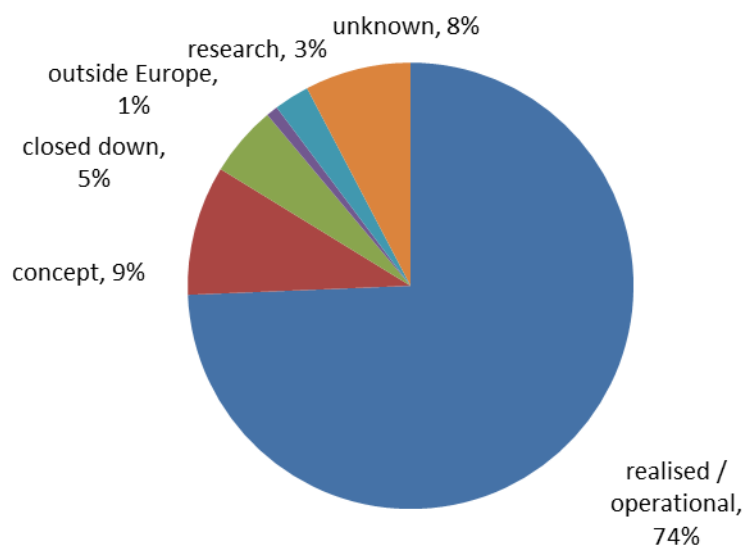


Figure 4: Status as a percentage of all the initiatives.

Table 3: Scale of algal production as a percentage of the initiatives per country.

		DE	NL	FR	UK	Total
< 250 m ²	< 75 m ³	32%	14%	4%	13%	19%
250 to 500 m ²	75 to 150 m ³	5%	0%	0%	6%	3%
500 to 1000 m ²	150 to 300 m ³	3%	8%	0%	0%	3%
1000 to 2500 m ²	300 to 750 m ³	3%	19%	0%	0%	7%
2500 m ² to 5000 m ²	750 m ³ to 1500 m ³	0%	3%	0%	0%	1%
> 5000 m ²	> 1500 m ³	0%	3%	0%	0%	2%
Unknown		57%	53%	96%	81%	66%
		100%	100%	100%	100%	100%

6 Types of algal production technologies

A broad range of cultivation modes/technologies is employed at the production facilities captured within the inventory, with open raceway ponds the most frequently encountered (20%) in those cases where the type of facility is known (Figure 5).

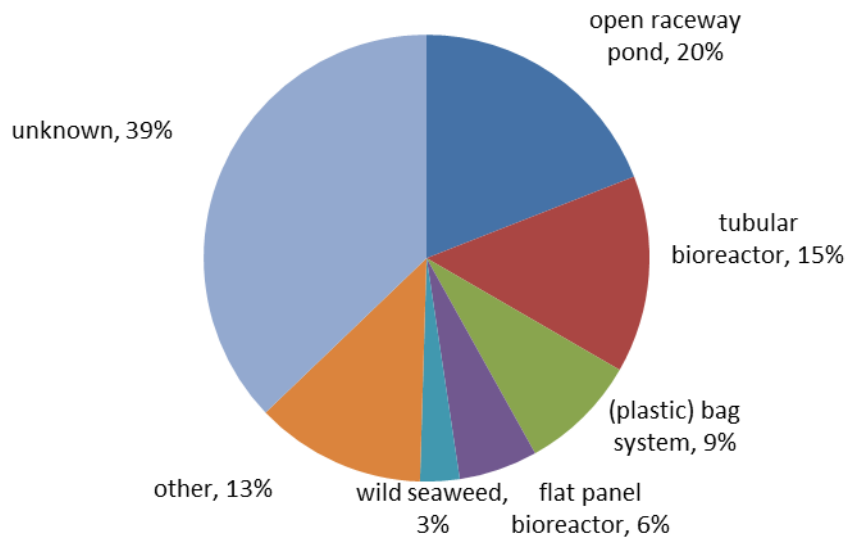


Figure 5: Type of production technology as a percentage of all the initiatives.

In Germany (plastic) bag systems, flat panel bioreactors and others are some of the most frequently used technologies. In Holland algae are often cultured in open raceway ponds and in the United Kingdom mainly in tubular bioreactors or in the sea (Table 4).

Table 4: Production mode as a percentage of the initiatives per country.

	DE	NL	FR	UK	Total
Open raceway pond	11%	50%	9%	0%	20%
Tubular bioreactor	14%	17%	4%	25%	15%
(Plastic) bag system	19%	6%	0%	6%	9%
Flat panel bioreactor	16%	0%	0%	6%	6%
Wild seaweed	0%	0%	0%	19%	3%
Other	19%	6%	9%	13%	13%
Unknown	22%	31%	87%	31%	39%
	100%	108%	109%	100%	104%

7 Market focus

Most of the initiatives try to serve or aim at more than one market. A lot of initiatives are using waste stream to produce algae for one or more algae markets. Examples of waste streams include CO₂, manure, and industrial or municipal wastes, and because it saves money to use these waste streams, waste stream handling can be viewed as a market sector in its own right. The waste stream market and the energy market are the most frequently named and have the lowest added value (Figure 6). High value molecules form the top of the market in terms of added value from algal biomass, and a lot of initiatives are focussed on this market.

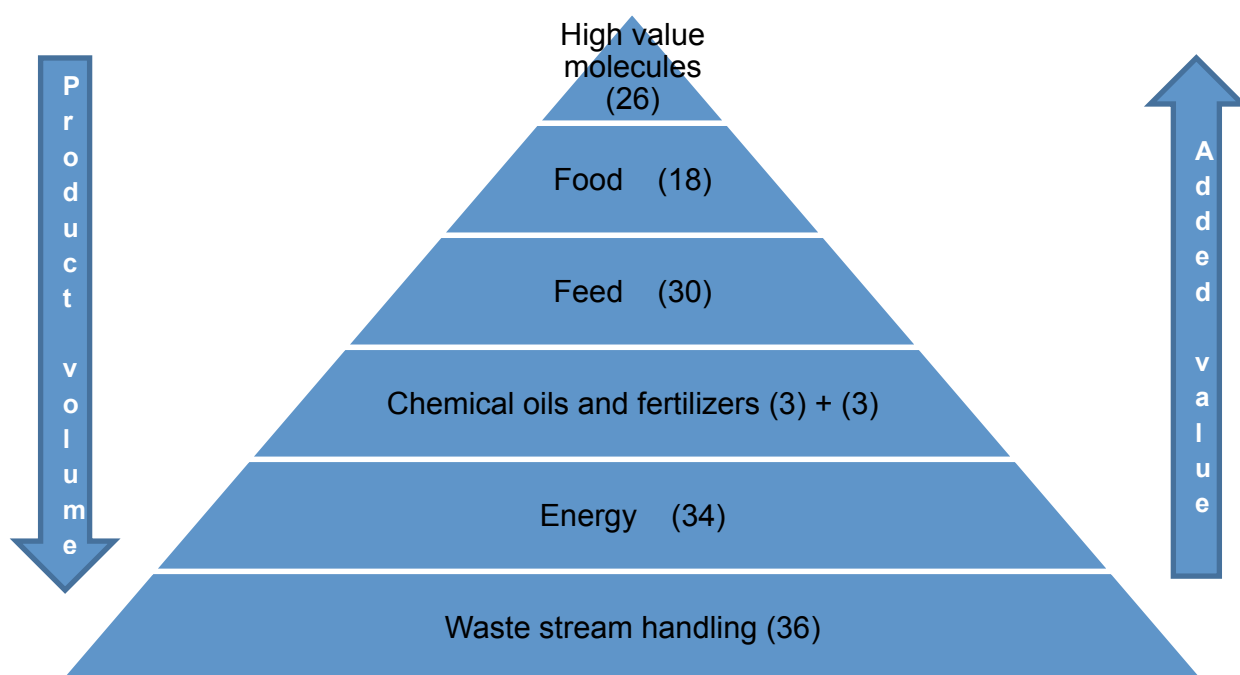


Figure 6: Number of initiatives in the algae market value pyramid.

In Germany a lot of the initiatives are focussed on energy and waste stream, in The Netherlands on waste stream and feed, in France on high value molecules and energy and in the United Kingdom on feed (Table 5). It is important to note that for a substantial number of initiatives the market(s) aimed at is (are) not disclosed.

The high diversity of markets reflects the juvenile stage of the algal industry and the search of the industry for profitable market outlets. Some of the initiatives are organisations that provide services to algae producers like technology or culture material.

Table 5: Market focus as a percentage of the initiatives per country.

	DE	NL	FR	UK	Total
Waste stream	43%	42%	4%	19%	31%
Energy	51%	6%	48%	0%	29%
Feed	16%	42%	9%	31%	26%
High value molecules	16%	8%	48%	19%	22%
Food	24%	6%	13%	13%	15%
Technology provider	14%	3%	9%	0%	8%
Chemical oils	8%	0%	0%	0%	3%
Fertilizers	0%	0%	4%	19%	3%
Provider of culture material	3%	0%	4%	0%	2%
Others	0%	0%	0%	6%	2%
Unknown	8%	33%	13%	31%	20%
	184%	139%	152%	138%	160%

8 Market status per country

8.1 Germany

In Germany the majority of the initiatives are pilots or researches. The research is very diverse, from screening algae species, research on cyanobacteria and optimizing PBR's to the production of high value molecules, biogas and hydrogen. A minority (about eight) of the initiatives are estimated to be commercially active and selling algae products or services. Three of them are technology providers, from which two also serve algae product markets. None of the commercially active organisations sell energy algae products. They mainly handle waste streams and/or produce feed/food products and two of them high value molecules.

8.2 The Netherlands

In The Netherlands most of the initiatives are also pilots- or research activities. There are relatively less scientific organisations involved than in Germany. Pilots often focus on waste stream handling, namely waste stream from the agricultural, industrial, domestic/municipal and transport sector. Four initiatives are producing (shell) fish feed, of which two are pilot facilities. Only about five organisations are commercially selling algae products or technology, none of them for the energy market.

8.3 France and Switzerland

For France a summary has been found with 13 companies and 10 R&D projects. The companies are mainly active in the high value molecule market (especially in France: cosmetic products) or in the low value energy market. There is rarely any information about the status or scale of these initiatives. Also in research projects the energy market is important. In Switzerland there is an operational research project concerning hydrothermal conversion of algae to methane.

8.4 United Kingdom and Ireland

In the United Kingdom and Ireland more activities concern macroalgae (seven out of seventeen initiatives). All of them are private companies. Macro algae are used to produce fertilizers (4x), feed additives (2x), food (2x), cosmetics (1x), high value molecules (1x) or to filter out microalgae from ecologically sensitive areas (1x). There was no information available about initiatives for the energy market.

8.5 Belgium

Two Belgian projects were reported on pilot-scale. They are producing for the high value market or other markets. One project in Belgium covers one hectare. In this project CO₂ is captured from the lime and glass industry to produce biofuel for the industrial furnaces and reduction of fuel energy consumption.

9 Initiatives for the algal energy market in NWE

As the scope of the EnAlgae project is on algae for energy purposes, we have taken a closer look at the algal initiatives concerning energy. At 34 of the 117 found algal initiatives energy products were mentioned, principally biogas (38%), hydrogen (26%) and biodiesel (15%) (Figure 7). Also see Table 6 for a breakdown of energy applications per country.

As discussed in the previous paragraphs, the initiatives for the energy market are mainly R&D or pilot projects. There is hardly any information about commercial activities concerning energy.

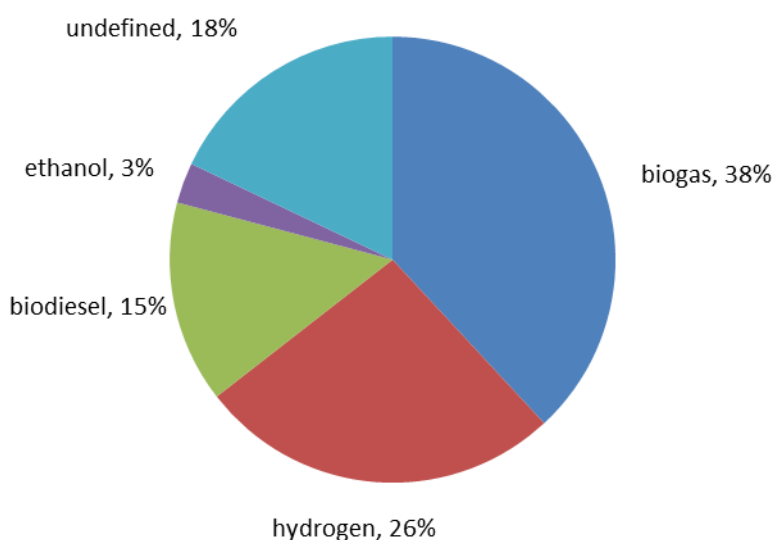


Figure 7: Type of energy product as a percentage of the 34 initiatives on algal energy.

Table 6: Initiatives per type of energy product per country.

	DE	NL	FR	UK
Biogas	7	2	3	-
Hydrogen	8	-	1	-
Biodiesel	2	-	3	-
Ethanol	1	-	-	-
Undefined	1	-	4	-
	19	2	11	0

Germany is very active in scientific projects for the energy algae market, mainly hydrogen and biogas. Some interesting details reported about these initiatives are listed below, sorted by energy product (and country).

9.1 Examples of algal biogas initiatives

- (i) Technische Hochschule Wildau (GE): Pilot plant in operation: PBR connected to a heat and power plant. Algae biomass is transformed/ fermented into biogas in a 2-stage process, which is used for power production in the connected heat and power plant; CO₂ produced in this process will again be used for the algae biomass production in the PBR. In operation.
- (ii) University Leipzig (GE): Private/scientific, operational. Development of a new process for production of biogas with algae. Development of new PBR with an aerobic part and an anaerobic part in order to produce Methane/biogas (in the anaerobic part with methane producing microorganisms) with reduced energy consumption.
- (iii) Ruhr Universität Bochum (GE): Scientific, concept, lab scale. Research: how efficient is biogas production with algae biomass (also research on hydrogen production).
- (iv) TERM (GE): Private/scientific. Technologies for the exploitation of microalgae resources. Biogas is an option for the future; new technology developed: up to 850 l biogas/ kg microalgae.
- (v) RWE Power AG (GE): Private/scientific, operational, no further information about biogas.
- (vi) Research Centre Jülich (GE): Scientific, concept. Research projects attached to the RWE pilot plant.
- (vii) VAR (NL): Private, pilot project (closed down). Harvested algae were used for analysis and fed into the locally present anaerobic digester.
- (viii) ACRRES (NL): Pilot project in operation running in co-operation between a public research organisations and several private companies. Algal production is connected to a CHP running on biogas, produced by a co-digester. The flue gas and low value heat as well as the digestate are used to produce algae in open raceway ponds. The algae paste produced is fed into the animal feed market. No commercial production (Figure 8).



Figure 8: ACRRES raceway ponds (in- and outdoor) in the Netherlands.

- (ix) Salinalgue (FR): Private/scientific project. Production for biogas (also biodiesel).
- (x) Myprobe (FR): R&D project. Amelioration of cyanobacterial photosynthesis yield and methane potential.
- (xi) Sunchem (SW): R&D project, operational. Hydrothermal conversion of the algal biomass to a methane-rich gas. The process is a closed-loop system with respect to nutrients and CO₂, which are recycled and reused for the growth of microalgae. Water which is not used as make up water is also reused.

9.2 Examples of algal hydrogen initiatives

- (i) University Kiel (GE): Scientific, concept. Cooperation with Linde Group: research on hydrogen production using green algae.
- (ii) HydroMicPro (GE): Private/scientific project in concept. Hydrogen from microalgae: cell and reactor design leading to economic production. Project objective: development of new PBRs; development of processes for efficient and sustainable hydrogen production with genetically optimised microorganisms; optimisation of biomass production; comparison with similar technology (including Life Cycle Analysis (LCA)).

- (iii) Ruhr Universität Bochum (GE): Scientific, concept, laboratory scale. Research on hydrogen production with *Chlamydomonas reinhardtii* (also research on biogas production).
- (iv) Universities of Bielefeld and Münster (GE): Scientific project which ran until 2011 "Bio hydrogen production in micro algae" researching the best conditions for hydrogen production; development of optimised PBR

9.3 Examples of algal biodiesel initiatives

- (i) Breen Biotech (GE): Concept. Production of algae (*Chlorella vulgaris*) on a 900 m² site in a specially designed PBR: 6 cm flat-panel reactors situated on the ground (no further attachments to greenhouses) made of plastic, each of these reactors have their own airflow for required water turbulence; harvest and oil extraction, algae oil gets sold to companies for biodiesel production.
- (ii) Hezinger ALGAETEC (GE): Private, operational. Aim: to develop, produce and commercialise PBRs and/ or complete process systems including processing of the produced algae biomass into biodiesel.
- (iii) Salinalgue (FR): Private/scientific project. Production for biodiesel (also biogas).
- (iv) Algoraffinerie (FR): R&D project. Development of methodologies and technical processes for the utilization of (high lipid content) microalgae for biodiesel production (and (high polysaccharide content) for pharmaceuticals).
- (v) Shamash (FR): R&D project. Lipid biofuel from microalgae.

9.4 Example of algal bio-ethanol initiatives

- (i) Cyano Biofuels GmbH (GE): Private, operational. Screening and (genetical) modifications of cyanobacteria for bioethanol production (lab-scale); after pre-selection in Germany the selected bacteria strains are entering pilot-scale testing at Algenol Florida (outdoor in plastic tubes).

9.5 Examples of other algal biofuel initiatives (undefined)

- (i) Cyano Biotech GmbH (GE): Private, operational. Applied R&D on cyanobacteria; transferring know-how from academic research into an innovative biotech company; products and services comprise cultivation of different cyanobacterial strains from own collection (1500 strains) or customer strains, harvest and freeze-drying of biomass, extraction and compound supply, cyanotoxins, analytical services.
- (ii) Karlsruhe Institute of Technology (KIT) (GE): Coordination of the project HydroMicPro. Testing of different photobioreactors, including process optimisation and Life Cycle Analysis (LCA). Hydrogen, Bioethanol, Biodiesel.
- (iii) Phytolution GmbH (GE): Main focus: development and selling photobioreactors; biofuel is one of the potentials.
- (iv) University Freiburg (GE): Takes part in the EU-project "DirectFuel" (Direct biological conversion of solar energy to volatile hydrocarbon fuels by engineered cyanobacteria).

- (v) Fraunhofer UMSICHT (GE): Private/scientific concept. Part of the EU-project AllGas: plant in South-Spain; algae production in waste water; oil extraction from harvested algae biomass => for feed additives and biodiesel; residues of algae biomass are fermented into biogas/ methane.
- (vi) Anhalt University of Applied Science (GE): Cultivation of micro- and macroalgae; testing of different species; maintenance of algae reference stocks; testing of different processing techniques and uses for algae biomass (a.o. biofuels).
- (vii) Biosolarzentrum (GE): Private/scientific, realisation. Development of a new photobioreactor (flexible tubular system); biofuel production.
- (viii) Agical (BE): Private/scientific, realisation. CO₂ capture for lime and glass industries. Aim: the biofuel produced from the algae will fuel the industrial furnaces and reduce fossil energy consumption.

10 Initiatives in other algal markets

10.1 The waste stream market

The waste stream market has the lowest added value, but is the most mentioned focus. Thirty-six out of the 117 recorded projects/organisations are involved in waste stream handling. A large number of these activities use agricultural waste streams, which means the use of CO₂ from flue gas from biogas engines and eventually digestate. Industrial/ transport and domestic/municipal waste stream are important too (Figure 9).

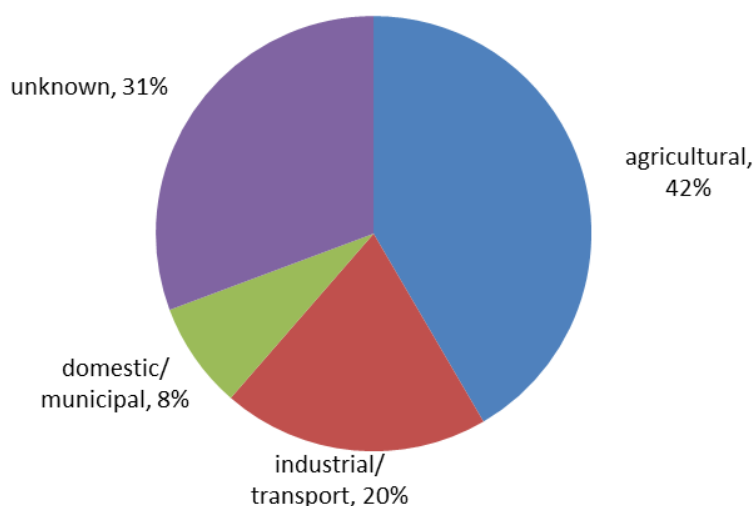


Figure 9: Type of waste stream used amongst the 36 initiatives focussing on waste stream handling.

10.2 The feed market

The feed market is (one of) the focus(es) for 30 of the 117 initiatives. The algal products are bulk feed, feed additives and (shell)fish feed (Figure 10), the latter particularly prevalent in The Netherlands and the UK.

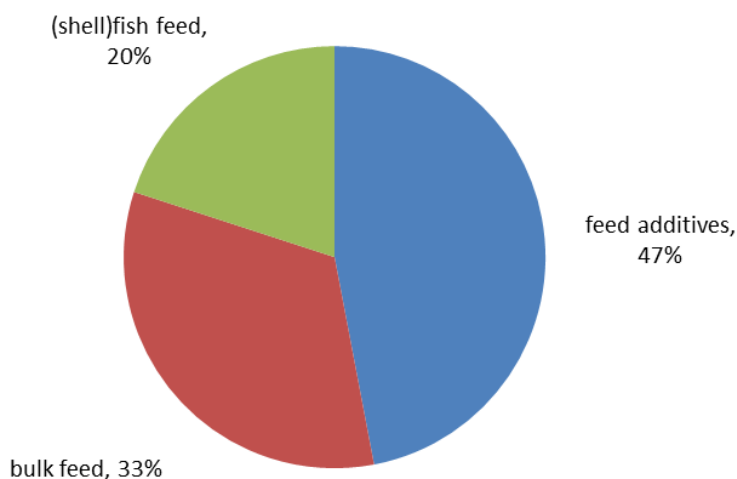


Figure 10: Type of feed product as a percentage of the 30 initiatives focussing on feed.

10.3 The high value molecules market

For 26 of the 117 recorded initiatives high value molecules are (one of) the intended markets. Algae can for example be used for cosmetics, pharmaceuticals, nutraceuticals and colorants.

10.4 The food market

The food market is the focus for 18 initiatives, 50% on food and 50% on food additives.

11 Annex 1: Format for data and information collection

General		
Name of project or company		
Country		
Organisations involved	please select	
Status	please select	
Permits & regulations		
How long did it take to obtain permission?		
What were the key steps involved?		
Which restrictions were imposed by environmental authorities?		
Which parts of the proces were appropriate (and/or useful)?		
Which parts of the proces were unnecessary / not helpful?		
How should the process be improved?		
What regulatory restrictions are imposedon the production process by the end use?		
Which aspects of these restrictions do you consider appropriate?		
Which do you consider unnecessary?		
How should the regulatory framework be improved		
Algae production		
Algal reactor type	<input type="checkbox"/> Flat panel bioreactor <input type="checkbox"/> Tubular bioreactor <input type="checkbox"/> Raceway pond <input type="checkbox"/> Open Pond <input type="checkbox"/> Other (please specify) 	
Algae type	please select	
Specie(s) used		
Volume of reactor		
Input for algae production	CO2	please select
	Temperature	
	Nutrients	please select
	Light	
Production environment	pH	
	fresh/salt	please select
	water circulation	
Output volume		
Processing of algae	centrifuge	
	drying	
	separation	
Market for produce	<input type="checkbox"/> Energy;electricity <input type="checkbox"/> Energy;biogas <input type="checkbox"/> Energy;biofuel <input type="checkbox"/> Chemical oils <input type="checkbox"/> Feed additive <input type="checkbox"/> bulk feed <input type="checkbox"/> Food additive <input type="checkbox"/> Food <input type="checkbox"/> Other; (please specify) 	
Description of value chain	functionality algae production	
	embedding of algal reactor	



EnAlgae is a four-year Strategic Initiative of the INTERREG IVB North West Europe programme. It brings together 19 partners and 14 observers across 7 EU Member States with the aim of developing sustainable technologies for algal biomass production.

www.enalgae.eu | info@enalgae.ac.uk