AQUAFUELS
ALGAE TOWARDS BIOFUELS

An industrial perpective on algae based biofuels

IDENTIFYING RESEARCH NEEDS

Vítor Verdelho Vieira, Necton / A4F AlgaFuel

AQUAFUELS PROJECT FINAL CONFERENCE

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Management Center Europe (MCE), Rue de l'Aqueduc 118, 1050 Brussels

SEVENTH FRAMEWORK PROGRAMME

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An industrial perpective on algae based biofuels: *identifying Research Needs*

applications !

applications !!

applications !!!

applications !!!!

applications !!!!!

please.

and … that's all ☺

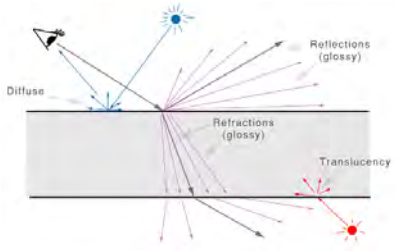
thank you for your attention !

An industrial perpective on algae based biofuels: *identifying Research Needs*

Necton / A4F insight ▪ Large-scale production

PRODUCTIVITY

- Enhance the microalgae **growth ratio** through the optimization of sunlight supply (avoiding photo-oxidation and photo-limitation phenomena, light intensity, direct vs. diffuse light supply, etc)
- Increasing the outdoor productivity of microalgae culture through **illumination during the night** period, maintaining a positive economic and energy balance (e.g. through LED technology)
- Utilization of phosphorescence particles inside PBRs to dilute light inside systems
- Studying the long term effects of **culture medium recirculation** on the microalgae productivity



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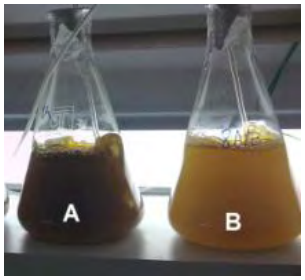
PRODUCTIVITY

- Optimization of the **culture medium formulation** for each microalgae specie, in order to minimize its wastage in large-scale production, establishing a commitment between costs and productivity
- Techniques for the control of several **contaminating species** (bacteria, fungi, protozoa, rotifers…)
- Maximizing microalgae productivity through **heterotrophic and mixotrophic** growth



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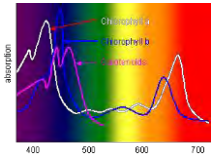
CARBONATION

- **Carbonation** and degasification processes in PBRs with flue gas
- Optimize the flue **gas injection** method in PBRs, in order to maximize the CO_2 uptake

TEMPERATURE

- Systems for the **thermoregulation** of PBRs in large-scale production of microalgae

ENGINEERING



- Enhancing PBRs design / **CFD** (tube diameter, culture pathway, flash-light effect…)

INDUSTRIAL INTEGRATION

- Develop the technology of microalgae production integrated in GHG emitting industries, and identify for each industry type the several points of possible cooperation / **synergies**

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ENERGY

- Evaluate synergetic interaction between microalgae and **biogas production**

BIOMASS HARVESTING

- Systems for harvesting the culture and **recirculating** the culture medium
- New **pumping** systems for energy saving in circulation and harvesting
- Development of **active bio compounds** for inside PBR fast cleaning
- Development of mechanisms / automats for PBR outside constant **cleaning**

- Development of models to **integrate weather forecast with culture conditions** for proper management of daily harvesting
- Systems for biomass **dewatering**, with reduced cost and energetic consume

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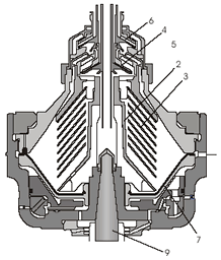
Necton / A4F insight ▪ Large-scale production

BIOMASS APPLICATIONS

- Utilization of agricultural, industrial and domestic waste as bulk nutrients
- Set most cultivated species as food and feed ingredient
- Biomass value increase – harvesting for specific applications
- Develop “clean” methods for added-value compounds extraction, as lipids, with positive economic and energetic balance



(…)

please see Deliverable 3.1. Research Needs - for more…

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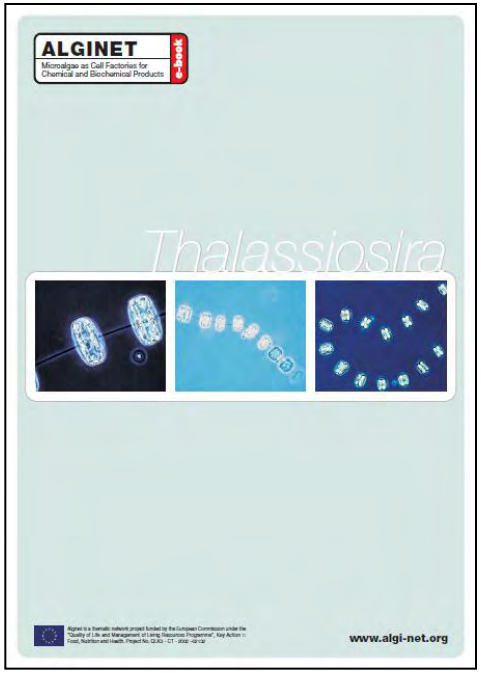

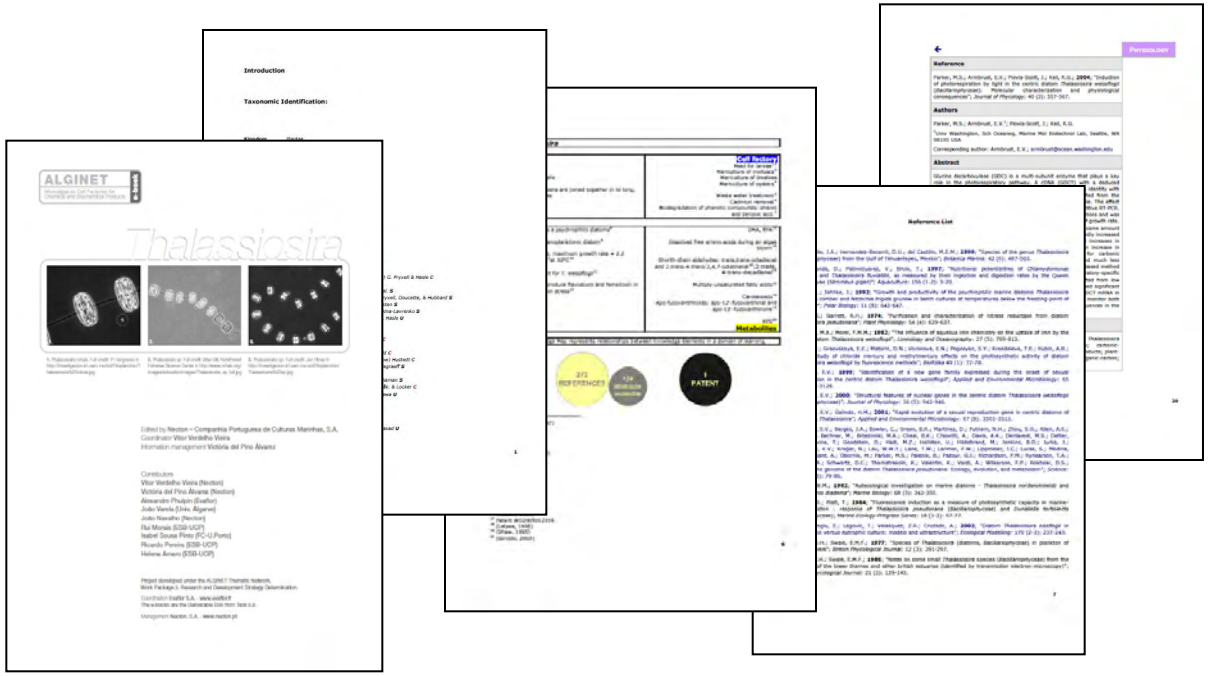

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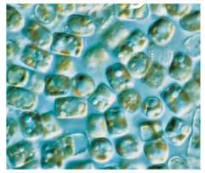
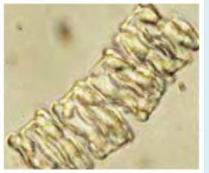
Cyclotella

Cell	**Cell factory**
Freshwater Diatom Drum-shaped Solitary Alveolate nature	Bioaccumulation of metals[1] Ingredients of foods and pharmaceuticals, especially. for prophylaxis of myocardial infarct[2]

53 abstracts available

143 REFERENCES

Biology	**Metabolites**
C. meneghiana, optimal temperature T=25ºC[3] *C. meneghiana*, maximum growth rates are 1.65, 0.73 and 0.95 d^{-1} for P-, N- and Si-limited cultures respectively.[4]	PUFA[5]

4 PATENTS

A Knowledge Map represents relationships between knowledge elements in a domain of learning.

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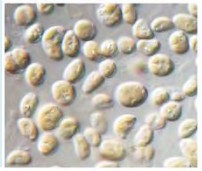
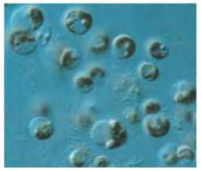
Nannochloropsis


Cell

Unicellular

Free-floating

Cells subspherical, 2-4µm diam. or cylindrical, 3-4 x 1.5µm.

Yellow-green parietal chloroplast

Zoospores not produced

Marine

Picoplankton

Cell factory

Poultry feed[1]

Aquaculture
Rotifer feed[2]
Bivalves aquaculture[3]
"Green-water effect" in water tanks[4]

Aqueous diesel fuel pollution[5]

76 abstracts available

94 REFERENCES

N. salina, T= 25±1ºC.[6]

N. gaditana, T= 25ºC[7]

N. gaditana is slow-growing, with a maximum specific growth rate of 0.56 day^{-1} at 23ºC[8]

Young or adult microalgae might be obtained according to the time of day[9]

Excretion of autoinhibitory substances[10]

Biology

Pigments[11]
Carotenoids[12]

Fatty acids (EPA, DHA)

β-glucan[13]

Aminoacids[14]

Long chain n-alkyl diols, hydroxy ketones and sterols[15]

Metabolites

4 PATENTS

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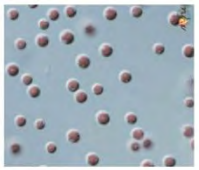
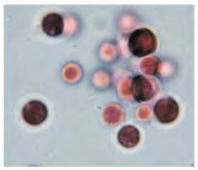
Porphyridium





Cell

Spherical to obovoid unicells

Solitary cells, but often grouped into irregular colonies

Cell diam. 5-10 µm in exponential, 7-16 µm in stationary phase.

P. aerugineum, freshwater
P. cruentum marine

Cell factory

Poultry feed[1]

Activity against *Herpes simplex* virus[2]

Effect on malignant cell transformation[3]

Cosmetic application: anit-oxidant[4]

119 abstracts available

P. cruentum, T=23ºC, pH=8, [NaCl]=0,42 M

Grow mixotrophically[5]

Biology

PUFA[6]

EPA[7]

B-phycoerithrin[8]

[9]Sulfated polysaccharides[10]

Galactolipids[11]

Arachnoid acid[12]

Sterols[13]

Sulfolipids[14]

Metabolites

333 REFERENCES

24 PATENTS

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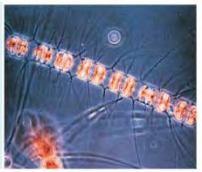
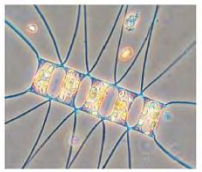
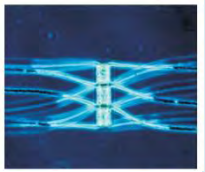
Chaetoceros

Cell	**Cell factory**
Marine Diatom Typically characterized by four bristles emanating from each corner of a rectangular frustule[1] Siliceous spines, termed setae, which greatly increase the effective size of the colony. Neritic or pelagic	Aquaculture of Crustaceans [2] Feed aquatic organisms (oysters, clams, Artemia)[3] Feed for shrimp larvae[4] Fish immunostimulants[5] Antibacterial agents stopping bacterial infections[6]

105 abstracts available

183 REFERENCES

Biology	**Metabolites**
C. muelleri thermo-tolerant[7] *C. lorenzianus* have high salinity and low temperature optima *C. calcitrans*, T=30±2ºC[8]	PUFA (EPA)[9] β-D-Glucans[10]

7 PATENTS

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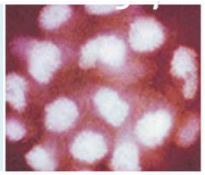
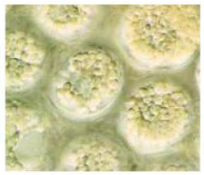
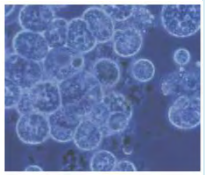
Crypthecodinium

Cell	**Cell factory**
Marine Dinoflagellate	Food applications Pharmaceuticals Pet foods[1] Colouring agent[2] Aquaculture feed[3] Extracts used in promoting lactic acid and bifidus bacteria growth[4]

41 abstracts available

119 REFERENCES

Biology	**Metabolites**
Heterotrophic conditions *C. cohnii* optimal culture conditions: pH = 7.5 and T = 15 – 30ºC[5] High temperature favours the microalgae growth and low temperature favours de formation of PUFA[6] Vitamin B12 should be added to the culture medium[7]	PUFA (especially DHA)

25 PATENTS

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Euglena



Cell

Green flagellates

Elongate, ovoid or fusiform cells

Varying in length from 20 to 500 µm

Freshwater (few species have been recorded from the open sea)

Cell factory

Detection kit - Indicator specie of acid mine drainage[1]

Aquaculture[2]

Anti-HIV action[3]

Potential protein source for feed, SCP[4]
Potential protein source for food, SCP[5]

164 abstracts available

Euglena species are photoauxotrophic, some facultatively heterotrophic, none phagotrophic.

E. gracilis (and less easily *E. anabaena*, *deses*, *pisciformis*, *stellata* and *viridis*) can be grown axenically in undefined media.

E. gracilis grows phototrophically or heterotrophically on acetates, organic acids, alcohols, or sugars.

Biology

α- Tocopherol [6]

Paramylon[7]

β - carotene[8]

Vitamin C[9]

Metabolites

224 REFERENCES

25 PATENTS

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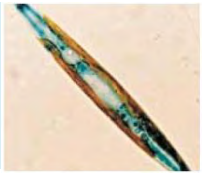
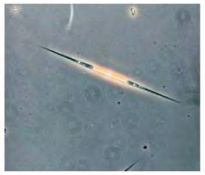
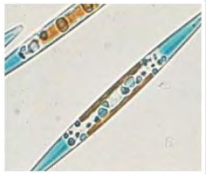
Haslea

Cell

Diatom

Naviculoid organization

Cell factory

Greening oyster[1]

Human health[2]

Anti-viral and anti-coagulant[3]

Colouring agent

33 abstracts available

37 REFERENCES

Growth temperature = 15ºC

Color changes marennine were observed in relation to pH.[4]

Marennine is not a carotenoid, but a chlorophyll degradation product.[5]

Blueing[6]

Biology

Pigment – marennine[7]

Isoprenoids[8]

Linoleic acid; EPA; eicosatetraenoic acid[9]

Tetra-unsaturated sesterterpenoids (haslenes)[10]

Metabolites

3 PATENTS

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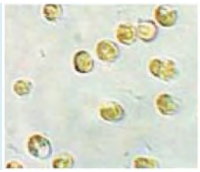
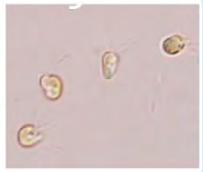
Isochrysis





Cell

Marine

Brown microalgae

Flagellate

Cell factory

Waste water treatment[1]

Mariculture[2]
Clam feed[3]
Oyster feed[4]

110 abstracts available

Optimal conditions: pH = 8ºC and T = 25ºC[5]

I. galbana: heterotrophic conditions[6]

Fermentation[7]

Biology

EPA[8]

α – tocopherol[9]

PUFA[10]

DHA[11]

Arachidonic acid[12]

Stearidonic acid[13]

Sterols[14]

Alkenone[15]

Metabolites

144 REFERENCES

8 PATENTS

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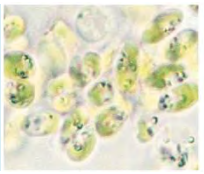
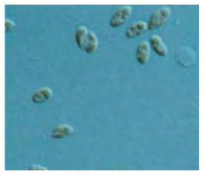
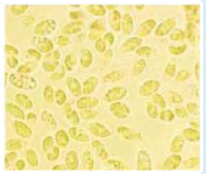
Monodus

Cell

Unicellular

Freshwater microalgae

With cell wall

M. coccomyxa 3.2 – 5 µm[1]
M. subterraneous 3.5 µm[2]

Cell factory

Most promising algal EPA producer[3]

Growth & productivity (outdoor cond.) not enough[4]

12 abstracts available

22 REFERENCES

Photoautotroph[5]

Optimal culture temperature T = 32 °C[6]

Optimal culture pH, pH = 7.5[7]

Biology

EPA

Metabolites

2 PATENTS

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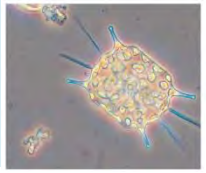
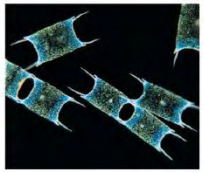
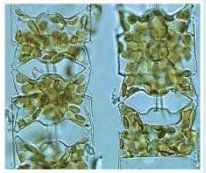
Odontella

Cell

Diatom

Marine

O. aurita looks like a bobbin

O. aurita ≈ 10 – 95 µm

Frequently associated to benthic macroalgae

Forms dense planktonic populations

Cell factory

Flavouring agent

Human diet: source of PUFA and trace elements

Cosmetic industry

13 abstracts available

21 REFERENCES

5α, 8α - epidioxysterol[1]

EPA
DHA

Betacarotene and fucoxanthin

Trace elements

Vitamins E, C, B2, B6, PP and provitamin A

1 PATENT

Biology

Metabolites

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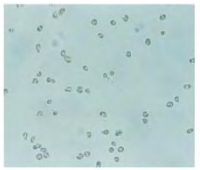
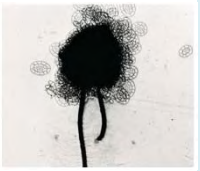
Pavlova

Cell

Freshwater and marine, although most species thrive in brackish waters

Flagellate

Phytoplankton

Golden/brown microalgae

P. lutheri, cell diameter ≈6 µm

Cell factory

Cosmetic: prevent aging[1]

TBT biodegradation[2]

Waste water treatment[3]

Oyster feeding[4]

Fish feed

Source of mineral supplements in mariculture[5]

33 abstracts available

60 REFERENCES

Very difficult to grow

Not used any many hatcheries.

Biology

EPA

DHA

Sterols: poriferasterol, 5-ergosterol, cholesterol[6]

Betaine lipid: 1,2-diacylglyceryl-3-*O*-carboxyhydroxymeth[7]

Metabolites

4 PATENTS

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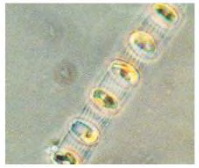
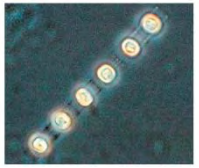
SEVENTH FRAMEWORK PROGRAMME

Skeletonema


Cell

Marine diatom

Form short colonies [1]

S. costatum 4-7,5 µm[2]

Cell factory

Cosmetic: anti-ageing; anti-cellulite[3]

Anti-proliferative effects of organic extract[4]

Antibacterial activity in Aquaculture[5]

Detoxification (Cd and Cu)[6]
Biodegradation 2,4 - dichlorophenol[7]

Diet for molluscs[8]
Diet for oysters[9]

91 abstracts available

219 REFERENCES

S. costatum; pH = 6,5 – 8,5[10]

Biology

EPA[11]

Exopolymers[12]

Octadienal[13]

Metabolites

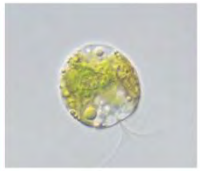
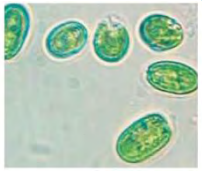
7 PATENTS

A Knowledge Map represents relationships between knowledge elements in a domain of learning.

AQUAFUELS
ALGAE TOWARDS BIOFUELS

SEVENTH FRAMEWORK PROGRAMME

Tetraselmis

Cell

Marine

Green algae

Unicellular

Flagellate

Cells cordiform, elliptical or almost spherical

Cell factory

Waste water treatment[1]
Cadmium removal[2]

Aquaculture feed
Rotifers feed[3]
Shrimp hatchery[4]
Oyster feed[5]
Clam feed[6]

Cosmetic: anti-wrinkles[7]

93 abstracts available

Normal salinity, [NaCl] = 0,5 M[8]

Mixotrophic conditions[9]
Heterotrophic conditions[10]

T. suecica: fructose as growth stimulator[11]

Maximum cell density *T. maculata* in a medium containing 150 mg l^{-1} $NaNO_3$[12]

Optimum growth conditions for *T. suecica* were 2, 4, and 8 mM of $NaNO_3$ which is equivalent to 170 , 340 and 680 mg l^{-1} of $NaNO_3$ [13]

Biology

α- tocopherol[14]

EPA

sterols: 24–methylenecholesterol, campesterol[15]

Metabolites

164 REFERENCES

6 PATENTS

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AQUAFUELS
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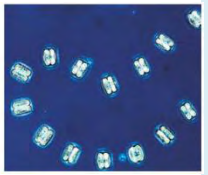
SEVENTH FRAMEWORK PROGRAMME

Thalassiosira





Cell

Diatom

Disc shaped cells

Most *Thalassiosira* are joined together in to long, flexible colonies

Cell factory

Feed for larvae[12]
Mariculture of molluscs[3]
Mariculture of bivalves
Mariculture of oysters[4]

Waste water treatment[5]
Cadmiun removal[6]
Biodegradation of phenolic compounds: phenol and benzoic acid [7]

124 abstracts available

T. antarctica is a psychrophilic diatoms[8]

T. fryxelliae nanoplanktonic diatom[9]

T. andamanica, maximum growth rate = 2.2 divisions.24 h^{-1}at 30ºC[10]

Cd is a nutrient for *T. weissflogii*[11]

T. weissflogii produce flavodoxin and ferredoxin in response to iron stress[12]

DHA, EPA[13]

Dissolved free amino-acids during an algae bloom[14]

Shorth-chain aldehydes: trans,trans-octadienal and 2-trans-4-trans-2,4,7-octatrienal[15];2-trans, 4-trans-decadienal[16]

Multiply-unsaturated fatty acids[17]

Carotenoids[18]
Apo-fucoxanthinoids: apo-12'-fucoxanthinal and apo-13'-fucoxanthinone[19]

EPS[20]

272 REFERENCES

1 PATENT

Biology

Metabolites

A Knowledge Map represents relationships between knowledge elements in a domain of learning.

AQUAFUELS
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allways keep the ballances

mass • • **energy**

•

economic

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Thank you !

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