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MINERVA
EU-JAPAN FELLOWSHIP

THE MICROALGAE/BIOMASS INDUSTRY IN JAPAN

- AN ASSESSMENT OF COOPERATION AND BUSINESS POTENTIAL WITH EUROPEAN COMPANIES –

Tokyo, April 2016

Manuel Herrador

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EXECUTIVE SUMMARY

This work has its main focus on the Industry of Microalgae in Japan mainly involving the products derived from Microalgal biomass, in order to create joint business opportunities with EU Companies.

In terms of size, the Industry of Microalgae in Japan consists of a small number of stakeholders - Companies, Public Administration and Universities -, the number could be around 100, however, when compared with EU countries and considering the size of the country, this specific Industry is **one of the most developed** worldwide.

This paper has been divided into 6 sections (Figure 0);

(1) An introduction to Microalgae, Microalgal biomass and products Derived from Microalgal Biomass.

(2) The Industry of Microalgae in Japan.

(3) The Industry of Microalgae in the EU.

(4) Potential business opportunities for EU Companies including challenges of the Japanese market and recommendations for EU Companies.

(5) Conclusions (including a SWOT diagram) and future perspectives.

(6) 4 Annexes; the first annex contains a list of member of the Algae Industry Incubation Consortium of Japan (AIIC); the second annex is represented in 2 virtual maps shows stakeholders and EU Companies of the sector; the third annex lists the contact points of Embassies in Tokyo, and lastly, a fourth annex depicts a potential Circular Economy Business Model based on Microalgae.

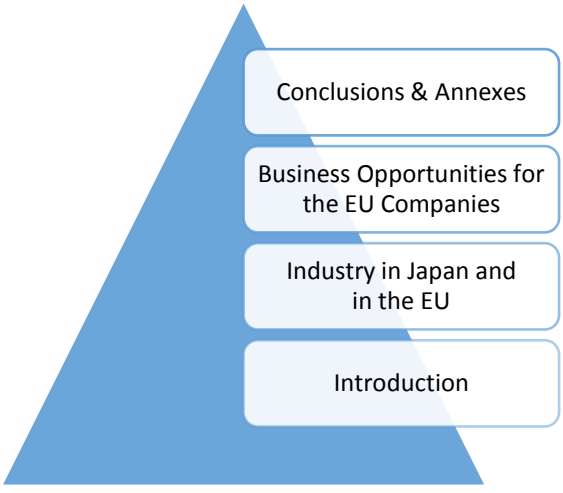

Figure 0. *Structure of the report.*

LIST OF ABBREVIATIONS

Abbreviation	Meaning
EU	European Union
CE	Circular Economy
Company	Small and Medium Enterprise
UN	United Nations
COP-21	United Nations Conference on Climate Change
METI	Ministry of Economy, Trade and Industry
CO_2	Carbon Dioxide
ACE	Actions for Cool Earth
PBR	Photobioreactor
CCS	Carbon Capture and Storage
Mt	Millions of tons
LNG	Liquified Natural Gas
R&D	Research and Development
GHG	Green House Gas
kWh	Kilowatt-hour
Kl	Kiloliters
RPF	Refuse Paper and Plastic Fuel
FIT	Feed-in tariff
BDF	Bio-diesel fuel
JPY	Japanese Yen
kW	Kilowatts
CDM	Clean Development Mechanism
J-VER	Japan-Verified Emission Reduction
JORE	Japan Organics Recycling Association
NEDO	New Energy and Industrial Technology Development Organization of Japan
BTL	Biomass gasification and liquefaction
TSS	Total Suspended Solids
DAF	Dissolved Air Flotation
DHA	Docosahexaenoic acid
EPA	Eicosapentaenoic acid
PLA	Poly-Lactic Acid
PCB	Polychlorinated Biphenyl
3R	Reduce, Rehuse and Recycle
DfE	Design for Environment
LCA	Life-cycle assessment
AD	Anaerobic Digestion
AIIC	Algae Industry Incubation Consortium
ANA	All Nippon Airways
HHV	Higher Heater Value

HTL	Hydrothermal liquefaction
HRT	Hydraulic Retention Times
AOAIS	Asia-Oceania Algae Innovation Summit
MAFF	Ministry of Agriculture, Forestry and Fisheries
FY	Fiscal Year
TF	Task Force
JCR	Journal Citations Report
ORP	Oxidation-reduction potential
CEN	European Committee for Standardization
USA	United States of America
H2020	Horizon 2020
MIC	Ministry of Internal Affairs and Communications
NICT	National Institute of Information and Communications Technology of Japan
NCP	National Contact Point
CONCERT	Connecting and coordinating European research and technology development
COSME	Competitiveness of Enterprises and Small and Medium Enterprise
JETRO	Japan External Trade Organization
EEN	Enterprise Europe Network
NCP	National Contact Point
JEUPISTE	Japan-EU Partnership in Innovation, Science and Technology
JBCE	Japan Business Council in Europe
EU-BRT	EU-Japan Business Round Table
ErP	Enterprise resource planning
WEEE	Waste Electrical and Electronic Equipment Directive
RoHS	Restriction of Hazardous Substances Directive
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
PEF	Product Environmental Footprint
EIG	European Interest Group
STI	Science Technology and Innovation
EUR	Euros
ISO	International Organization for Standardization

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JAPANESE PM ABE SELECTS HIS FAVORITE STARTUP "EUGLENA", A COMPANY THAT PRODUCES MICROALGAE AND PRODUCTS DERIVED FROM MICROALGAE BIOMASS[1]

HE PERSONALLY DELIVERED "PRIME MINISTER'S AWARD" TO EUGLENA CO. LTD. AT THE FIRST ANNUAL JAPAN VENTURE AWARDS (2015). THE COMPANY PRODUCES ***MICROALGAE*** *TO FIGHT FOOD AND ENVIRONMENTAL PROBLEMS. ABE ACKNOWLEDGED THE CHALLENGES THAT REMAIN AND GAVE REASON FOR COMING TO THE AWARD CEREMONY IN PERSON. "WE WANT TO RECOGNIZE THE IMPORTANCE OF THESE COMPANIES WHICH HAVE FOUND A PATH TO SUCCESS"*

SHINZŌ ABE

PRIME MINISTER OF JAPAN

"THE KEY TO CLIMATE CHANGE IS A CIRCULAR ECONOMY"[2]

"SOLUTION TO THE QUESTIONS WORLD LEADERS CONFRONT AT THE U.N. CLIMATE CHANGE CONFERENCE IN PARIS (COP-21), SEEKING A UNIVERSAL AGREEMENT TO KEEP GLOBAL WARMING BELOW A CRITICAL THRESHOLD. BUT IT'S ALSO ABOUT MORE THAN CONSERVING NATURAL RESOURCES AND ACTING AGAINST CLIMATE CHANGE, VITAL THOUGH THOSE ISSUES ARE. IT'S ALSO AN OPPORTUNITY FOR GROWTH AND JOB CREATION IN WESTERN ECONOMIES AND FOR DEVELOPMENT THROUGHOUT THE WORLD. PROPONENTS OF CIRCULAR ECONOMY SAY IT COULD LEAD TO 100,000 NEW JOBS IN 5 YEARS—AND 2 MILLION BY 2030. WITH THE CIRCULAR ECONOMY, WE CAN HAVE GROWTH WITHOUT INCREASED CONSUMPTION. A CHANGE THAT PUTS US ON THE VERGE OF A 2ND INDUSTRIAL REVOLUTION"

WERNER HOYER

PRESIDENT OF THE EUROPEAN INVESTMENT BANK, THE E.U. BANK

[1] https://www.techinasia.com/prime-minister-abe-favorite-startup

[2] http://www.newsweek.com/key-climate-change-circular-economy-not-circular-reasoning-399335

1. - INTRODUCTION

1.1. MICROALGAE

*Microalgae are microscopic plants [1] that can be grown using water resources through photosynthesis - by converting sunlight, CO_2 and nutrients into **biomass** - which in turn is able to produce high-value products (Figure 1) [2-3] such as animal feeds, foods (supplements, nutraceuticals, vitamins, anti-oxidants, etc.), chemicals (cosmetics, biodegradable plastics, cosmeceuticals, etc.) or even variety bio-fuels [4]. Finally, it is possible to recycle waste water using Microalgae [5]. These unique characteristics set up a Sustainable Business Model for a Circular Economy as a renewable source, as detailed in the Annex 4.*

Commercial uses of algae

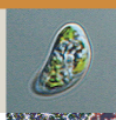
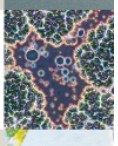
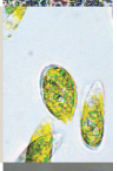
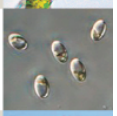
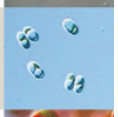
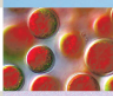
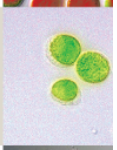
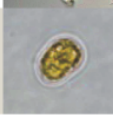
Type of algae	Company	Characteristics, potential uses	
Pseudochoricystis	Denso	• High oil content; grows in environment with acid level comparable to yogurt • Jet fuel, diesel; technological framework for large-scale production to be established by around fiscal 2018	
Botryococcus braunii	IHI	• Similar components to petroleum, with high oil content of 50%; enhancements could lead to faster cultivation • Jet fuel; technological framework for commercialization to be established by 2020	
Euglena gracilis	euglena	• Mass cultivation successfully carried out on Ishigaki Island, Okinawa; company now selecting new varieties suitable for jet fuel • Jet fuel, healthy food; integrated production technology for jet fuel to be established by 2018, followed by commercialization in 2020	
Kirchneriella lunaris	J-Power (Electric Power Development)	• Grows well under temperatures ranging from 4 C to 25 C; capable of resisting cold at zero; also grows in seawater • Jet fuel, diesel; ready for use in jet fuel by 2025	
Fistulifera solaris	J-Power (Electric Power Development)	• Grows well under temperatures ranging from 15 C to 45 C; suitable for cultivation in warm weather; also grows in seawater • Jet fuel, diesel; ready for use in jet fuel by 2025	
Haematococcus	Alvita	• Generates antioxidant astaxanthin • Cosmetics; commercial production to start in Japan's Saga Prefecture in April 2016	
Chlamydomonas	DIC	• High oil content of 60-70% allows quick growth; company applies algae cultivation technology for generating natural pigments • Jet fuel, ink; research phase for jet fuel underway in U.S.; use as ink ingredient under consideration	
Euglena gracilis Strain EOD-1	Kobelco Eco-Solutions	• High oil content; cultivated in sealed tanks • Food, cosmetics; distribution of samples underway	
Symbiodinium	Kao	• Coexists with coral; contains surfactant element • Shampoo, washing agents; basic technology to be established by 2020	

Figure 1. *Various species of Microalgae and their biomass-based product applications [3].*

Microalgae systems can absorb up to 200 times more CO_2 than trees [6], current systems [7] – *photobioreactors* – (Figure 2) are used as a Sustainable method to generate through biomass value added products such as bio-fuels or foods, in fact, several scholars have recently pointed out Microalgae as the *"food of the future"* [8-9].

Figure 2. *A photobioreactor (PBR).*

Microalgae are capable of performing photosynthesis with the help of the sun, water CO_2 and nutrients, providing biomass that can be used for applications such as bio-fuel, and feed or foods (Figure 3).

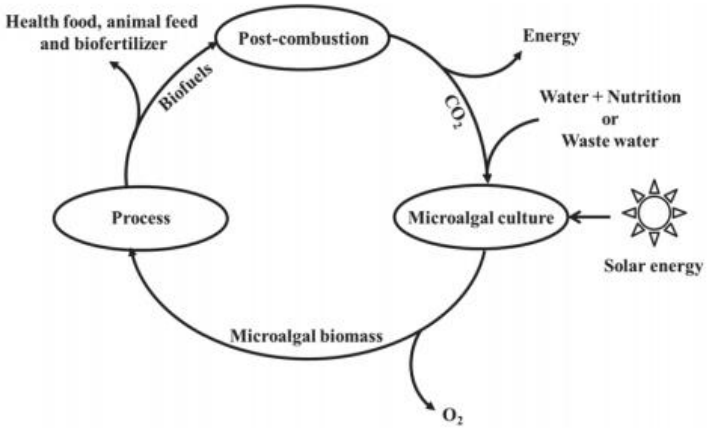


Figure 3. *An integration of Microalgae cultivation and possible application.*

Introduction to the cultivation systems: Open Systems and Closed Systems

The Microalgae cultivation systems are categorized into open and closed systems (Figure 4) [10], namely:

- **Open systems** – as the name suggests, they consist of open areas such as ponds, lagoons or creeks that receive direct sunlight.
- **Closed systems** – consist of transparent vessels and containers that are kept outside under the sun or under artificial light.

Open systems

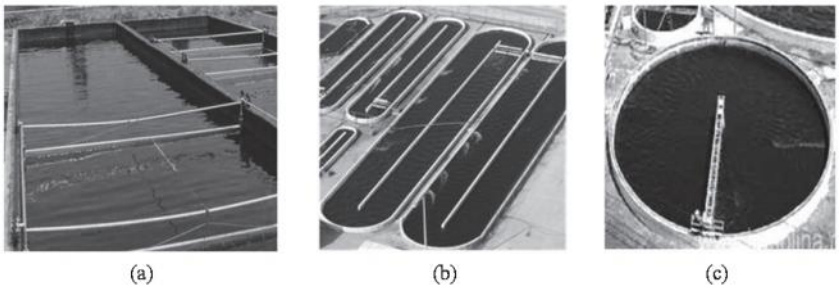


Figure 4. *Cultivation systems: (a) unstirred pond, (b) raceway pond and (c) circular pond [10].*

Until now, open ponds have been used for large-scale Microalgae cultivation due to their simple construction and easy operation. The cultivation systems can be classified as (1) natural waters (e.g., lakes, lagoons, ponds, etc.) and (2) artificial water systems (e.g., artificial ponds, tanks, and containers). The shapes, sizes and types (agitated, inclined, etc.) of open systems depend on the applications. There are various types of ponds, including unstirred, raceway and circular ponds.

- **Unstirred ponds** (Figure 4(a)) – this is the most convenient type of pond because of its easy creation and management. These ponds are used for Microalgae cultivation by constructing them with a depth of half a meter or less. Although easy to manage, this type of pond is not very practical since it allows other bacteria and viruses to breed, which affects the growth of Microalgae.

- **Raceway ponds** (Figure 4(b)) – also called stirred paddlewheel open ponds, they have a depth of 15 to 25 cm. Paddles are used in these ponds to circulate the water. A specific velocity has to be maintained so there are no sediment deposits. If the water remains still, then sediment deposits can create complications that are difficult to overcome. These ponds can be constructed individually or as a group of ponds connected together. In this pond, the productivity of Microalgae is 60-100 mg dry weight/L/day. Four species of Microalgae are cultivated in raceway ponds, namely: *Chlorella sp., Spirulina platensis, Haematococcus sp.* and *Dunaliella salina.*

- **Circular ponds** (Figure 4(c)) – these are the largest types of open ponds with a center pivot that rotates to provide circular motion to the water, being exposed to sunlight and CO_2 bubbles. Their depth is 25 to 30 cm and their diameter is 45 m.

Although the advantages of open systems are many, including their easy construction and management, there are some limitations of these systems, described below:

- The cells don’t absorb enough light.
- Numerous nutrients are lost during evaporation.
- The inability to diffuse carbon dioxide from the environment.

- A lot of area is required to build these open ponds.
- A lot of unwanted bacteria, protozoa and viruses grow in the pond which inhibits the growth of Microalgae.

A few of these drawbacks can be mitigated by placing green house sheets and transparent sheets over the ponds. Although the problems of light absorption and evaporation could be solved through these, the unwanted bacteria and molds still pose big problems. Because these ponds cover a large area of land, their construction and maintenance costs are high. The problem of overheating through the greenhouse sheets cannot be overlooked as well.

Closed Systems

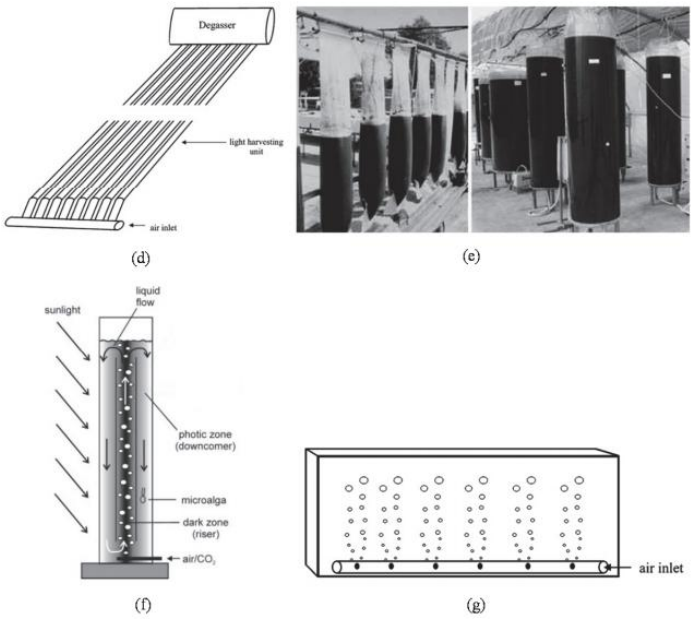


Figure 5. *Cultivation closed systems: tubular (a), photobioreactor (b), airlift (c) and flat plate (d) [10].*

The solutions to the previous problems come in the form of a closed system. This system consists of closed containers or vessels that can be placed in an environment with customized conditions of light, heat and carbon dioxide. One type of closed system is the photobioreactor. These work under controlled conditions. Thus, problems of water evaporation and carbon dioxide absorption are taken care of. The growth of unwanted algae and molds can also be minimized through this system. However, this contamination is not completely eliminated even with closed systems. The disadvantages of this system are that it is rather difficult to construct (compared to open systems) and they also incur greater maintenance costs. There are various types of photobioreactors.

- **Tubular photobioreactors** (Figure 5(d)) – these vessels are of tubular shape and are constructed with a transparent material. They are constructed with a large diameter and minimum depth so as to increase the surface area for better sunlight

absorption. These are then placed directly under sunlight. The vessels are connected to chambers through which carbon dioxide and other nutrients are supplied to the main vessel and oxygen is removed. The mechanism of working is such that the medium is passed through the tubes. Sunlight is absorbed through the tubes and the process of photosynthesis occurs. The medium is then circulated back to the main vessel where some portion of the algae is collected and the process continues again from the start. A lot of research has been done on these tubular photobioreactors. Another variation of this system called helical-tubular photobioreactor has tubes that are placed in a spiral shape. These can be used directly under the sun or can also be placed under artificial light to enhance the growth of Microalgae. However, the use of artificial light in these helical-tubular photobioreactors increases its construction and management costs. This makes these systems only suitable for the production of high-value products that cannot be produced otherwise.

- **Plastic bag photobioreactors** (Figure 5(e)) – in this type of photobioreactor, algae are grown in transparent polyethylene bags that are hung under direct sunlight. The construction and shape of the bags ensure that there are minimum sediment deposits underneath. The light source is direct sunlight and air is mixed with the Microalgae at the bottom of the bags to supply all the needed nutrients.

- **Airlift photobioreactors** (Figure 5(f)) – this type of photobioreactor is useful for large scale cultivation of Microalgae. For the construction of the containers, acrylic glass is used which is not expensive and is readily available. The containers are divided into two parts: the dark part called *"rinser"* and the irradiated zones. It consists of airlift cylinders and vertical bubble columns through which the medium is passed through in a circular manner achieving high cycling between the dark zones and the irradiated zones. Because of the design of these airlift containers, they allow for better light absorption. The contamination content is very small in these containers. The cost of maintaining these containers is also not very much. This makes them one of the best options for the cultivation of Microalgae and biomass production. The disadvantage of these containers is that because of their complex design, they cannot be scaled easily to increase the cultivation of Microalgae. They incur more construction and maintenance costs. They provide lesser light absorption per unit, so a lot of individual units are required to make up a large scale cultivation unit. The advantages of these systems are that they consume little energy and are able to produce results on a large scale. The operation and maintenance of these units are also easy to achieve. They are able to absorb better light and carbon dioxide losses are minimized. These units achieve good mixing of the mediums which results in better cultivation of stagnant algae on moving media.

- **Flat plate photobioreactors** (Figure 5(g)) – in this type of photobioreactor, a large surface area to volume ratio is provided through a unique design. Thus, the amount of sunlight absorption is increased which means large scale cultivation of Microalgae is possible. The design also supports scaling up to larger production units. They are relatively cheap to construct and maintain. The maintenance is also quite easy. It consists of vertical flat plates that can be constructed in 1000-2000 L volume capacity. Thus they provide for large scale cultivation of Microalgae and biomass production that are scalable and convenient to maintain.

Comparison: open ponds (raceways) VS closed photobioreactor (tubular)

The next Table 1 compares parameters of both technologies.

Parameter or issue	Open ponds and raceways	Photobioreactors (PBR)
Required space	High	For PBR itself low
Water loss	Very high, may also cause salt precipitation	Low
CO_2-loss	High, depending on pond depth	Low
Oxygen concentration	Usually low enough because of continuous spontaneous outgassing	Build-up in closed system requires gas exchange devices (O_2 must be removed to prevent inhibition of photosynthesis and photo oxidative damage)
Temperature	Highly variable, some control possible by pond depth	Cooling often required (by spraying water on PBR or immersing tubes in cooling baths)
Shear	Usually low (gentle mixing)	Usually high (fast and turbulent flows required for good mixing, pumping through gas exchange devices)
Cleaning	No issue	Required (wall-growth and dirt reduce light intensity), but causes abrasion, limiting PBR life-time
Contamination risk	High (limiting the number of species that can be grown)	Low (Medium to Low)
Biomass quality	Variable	Reproducible
Biomass concentration	Low, between 0.1 and 0.5 g/l	High, generally between 0.5 and 8 g/l
Production flexibility	Only few species possible, difficult to switch	High, switching possible
Process control and reproducibility	Limited (flow speed, mixing, temperature only by pond depth)	Possible within certain tolerances
Weather dependence	High (light intensity, temperature, rainfall)	Medium (light intensity, cooling required)
Start-up	6 – 8 weeks	2 – 4 weeks

Table 1. *Open ponds (raceways) VS closed photobioreactor (tubular).*

The following table 2 compares the costs of using both technologies.

Capital costs	High ~ US$100 000 per hectare	Very high ~ US$250 000 to 1 000 000 per hectare (PBR plus supporting systems)
Operating costs	Low (paddle wheel, CO_2 addition)	Higher (CO_2 addition, oxygen removal, cooling, cleaning, maintenance)
Harvesting cost	High, species dependent	Lower due to high biomass concentration and better control over species and conditions
Current commercial applications	5 000 (8 to 10 000) t of algal biomass per year	Limited to processes for high added value compounds or algae used in food and cosmetics

Table 2. *Costs of using both technologies.*

How do the CO_2 levels affect Microalgae species?

For the cultivation of Microalgae, carbon is required. This is retrieved through carbon dioxide. A proper supply of carbon dioxide is required to ensure a proper production of Microalgae. Thus, the process of Microalgae cultivation through microalgal photosynthesis is advantageous to the human ecosystem as it reduces the amount of carbon dioxide in the atmosphere.

Certain levels of carbon dioxide are required for different types of algae. For example, *Chlorella sp.*, requires a carbon dioxide concentration of 5% (v/v). Any rate higher than this level will affect the algae production in a negative way. Other types of algae can even be cultivated in a carbon dioxide concentration of 10-15% (v/v). Some Microalgae species can tolerate a CO_2 level as high as 70% such as *Chlorella sp KR-1* and *Chlorella sp ZY-1*. *Chlorella sp T-1* can even survive in a carbon dioxide concentration of 100%. In general, if the carbon dioxide concentration is between 0.038 to 10%, which it is considered an ideal situation for Microalgae cultivation.

Microalgal biomass VS standard biomass for biodiesel production

Table 3 illustrates how Microalgae have the best properties for bio-fuel production.

Raw Material	Oil Content (% in Dry Weight Biomass)	Output (L oil/ha year)	Land Used (m^2 year/kg Biodiesel)	Water Footprint (m^3/ton)	Production Cost (US$/L)	Acid Value of Oil	Biodiesel Yield (%)
Soybeans	18	636	18	4200	0.40 - 0.60	0.2	90
Rapeseed	41	974	12	4300	0.99	2.0	87
Sunflower	40	1070	11	6800	0.62	0.1	90
Oil Palm	36	5366	2	5000	0.68	6.1	95
Castor	48	1307	9	24700	0.92 - 1.56	4.6	89
Microalgae*	50	97800	0.1	591 - 3276	3.96 - 10.56	8.9	60

Table 3. *Comparison of productivity between diverse sources of biomass.*

1.2. MICROALGAL BIOMASS

Once the Microalgae is cultivated, the rate of growth slows down and it gets suspended in the middle of the container. The produced biomass is then recovered from water after which fuel precursors are extracted and they are converted (in this case) to bio-fuels. There are several ways in which harvesting is done. The exact technique is chosen based on factors such as size, density and concentration of slurry. The steps involved for obtaining biomass derived from Microalgae are illustrated in the following Figure 6 [11].

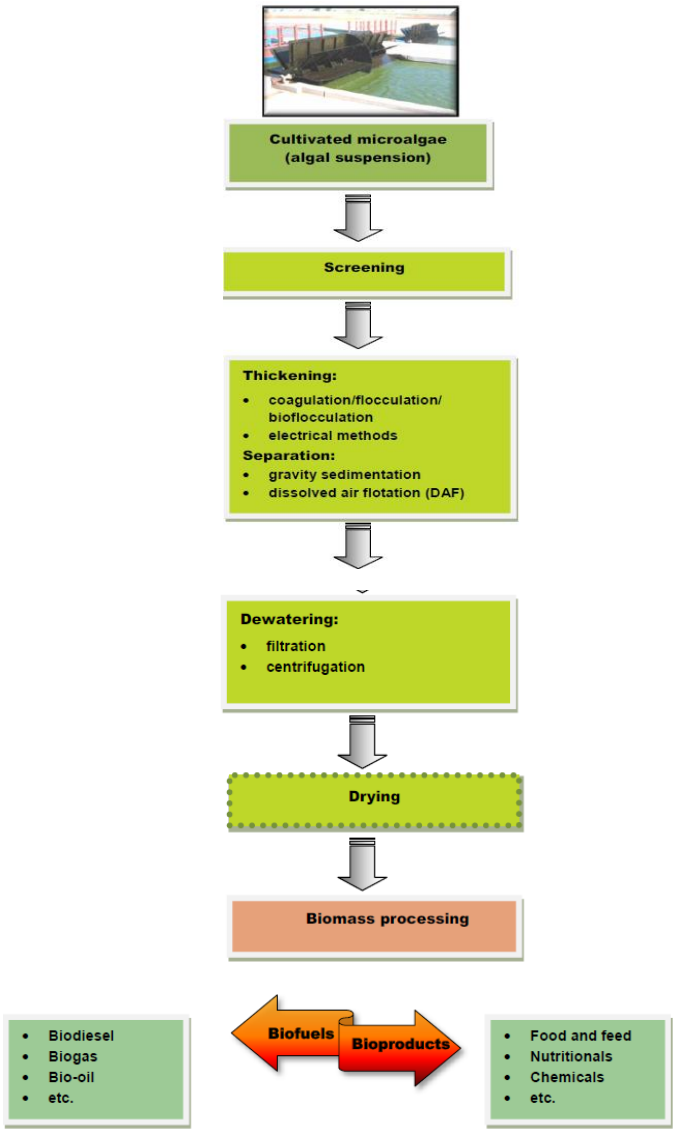


Figure 6. *Process flows of harvesting methods for recovery and dewatering of microalgal biomass. Drying is optional, depending on the selected downstream process for conversion of Microalgae to bio-fuels and/or bioproducts [11].*

- **Screening pre-treatment** – in the first step, the Microalgae are passed through various meshes and they are screened by using various vibration shades.

- **Thickening** – this process involves transforming the Microalgae suspension into slurry that has a concentration of 6-10% TSS (total suspended solids). Then water is removed from the slurry to form an algae paste that has a concentration of 10-25% TSS. The paste is then further dried off to get a solid biomass product.
- **Chemical coagulation/flocculation** – the biomass product from the previous step is further PH-adjusted and chemical coagulants or flocculants (chlorides, sulphates, aluminium and calcium hydroxide) are added to it to get a processed product. The purpose of this step is to allow agglomeration of algae cells. This will result in large collections of algae cells that will eventually settle on the ground through sedimentation. The different types of algae cells require different types of coagulants and flocculants to achieve the best chemical results.
- **Electricity-based processes** – in this approach, instead of adding a chemical, an electricity charge can be used to separate the algae cells from water. The Microalgae cells are negatively charged, so by applying an electric field, algae cells can be found either at the electrodes (electrophoresis) or at the bottom of the container (electro-flocculation).
- **Autoflocculation or bioflocculation** – when the Microalgae broth is kept under direct sunlight, its carbon dioxide supply is reduced and the PH conditions are kept between 8.6 – 10.5, which will also result in algae aggregates being formed. This process does not require any chemicals for the aggregates to be formed.
- **Gravity sedimentation** – this step occurs after coagulation or flocculation has occurred. The algae aggregates settle down at the bottom of the container. It is even possible to collect the different strains of Microalgae based on their different densities. Although this is an easy process, it has the drawback of being slow.
- **Dissolved air flotation (DAF)** – this process is the opposite of the gravity sedimentation process as it involves making the algae aggregates float on the surface of water as opposed to at the bottom of water. This process is achieved by injecting gas bubbles into the broth after the coagulation and flocculation.
- **Filtration** – depending on what type of algae strain is being used, this process can be used individually or in combination with thickening and separation steps. As the name suggests, this process involves filtering the algae broth through a membrane with a particular pore size by applying constant pressure. This process has many issues and is expensive. One of the most common problems is the deposition of Microalgae on the filtration membrane which affects the filtration process. Thus, it involves careful and timely maintenance in which the membranes are cleaned periodically to ensure a particular level of biomass production.

- **Centrifugation** – this is a process through which solids or liquids are separated and Microalgae are retrieved from the water. This process can be done individually or after coagulation or flocculation has taken place. Introducing this step after coagulation/flocculation reduces the power costs since there is lesser volume of broth to work on.

- **Drying** – this process may or may not be used, depending on whether lipids from dried algal biomass are required in the conversion to biodiesel. To achieve this process, heat is required which may be obtained through natural or artificial means. If favourable climatic and humidity conditions are present, then wind and solar drying can be utilized to cut the overall costs of conversion from biomass to bio-fuels. The disadvantage of this technique is the requirement of a large area of land for the drying process to work as well as long period of time required to achieve the results.

- Finally, the **dried biomass** derived from Microalgae can be obtained (Figure 7).

Figure 7. *Biomass extracted from Microalgae harvesting [12].*

1.3. PRODUCTS DERIVED FROM MICROALGAL BIOMASS

Finally, once the Microalgae have been dried, it is possible to obtain products derived from microalgal biomass. It is noticeable how every strain has particular characteristics on the resulting biomass sub-products, therefore, certain stains will be only available for bio-fuel production and others for foods/feeds applications.

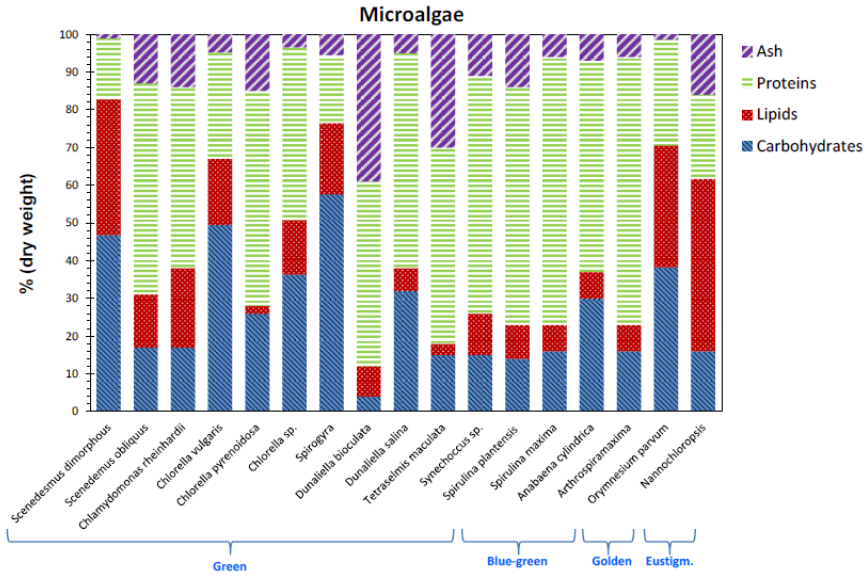


Figure 8. *Chemical composition of microalgal species of different groups.*

Table 4 depicts the recovery efficiency of microalgal biomass (in %) depending on various Microalgae strains and the harvesting methods selected.

Microalgal species	Harvesting	Efficiency
		%
Chlorella vulgaris	• Coagulation/flocculation+sedimentation	92-99
	• Autoflocculation+Sedimentation	98
	• Bioflocculation+Sedimentation	34-99
	• Filtration	98
Chlorella minutissima	Coagulation/flocculation+sedimentation	80
Chlorella sp.	Flotation	90
Chlorella sorokiniana	Coagulation/flocculation+sedimentation	99
Dunaliella salina	• Flocculation+flotation	98.2
	• Electrolytic Flocculation	98.9
Tetraselmins sp.	• Electro-Flocculation	87
	• Electro-Flocculation+sedimentation	91
Nannochloropsis oc.	Bioflocculation+Sedimentation	88
Nannochloropsis sp.	Centrifugation	96
		17
Scenedesmus sp. and *Coelastrum rob.*	Centrifugation	2-15
Phaeodactylum tr.	Coagulation/flocculation+sedimentation	67-91.8

Table 4. *Recovery efficiency of microalgal biomass.*

The Microalgae-based biomass products need to be discussed separately depending of the species of Microalgae and the category of sub-products which are going to be produced (different industries with diverse bio refineries are required for each product). For instance, Figure 9 illustrates a possible design which combines various options.

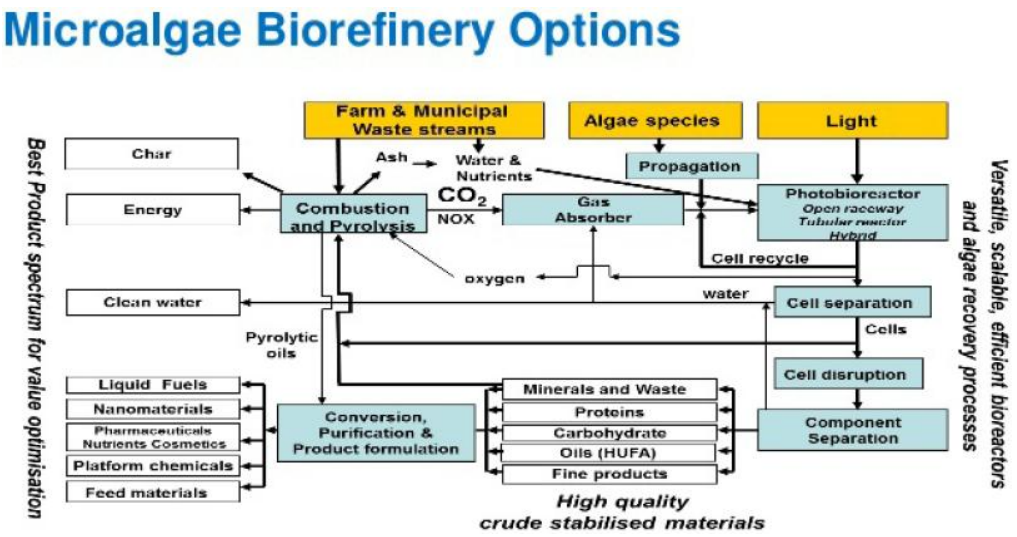


Figure 9. *A possible Microalgae biorefinery [13].*

Table 5 enumerates the variety of sub-products that can be produced from Microalgae-based biomass.

High-value	Medium-High value	Low to Medium value
Nutraceuticals a) Astaxanthin b) Beta carotene c) Omega-3 fatty acid (DHA and EPA) d) CoenzymeQ10 **Cosmetics** a) Anti-cellulite b) Skin Anti-ageing and sensitive skin treatment – Alguronic acid ***Pharmaceuticals***	**Nutraceuticals** - Spirulina and Chlorella **Hydrocolloids** - Agar, Alginate, Carrageenan **Chemicals** - Paints, Dyes and Colourants	**Fertilizer and Animal Feed** **a)** Aquaculture feed **(** Shrimp feed, Shellfish Feed, Marine Fish Larvae cultivation) b) Animal Feed c) Fertilizer **Substitutes for Synthetics** a) Biopolymers and Bioplastics b) Lubricants **Bioremediation** a) Wastewater treatment and nutrient credits b) CO2 capture and carbon credits

Table 5. *Categories of biomass-based products depending of its value [14].*

Next, it will be explained how Microalgae-based products are obtained.

Energy

The Energy Industry is - to date - the one which is bringing the most attention to this field, but it is also aided by the Government due to the elevated number of existing initiatives in order to tackle the - still high - dependence on fossil oil imports and to reduce the CO_2 emissions. So far, this report has briefly highlighted several examples of Companies that are exploiting this technology.

Recently, extensive research has been carried out on how biodiesel can be obtained from Microalgae. It has been found to be one of the most efficient ways of getting bio-fuels from Microalgae. Numerous species of Microalgae contain high amounts of lipids, hydrocarbons and other complex oils which can be used to obtain biodiesel. Terrestrial oil crops are also being used to produce biodiesel but Microalgae boasts a higher production rate. However, the process of extracting biodiesel from Microalgae is difficult because the cells have to be set free from thick walls. Research is being done on extracting lipids from Microalgae biomass which can then be used to produce biodiesel.

The process of extraction of lipids (Figure 10) from Microalgae biomass involves chemical extraction. The process consists of solubilising the Microalgae lipids by using n-hexane, chloroform or methanol. Different types of solvents may be used for different types of strains of Microalgae to achieve different levels of efficiency. This step also involves drying which means significant energy has to be used.

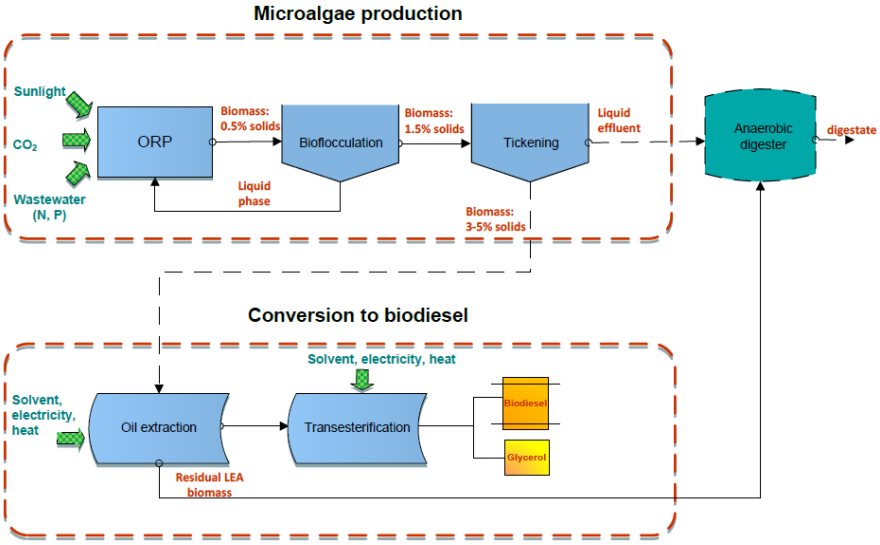


Figure 10. *Summary of the Microalgae-based bio refinery process.*

Once the lipids have been extracted from the Microalgae aggregates, they are converted to biodiesel by the process of transesterification (alcoholysis). The process can be sped up by using acid and base catalysts. Another alternative to this approach is to perform in-situ transesterification in which lipids are extracted through chemical process and then transesterification is performed without any catalysts. The advantage of this technique is that the solvent can be used more efficiently as a reactant in the extraction and transesterification processes.

For instance, research performed at laboratory-scale on dried Microalgae samples (e.g. Chlorella v.) has shown 90% efficiency in converting the extracted lipids to biodiesel by means of in-situ transesterification. The concentration of Microalgae lipids indicates the level of availability for bio-fuel applications (Table 6).

Microalgal strains	Lipids content	Lipids productivity
	% dry wt. biomass	mg/l/day
Green		
Chlorella emersonii	25-63	10.3-50
Chlorella protothecoides	14.6-57.8	1,214
Chlorella sorokiniana	19-22	44.7
Chlorella vulgaris CCAP 211/11b	19.2	170
Chlorella vulgaris	5-58	11.2-40
Chlorella sp.	10-48	42.1
Chlorococcum sp. UMACC 112	19.3	53.7
Dunaliella salina	16-44	46.0
Nannochloropsis oculata NCTU-3	30.8-50.4	142
Nannochloropsis oculata	22.7-29.7	84-142
Neochloris oleoabundans	29-65	90-134
Scenedesmus quadricauda	1.9-18.4	35.1
Schizochytrium sp.	50-57	35.1
Tetraselmis suecica	8.5-23	27-36.4
Tetraselmis sp.	12.6-14.7	43.4
Diatoms		
Chaetoceros muelleri	33.6	21.8
Chaetoceros calcitrans	14.6-39.8	17.6
Phaeodactylum tricornutum	18-57	44.8
Skeletonema sp.	13.3-31.8	27.3
Skeletonema costatum	13.5-51.3	17.4
Thalassiosira pseudonana	20.6	17.4
Eustigmatophyceae		
Ellipsoidion sp.	27.4	47.3
Nannochloris sp.	20-56	60.9-76.5

Table 6. *Concentration levels of lipids for bio-fuel applications.*

The biodiesel attained from Microalgae is shown to possess the same chemical and physical properties as those of petroleum, diesel and other first generation bio-fuels according to the guidelines of the International Biodiesel Standard for Vehicles (EN14214). Biodiesel obtained from Microalgae has the properties of being non-toxic and generating production of hydrocarbons, and carbon monoxide. Thus, it can be used in the aviation industry as well.

Table 7 depicts how the *Parachlorella Kessleri* is one of the most promising stains for bio-fuels production.

Oil productivity of microalgae[1)]

The number of days necessary to produce 1 ton of oil

Species	Oil content (%DW)	Biomass (g/L/day)	Oil (g/L/day)	Period producing 1t of oil
Parachlorella kessleri	75.0	1.29	0.97	21
Chlorella sorokiniana	22.0	1.47	0.32	63
Nannochloropsis oculata	29.7	0.48	0.14	140
Dunaliella tertiolecta	71.0	0.12	0.085	240
Chlorella pyrenoidosa	2.0	3.64	0.073	270
Pavlova salina	30.9	0.16	0.049	410
Chlorella emersonii	63.0	0.041	0.026	770
Chaetoceros muelleri	33.6	0.07	0.024	833
Spirulina maxima	9.0	0.25	0.023	870
Thalassiosira pseudonana	20.6	0.08	0.016	1250
Haematococcus pluvialis	25.0	0.06	0.015	1300
Botryococcus braunii	75.0	0.02	0.015	1300

1) Watanabe *et al.*,2012; Přibyl *et al.*,2012
2) We assumed that cultivation facilities of 50,000 large were used, and the number of days necessary to production per 1 ton of oil was calculated.

Table 7. *Oil productivity of microalgae.*

Besides bio-fuel, there are various sub-products that can be used as Energy, such as bio-oil (or bio-crude), bio-hydrogen, bio-ethanol and bio-methane. While relevant applications are made possible by using these sub-products, it is not necessary for this research to go into further detail because bio-fuels represent the most notable applications.

Nutritional

Another area in which Microalgae is being used is in the global food market (drinks, yogurts, supplements, etc.). Microalgae based foods and supplements are gaining popularity. They are used as dried Microalgae as well as in the form of supplements and colorants. Although, this market constitutes a small portion of Microalgae production as compared to other resources, it has grown rapidly in the past few years. Although Microalgae strains such as food sources of mineral and vitamins are being considered beneficial for one's health, the large scale production of these food supplements is still not being carried out. The nutrition industry uses these sources to produce food supplements called nutraceuticals that are rich in vitamins and proteins. It is also used in the animal industry in the form of fertilizers as well as providing necessary nutrition to them [15].

The use of Microalgae in the food/feeds industries is a subject that is gaining popularity, because of the rapid increase in the world's population which calls for new ideas to provide better nutrition for everyone. With this population growth, conventional food production methods will have to be replaced by newer methods to ensure proper supply of nutrition for everyone. Microalgae like *chlorella* and *spirulina* are already being used as dietary supplements in their pure forms. They have a lot of health benefits. That is why Japan is now the biggest consumer of these products. Studies have shown that Microalgae *spirulina* has over 30 healthy nutrients that are beneficial for the body. 100 grams of *spirulina* can yield about 50-80 grams of vegetable proteins. Apart from these proteins, *spirulina* also provides beneficial vitamins and minerals such as calcium, magnesium and beta carotenes [16]. Table 8 illustrates a range of components extracted from diverse Microalgae stains.

Microalgae source	High-value component
Pigments	
Dunaliella & Salina	β -carotene (Pigment/ Carotenoid)
Haematococcus & Pluvialis	Astaxanthin (Pigment/Carotenoid)
Arthrospira & Porphyridium	Phycocyanin (Phycobili-protein)
Fatty acids	
Nannochloropsis, Phaeodactylum & Nitzschia	EPA
Schizochrytium & Cryptocodinium	DHA

Table 8. *High-value components from Microalgae strains.*

Table 9 contains a range of diverse products of foods and feeds obtained from Microalgae.

Microalgae source	Products currently in the market
Foods	
Haematococcus Pluvialis	Astaxanthin (Dietary supplement, Food Ingredient & Additive)
Spirulina	Spirulina (Dietary supplement)
Chlorella	Chlorella (Dietary supplement & Food ingredient)
Porphyridum	Other Dietary supplements (Dietary Supplement)
Nannochloropsis	EPA/DHA (omega-3) as dietary supplement
Schizochrytium	
Odontella	
Ulkenia	
Dunaliella Salina	β -carotene (as additive/vitamin/ colourant)
Spirulina	Phycocyanin (colourant)
Feeds	
Spirulina	Spirulina (Dietary supplements)
Chlorella	Chlorella (Dietary supplements)
Astaxanthin (Dietary supplement)	Haematococcus pluvialis
Nannochloropsis, Isochrysis, Pavlova, Phaeodactylum, Chaetoceros, Skelotenma, Thalassiosira & Tetraselmis	Biomass for aquaculture
Haematococcus pluvialis	Astaxanthin (Colourant for living fish)
Nannochloropsis & Isoschrysis	Algaepaste

Table 9. *Variety of foods and feeds obtained from Microalgae.*

Figure 11 illustrates Japan-made *Spirulina* tablets as a dietary supplement product.

Figure 11. *An example of Spirulina tablets [17].*

Other applications

There are other applications - but no less important – which are related to various fields, especially related to chemistry-based products, highlights include: bio-degradable plastics, cosmetics and medicine.

Bio-degradable plastics

Microalgae provides an exceptional feedstock for production of plastic due to its advantages such as high yield and its ability to grow in a wide range of different environments. The world market for bio-plastics is set to grow by 8-10% annually, increasing from $1bn (€0.6bn) in 2007 to $10bn (€6.4bn) by 2020 [14].

Algae have properties that allow them to grow in many varying environments. This makes them a good choice for use in the production of plastic. One type of plastic is called bio-plastics or organic plastics. These types of plastics are obtained through renewable biomass oils such as vegetable oil, corn starch and pea starch. In contrast, plastics made from fossil fuels are derived from petroleum. The drawback of fossil fuel plastics is that it results in carbon dioxide emissions which are harmful for the environment. Production of bio-plastics does not result in carbon dioxide emissions which makes it an environment friendly option. Also, using bio-plastics instead of fossil fuel plastics results in the conservation of valuable fossil resources.

When Microalgae were being used for the production of bio-fuels, Companies explored different ideas to increase their profit. Bio-plastics were discovered as a by-product in bio-fuels production. The process is environment friendly as it results in a much lower percentage of carbon dioxide emissions. This has proved to be a newer development in the field of plastic production instead of the conventional plastics made from corn starch and other vegetable oils. The development of bio-plastics is a rather newer concept. Thus, its applications are limited. There are different types of bio-plastics that are made from Microalgae. These are described below [18].

- **Hybrid plastics** – these are a mixture of petroleum plastics and algae based plastics. Microalgae biomass is used as filters during production of polyurethane and polyethylene. The final product properties are very similar to petroleum based plastics while using less petroleum in the process. Filamentous green algae are used in the production of hybrid plastics.

- **Cellulose-based plastics** – these are the types of plastics obtained from cellulose (which is a polymer of glucose). It is one of the oldest and cheapest types of plastic. In the process of biomass production, almost 30% of the product is cellulose. This cellulose can then be used to form cellulose based plastics.

- **Poly-lactic acid (PLA)** – when feedstock is fermented, it results in the generation of lactic acid which can then by polymerized to form poly-lactic acid. Poly-lactic acid can also be obtained by fermenting microalgal biomass. Poly-lactic acid is being used for large scale productions of bio-plastics.

- **Bio-polyethylene** – these are the type of plastics that are obtained from ethanol. Using a chemical reaction called cracking, ethanol is converted into ethylene which is then used in the production of bio-plastics. Currently, ethanol is derived from petroleum and natural gas but this can also be obtained from bacterial digestion of microalgal biomass. However, this type of plastic is not very viable as the process of getting ethanol from Microalgae incurs a cost that is much greater than the process of getting ethanol from petroleum or natural gas.

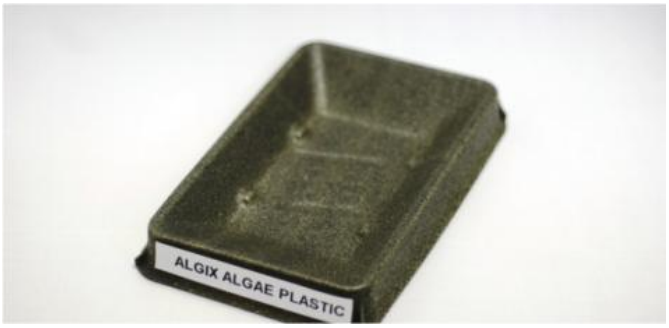


Figure 12. *A plastic figure made of Microalgae-based biomass [19].*

Cosmetics

Microalgae are not only being used in the plastic industry but they are also being used in the cosmetics industry. Various Companies are coming up with products that use Microalgae to treat various skin conditions and problems. Different types of skin whitening creams and anti-aging creams can be made using Microalgae as their base ingredient. Currently, Microalgae are being used in moisturizing creams but they can also be used for treating other skin problems such as pigmentation. The main factor which is inhibiting this advanced utilization of Microalgae is a lack of research investigating the use of Microalgae as a primary ingredient [20]. Table 10 depicts various examples of cosmetic applications.

Products currently on the markets	Microalgae product
Personal care skin products	Spirulina, Chlorella & Alguronic acid
Anti aging skin product (lipid)	Skeletonema costatum, Arthropira (Spirulina), Nannochloropsis & Dunaliella Salina
Hydrating skin product	Porphyridium cruentum & Chlorella
Anti-inflammation (peptide)	Phaeodactylum tricornutum
Slimming products	Dysmorphococcus globosus

Table 10. *List of existing of the various existing Microalgae-based cosmetic products.*

Advances in Medicine

Recently, several advances have been discovered in the field of medicine:

- *"Genetically engineered algae kill 90% of cancer cells without harming healthy ones" [21].*
- *"Bioactive Compounds Isolated from Microalgae in Chronic Inflammation and Cancer" [22].*
- *"Carotenoids from Marine Microalgae: A Valuable Natural Source for the Prevention of Chronic Diseases" [23].*
- *"Microalgae for the prevention of cardiovascular disease and strokes" [24].*

Figure 13 illustrates the development of Medicines from algae-based compounds.

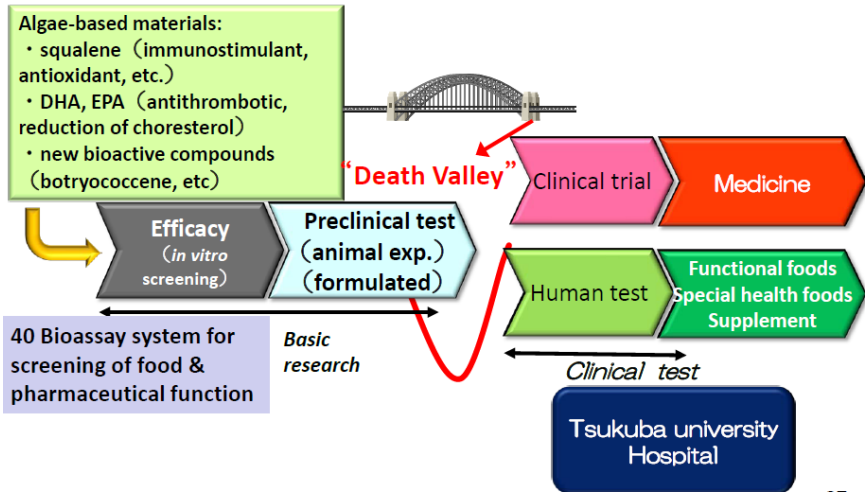


Figure 13. *Applications in Medicine.*

2. THE MICROALGAE INDUSTRY IN JAPAN

The Microalgae Industry is not an industrial sector by itself since there is no direct business associated with its harvesting, although it has potential for R&D applications, for instance, in order to absorb the CO_2 emissions existing in the environment. However, there are indirect sectors associated to Microalgae related to the production of biomass that can be processed into diverse products, as depicted previously.

Japan is one of the countries with the highest investments and expectations in the Microalgae Industry, being specially focused in the production of biomass-based outcomes, in order to tackle Japan's Vulnerable Energy Supply Situation and also to open new markets related to foods, feeds and bio-chemicals (such as plastics).

There are big players involved in the production of Microalgal-based projects, to name a few, DENSO Corporation, Euglena Corporation, ISUZU Motors Corporation and All Nippon Airways. The Japanese government is also involved in supporting these initiatives, as well as Universities such as the University of Tsukuba, which is a world-class leader in R&D, who are aiming to develop Microalgal technologies in various plants.

Even when the Industry of Microalgae is more or less mature, there are numerous ongoing R&D activities - for instance - wastewater treatment in order to purify the water resources for human consumption as well as for the recovery of the nutrients in sustainable forms, in which the Industry of Microalgae stills are in early stages of development of various technologies.

Japan's Vulnerable Energy Supply Situation

Scholars of the *"Global Footprint Network"* highlighted that it would need 5.5 countries of its own size to meet its consumption requirements [25].

Japan is a country that is not self sufficient in resources. Therefore, it has to import resources to meet 94% of its energy requirements [26]. This puts Japan in a very vulnerable state. When the oil crisis of 1970 hit, Japan changed its strategy and started using nuclear energy, coal and natural gas. Still today, 40% of Japan's energy sources come from oil. 80% of this oil is imported from the Middle East. All these types of energy sources result in carbon dioxide emissions which have had a negative impact on the environment and climate. Japan also has to cater for its electricity requirements. It cannot be imported from any of its neighboring countries since it is an island. However, to ensure that the electricity requirements of Japan are met, such a system has to be devised that is not only efficient in its productivity but also ensures safety for everyone and its climate.

Japan has to improve its nuclear energy systems to ensure that there is no danger to anyone. It also has to make maximum efforts to use renewable energy in its systems to reduce waste. In April 2014, the *"Strategic Energy Plan"* was proposed which stated that

nuclear power can satisfy all the energy requirements of the country provided it was safe. Based on this plan, a future plan was proposed in June 2015. According to the plan, by the year 2030, nuclear power would make up for 20-22% of their total energy mix.

Regarding energy dependency, it is also important to highlight the following facts:

- Because Japan is largely composed of mountainous regions, it does not have abundant energy resources. Apart from coal, it lacks almost all sorts of fossil energy sources. To make up for this deficiency, Japan has to import natural gas, crude oil and uranium to power its nuclear reactors. In 2010 [27], it was recorded that Japan imported crude oil to meet up for approximately 42% of its energy requirements. Although, Japan has some coal resources of its own, it still accounted for 20% of the world's coal imports in 2010.
- Japan is the world's largest liquefied natural gas importer, second-largest coal importer, and third-largest net importer of crude oil and oil products.
- Because of Japan's lack of energy resources, it was able to produce only 9% of the total energy requirements in 2012. Therefore, it has to import energy resources from other countries. This makes Japan the largest importer of LNG (liquefied natural gas). It is the second-largest importer of coal with China being the largest. Also, it is the third largest importer of crude oil in the world with the first and second largest being the United States and China respectively [28]. Japan used to make up for an additional 11% of its energy requirements through nuclear power. However, after the Fukushima nuclear plant accident in 2011, it had to be shut down. As a result, Japan has had to import more resources to meet its energy requirements.

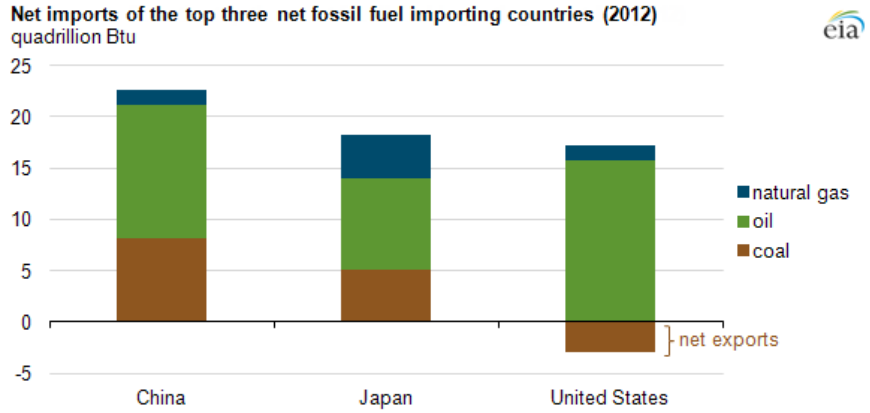


Figure 14. *Comparison between the fossil fuel imports.*

2.1. PROFILE OF MICROALGAE INDUSTRY IN JAPAN

This section highlights in 10 points the composition of the Microalgae Industry in Japan (Table 11).

1. Main Strains of Microalgae Used in Japan
2. The AIIC (Algae Industry Incubation Consortium, Japan)
3. The Japan Association for Microalgae Fuels (JMAF)
4. The International Symposium on Algal Biomass
5. Algae Science Japan
6. Tsukuba 3E Forum
7. Tsukuba System of International Strategic Zone
8. Core Laboratory for Algal Biomass and Energy System
9. Initiatives for Next Generation Aviation Fuels (INAF)
10. Newest trends on Microalgae in Japan

Table 11. *Aspects and initiatives that compose the profile of the Microalgae Industry in Japan.*

Figure 15 details the domestic algal markets in Japan.

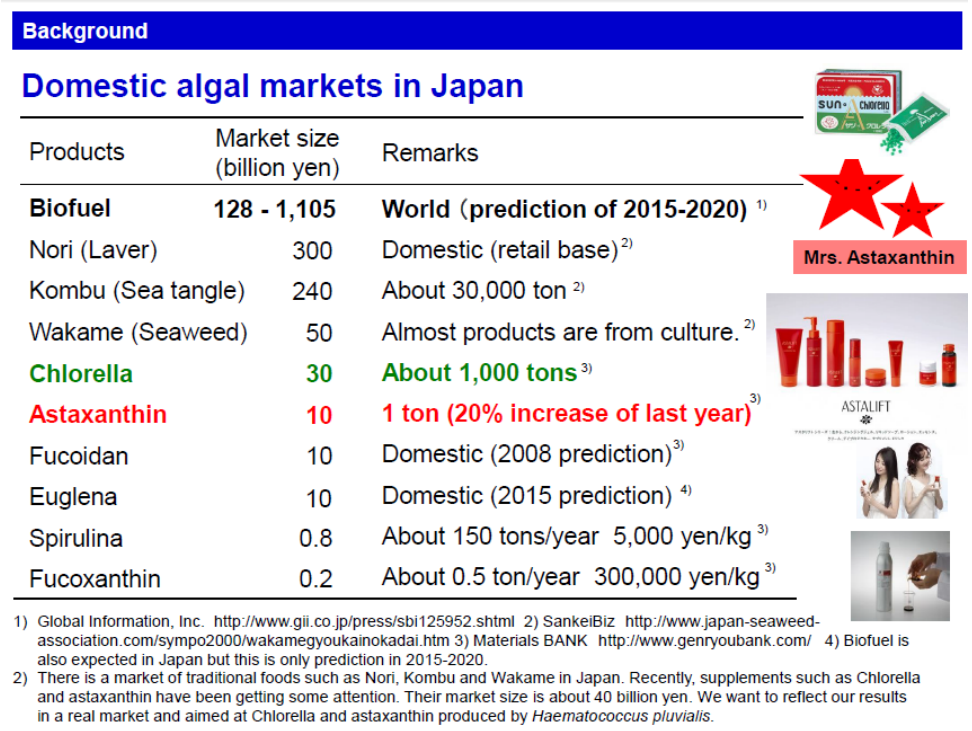


Figure 15. *Domestic algal markets in Japan.*

2.1.1. Main Strains of Microalgae Used in Japan

This subsection is useful for understanding the diversity of products that are currently produced in Japan.

Chlorella

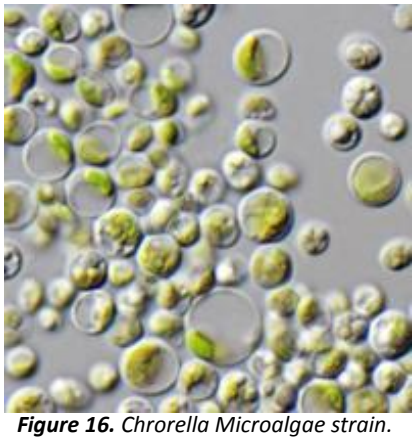


Figure 16. *Chrorella Microalgae strain.*

In form of dry matter it has 45% of protein, 20% of lipid, 20% of carbohydrates and other vitamins and minerals. In the 1960s became possible its mass culture, since then it has been established in the markets as a healthy food. In 2010 its whole genome was decoded by the *National Center for Scientific Research* (CNRS), in France. Through the resulting genome analysis the applications have been expanded to industrial raw materials and healthy supplements.

Dunaliella

Figure 17. *Dunaliella Microalgae strain.*

Dunaliella is an excellent antioxidant that helps the regeneration of cells. Not only utilized in cosmetics, but also commercially available as healthy food.

Spirulina

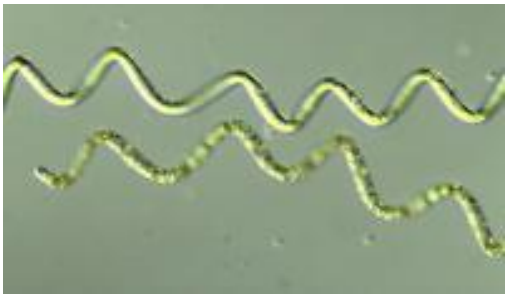


Figure 18. *Spirulina Microalgae strain.*

Dry Spirulina (biomass) is composed of 60% proteins, with vitamins, minerals, polysaccharides and chlorophyll. It has been used in frozen desserts, dairy products, beverages, gum and natural coloring material for blue.

Euglena

Figure 19. *Euglena Microalgae strain.*

With a very elevated rate of growth, this Microalgae strain is mostly used for oil-based products such as bio-fuel and jet-fuel. The Company with the same name as the strain - Euglena Corporation - is the main contributor in its R&D activities.

Nannochloropsis

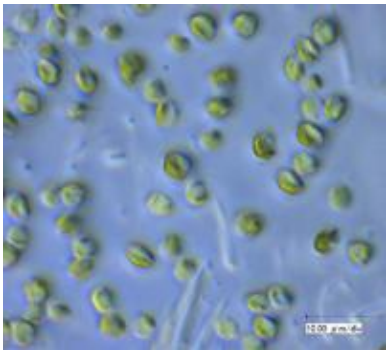


Figure 20. *Nannocholopsis Microalgae strain.*

It has a fatty acid content of approximately 30%, the fatty acid in the EPA is included at a rate of about 35 percent. It recently attracted the attention for its applications such as anti-tumor action, the improvement of learning function, blood sugar lowering action, anti-rheumatic effect and hair growth.

Haematococcus

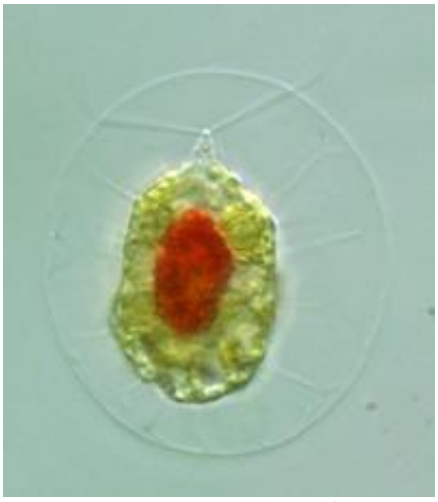


Figure 21. *Haematococcus Microalgae strain.*

High anti-oxidant action is a carotenoid with astaxanthin that has been widely used in healthy food and cosmetics. Indoor culture facilities of Haematococcus are used for producing *astaxanthin*. **YAMAHA**, which is a conglomerate with a very wide range of products and services, predominantly motorcycles, also produces high-quality astaxanthin.

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2.1.2. The AIIC (Algae Industry Incubation Consortium, Japan)

"Algae Industry Incubation Consortium (AIIC), Japan was established in June 2010 to contribute to the incubation of algae industry and the actualization of low-carbon society, which is being promoted by the Japanese government. The Consortium shifted to non-profitable general incorporated association in April 2013. The Consortium has become the largest group in this field in Japan; number of regular members (organizational and individual members) of the Consortium is over a hundred by now.

Objective of the Consortium is the early establishment of algae industry by researching on industrial utilization of algae and related technological development subjects, collecting, providing, and exchanging domestic and foreign study and information regarding algae and activities including technological development with the participation of member enterprises".

Figure 22. *AIIC logo and banner*

Activities:

- R&D towards the commercialization of bio-fuels.
- Industrial use and R&D on innovative technologies.
- Collection of domestic and international research and information related to algae.
- Organizations involved in algae research and exchanges with government and local governments.
- Dissemination tasks with international conferences related to algae R&D.
- Seminars, lectures, meetings and training sessions.
- Newsletter and printed materials.
- Algae science-related education, HR development, social contributions, etc.
- Contact between the members, the promotion of cooperation and alliances.


Figure 23. *Activities of the AIIC.*

2.1.3. The Japan Association for Microalgae Fuels (JMAF)

Established May 25, 2012, the JMAF association aims to promote the development of technologies for Microalgae bio-fuel production and recommend measures necessary for technology development. Oil production from renewable Microalgae biomass is expected to help reduce CO_2 emissions in logistics and transportation.

The JMAF focus on commercializing Microalgae bio-fuel and to facilitate joint efforts across industry, government and academia on a national basis. JMAF will work to establish an integrated Microalgae bio-fuel production system, targeting fiscal year 2020.

The member Companies are JX Nippon Oil & Energy Corporation, IHI Corporation, DENSO Corporation, Hitachi Plant Technologies, Ltd., Mitsubishi Corporation, Idemitsu Kosan Co., Ltd., Euglena Co. Ltd., Neo-Morgan Laboratory Incorporated, IDEA Consultants, Inc., YANMAR Co., Ltd. The chairperson of the association is Mr. Kenichiro Saitoh, General Manager, Research & Development Planning, Research & Development Division, JX Nippon Oil & Energy Corporation (Figure 24).

Figure 24. *The Nippon Oil & Energy logo.*

2.1.4. The International Symposium on Algal Biomass (ISAB)

ISAB is an international symposium co-organized by the University of Tsukuba and the Algae Industry Incubation Consortium, Japan (AIIC) held in 2013 and 2015. It aims to share visions of how to promote the development of algae biomass commercialization among the world.

Figure 25. *Logo of the ISAB.*

2.1.5. Algae Science Japan

Algae Science Japan Inc. is a Company that *"promotes the business for creating a better life for people"*. It has their major business in:

1. Research for microalgae bio-fuel.
2. Research and planning for launching microalgae plants for bio-fuel production.
3. Producing and selling diverse products (foods, feeds, chemicals, etc.) derived from Microalgal biomass.
4. Producing and selling microalgal bio-fuel.
5. Consulting for enhancing rural development, social development and environmental development.

The Business of Algae Science Japan follows the *"5Fs" (Figure 26)*.

Figure 26. *Business domain of 5Fs.*

Algae Science Japan's Microalgae culture supports 2 main branches for Microalgal biomass based products, (fuels and diverse products) (Figure 27 & 28).

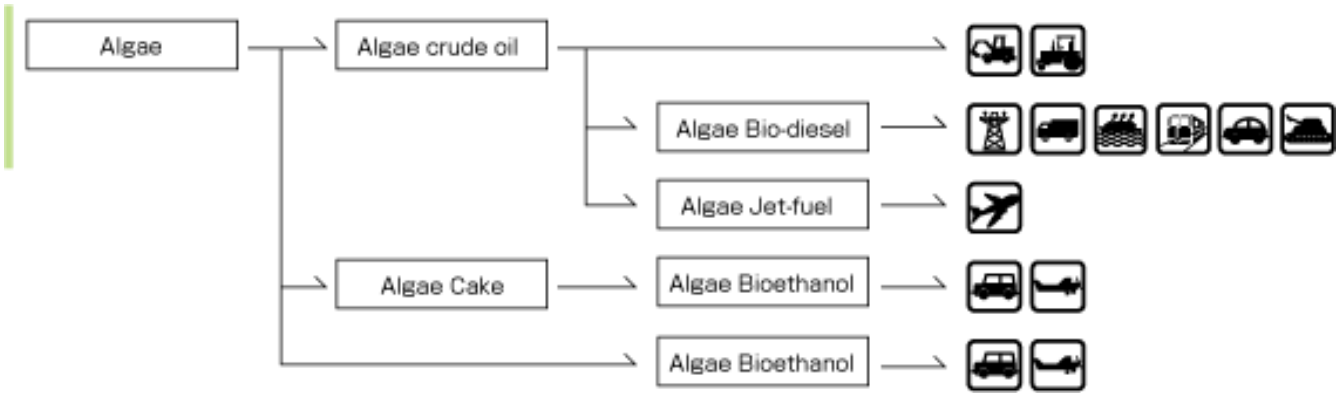


Figure 27. *Diversity of Microalgal-based fuels.*

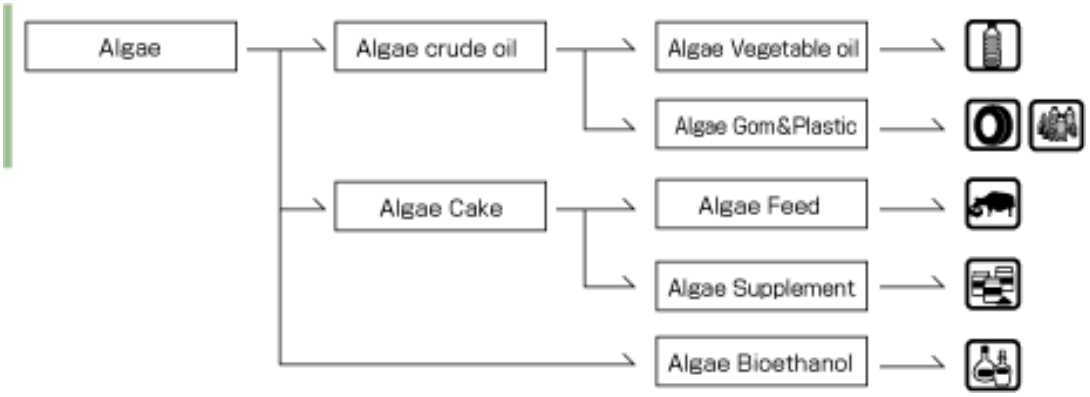


Figure 28. *Diverse products from Microalgal biomass.*

2.1.6. Tsukuba 3E Forum

"It was collaboratively organized by universities, research institutes, and municipalities in 2007 with the aim of tackling research that establishes Tsukuba as an energy-saving, low-carbon city of science, based on the Tsukuba Eco City Concept. It operates on a forum of open discussion. The goal is to "reduce CO2 emissions by 50% in Tsukuba by 2030 (Tsukuba 3E Declaration 2007)" while balancing the "3Es" of environment, energy, and economy. Task forces organized within the forum propose suggested technologies and systems to the city to achieve an eco city through demonstration and incorporation. A committee has been created within the Tsukuba Science City Network (TSCN) that discusses objectives for the entire forum and draws up proposals for the city. This network also contributes to build an ideal, cosmopolitan and mature city. The occurrence of the Great East Japan Earthquake in 2011 led to a call for the need to reassess energy policies, and investigations are being conducted that include the ideal vision for a new environmental city of the future that focuses on restoration".

Figure 29. *Goal of the Tsukuba 3E Declaration 2007*

What is the Tsukuba Eco City Concept?

The University of Tsukuba proposed the *"Tsukuba Eco City Initiative"* (Figure 30) as a collaborative, joint R&D project for Tsukuba Science City. It establishes the foundation of the *"Tsukuba 3E Forum"*.

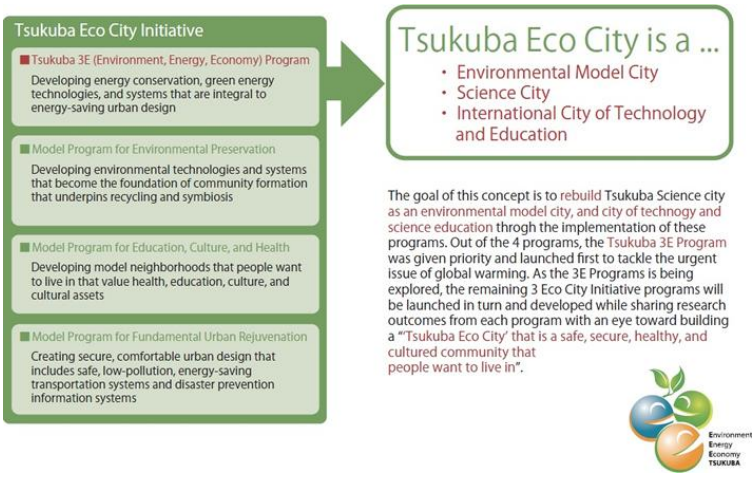


Figure 30*. The Tsukuba Eco City concept.*

"The goal of this concept is to rebuild Tsukuba Science City as an environmental model city, and city of technology and science education through the implementation of these programs. Out of the 4 programs, the Tsukuba 3E Program was given priority and launched first to tackle the urgent issue of global warming. As the 3E Program is being explored, the remaining 3 Eco City Initiative programs will be launched in turn and developed while sharing research outcomes from each program with an eye toward building a Tsukuba Eco City' that is a safe, secure, healthy, and cultured community that people want to live in".

Organization

The Tsukuba 3E Forum is an open discussion forum (Figure 31).

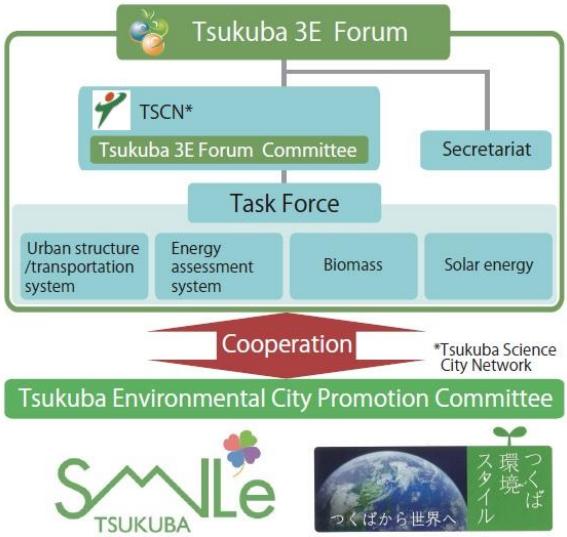


Figure 31. *Structure of the Tsukuba 3E Forum.*

Biomass Task Force

The task force promotes the utilization of biomass in Tsukuba by contributing experiences and technologies of their own or these belonging to their organization in order to aid environmental preservation including the establishment of a recycling-oriented society, human networks, revitalization of rural regions and the prevention of global warming.

Issues that are being addressed:

- Support to create a plan to promote the utilization of a biomass town in Tsukuba.
- Policies to preserve the forests plus undeveloped woodland near populated areas.
- Promotion of algae-based energy.

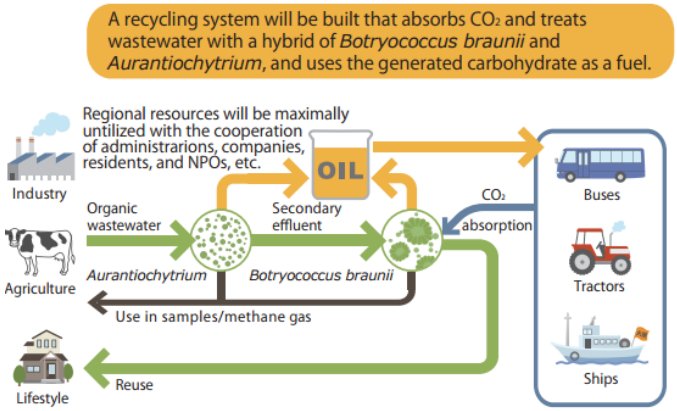


Figure 32. *Biotask force for biomass.*

ABES

"The Algae Biomass Energy System Development Research Center (ABES), was established ***at the University of Tsukuba on July 1, 2015.*** *As one of the largest algae biomass research centers in Japan, the center consists of more than fifty members of the university faculty. The center is composed of six research categories including Bio-Resources, Metabolic and Genetic Engineering, Production Systems Engineering, Green Chemistry, Energy Systems, and Wellness Medicine. A research promotion system has been prepared at the center to conduct fundamental research, empirical studies, and industrial applications of algae research in a consistent manner. Also, ABES was established as the first research center utilizing this system which the university introduced a new system, the System for Development Research Centers to run research organizations.*

The system allows the university to receive outside funding to run research organizations. Its duties include fundamental research and empirical studies on algae biomass and applications of the research for industry. The final objective of the center is to put algae-derived oil into practical use and to create a new algae industry. For industrial applications of algae research, ABES intends to promote to develop an algae-based bio-fuel production system, an algae-based wastewater treatment system, the production of livestock feed from algae, and the application of algae-derived oil for cosmetics and medical products. Furthermore, ABES intends to invite top-level researchers from abroad and to enhance development of human resources by conferring degrees on highly motivated students from all over the world".

Figure 33. *Logo of ABES.*

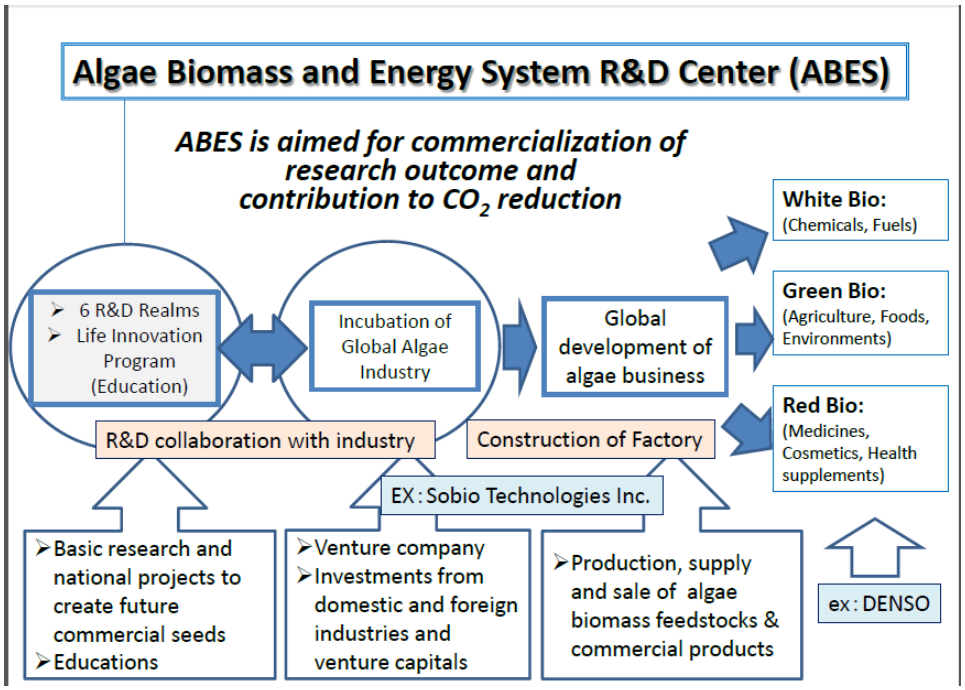


Figure 34. *Aims of the ABES.*

R& Activities of the ABES

The R&D activities of the ABES is illustrated with the following Figure 35.

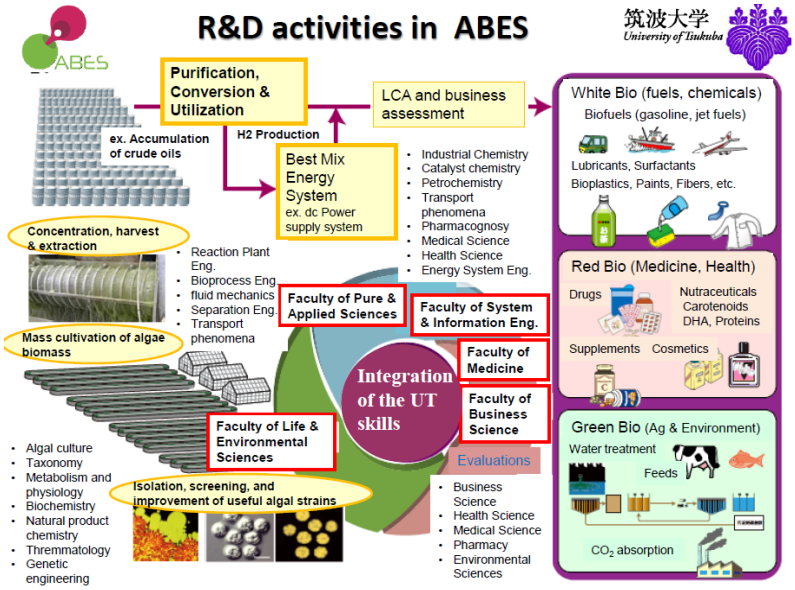


Figure 35. *R&D activities in ABES.*

Structure

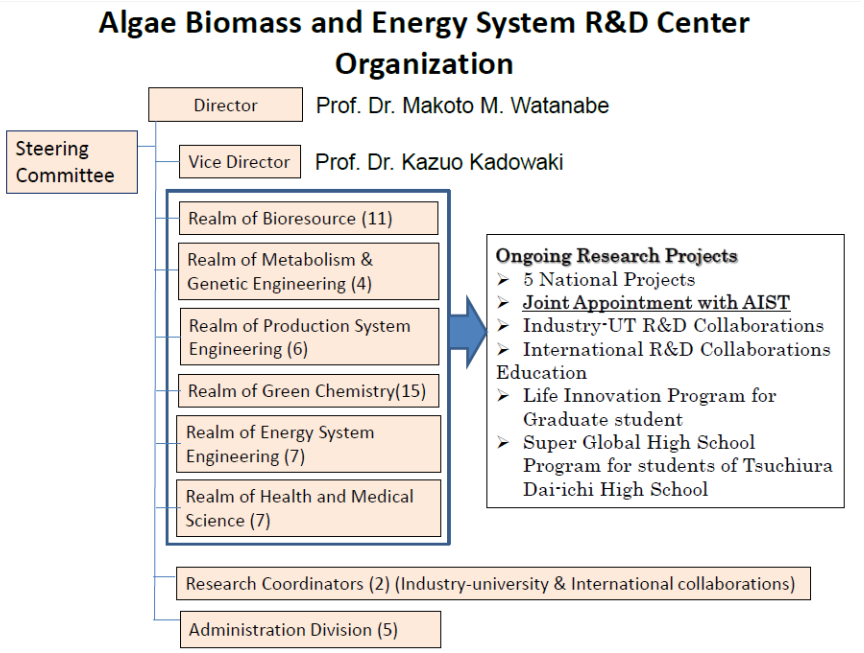


Figure 36. *Structure of the ABES.*

Figure 37 summarizes the structure of the ABES Consortium.

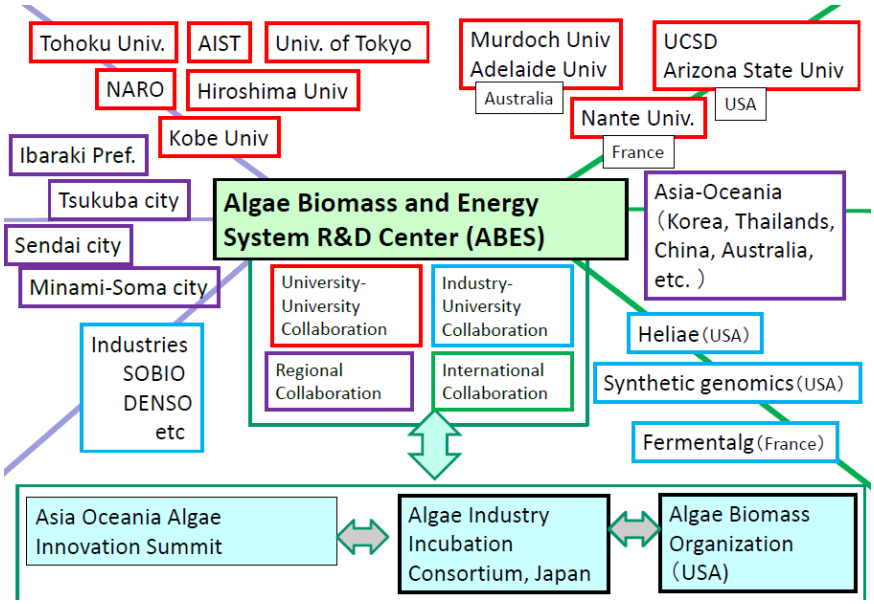


Figure 37. *ABES Research Consortium.*

Universities also play an important role in the development of Microalgal technologies (Figure 38).

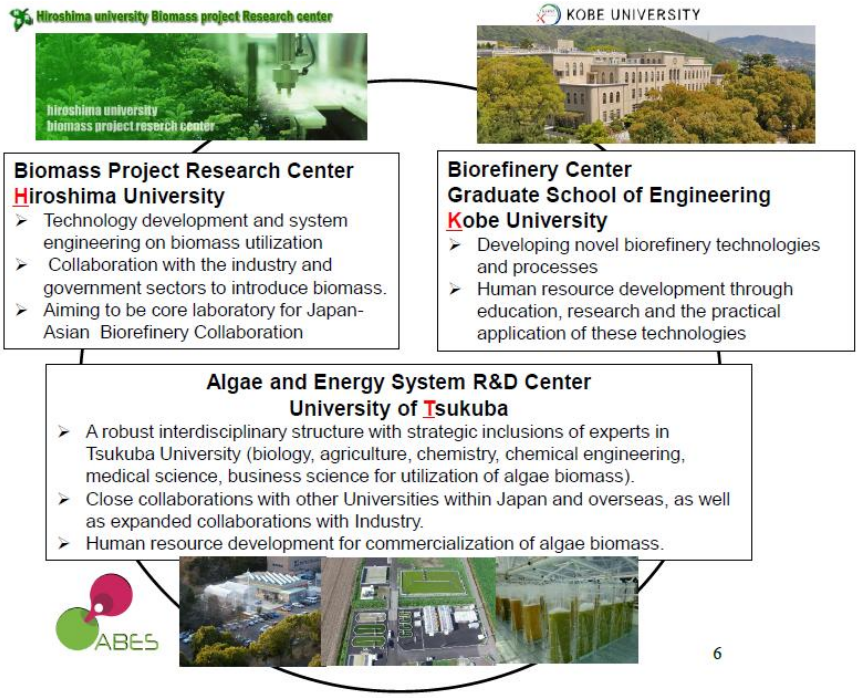


Figure 38. *Collaboration of 3 Japanese Universities on Microalgae projects.*

Targets of ABES

The next diagram (Figure 39) details a timetable of ABES for profitability.

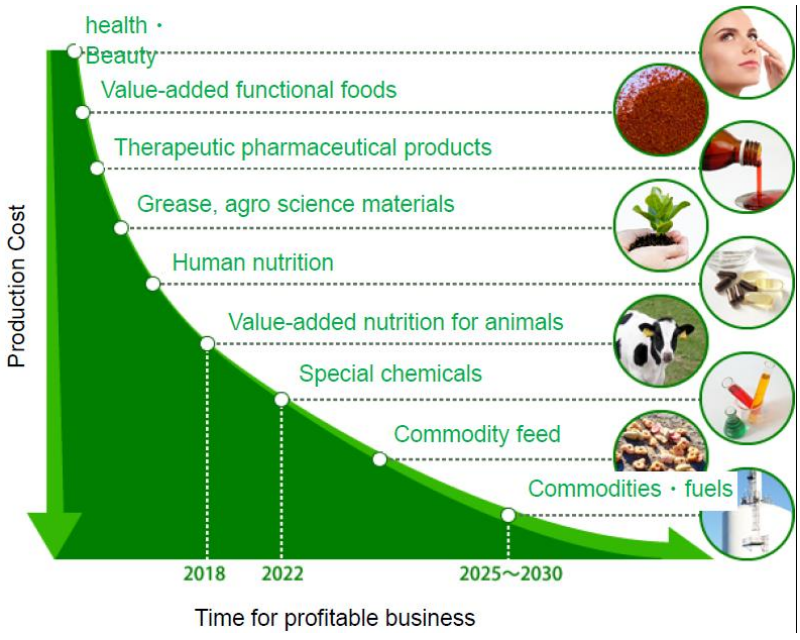


Figure 39. *Timetable of ABES for profitability.*

Next, there is a brief description of 3 projects in which the ABES is involved:

1. Practical use of algae biomass energy (Tsukuba international strategic zone)

For conducting R&D in Microalgae production using outdoor large-scale cultivation, after harvesting, the algae oil is extracted and experimented with blended fuels.

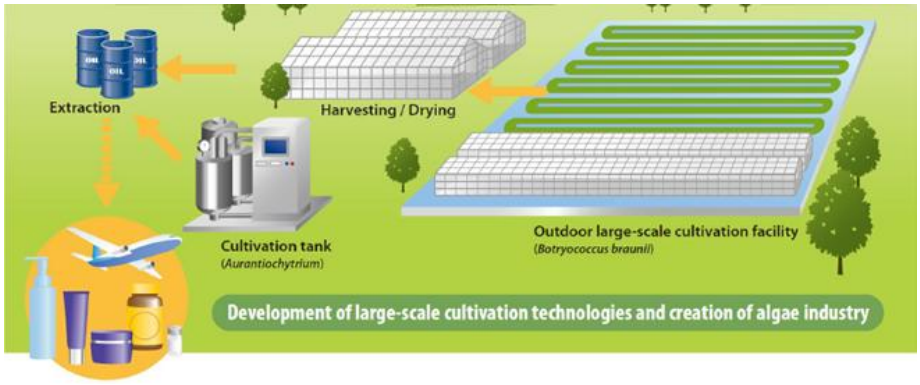


Figure 40. *Plant for extraction of Microalgal bio-fuel.*

Facilities for Microalgae biomass and bio-fuel production in Kurihara, Tsukuba, Ibaraki.

Figure 41. *Open systems for harvesting of Microalgae.*

First driving experiment using algae blended fuel on March 24th, 2014.

Figure 42. *First driving experiment using algae blended fuel.*

Botryococcus oil for hand cream *"moina"* released in markets, November 2014.

Figure 43. *Hand cream "moina" with the participation of DENSO Corporation.*

2. Research and development for the use of microalgae Energy (*"Tohoku Recovery Next-Generation Energy Research and Development Project"*)

Together with Sendai City and Tohoku University, was constructed a new circulation system in the waste water treatment process, which produces oil by algae and uses the oil in the sludge incineration facility, combining the cultivation of two strains (Aurantiochytrium and Botryococcus braunii) in the sewage treatment process at the Minami-Gamo Wastewater Treatment Plant (were damaged by the tsunami).

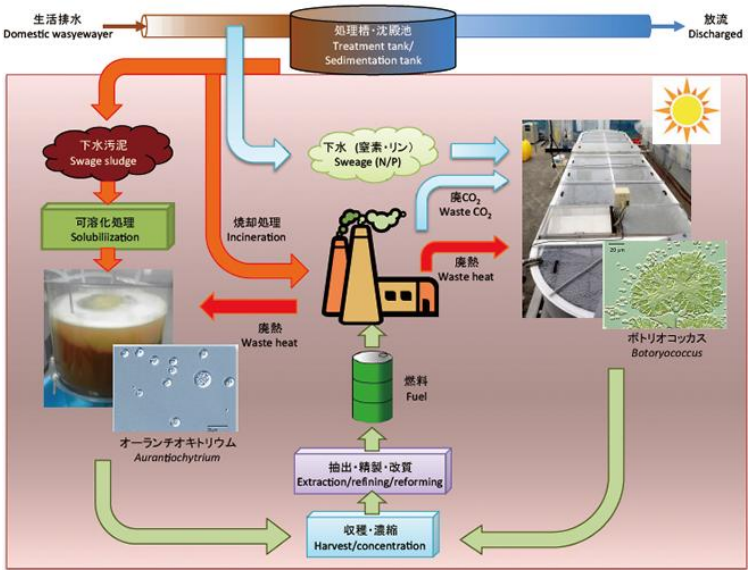


Figure 44. *Sustainable system of oil production in the sewage treatment and use as fuel in the sludge incineration.*

- Aurantiochytrium produces oil by absorbing the organic matters found in sewage sludge.
- Botryococcus braunii is a photosynthetic Microalgae and it absorbs nitrogen and phosphorus in the treated sewage water as nutrients and produces oil.
- Waste heat and waste CO_2 generated during the sludge incineration process are used in the cultivation of algae.

- The algae oil, which is produced during the sewerage treatment process can be use as a fuel of sludge incineration.

3. Demonstration project on microalgae fuel production

The project was developed in Minamisoma, Fukushima. This demonstration project cultivated a large amount of native algae to produce bio-fuel. The goal is to reduce production costs and lower energy consumption during the fuel production process. In order to achieve this goal, it used waste heat, CO_2 and sewage water in the cultivation process, and optimized the processes of drying, concentration, conversion (to crude oil using HTL), as well as the stage of residue recycling. The AIST (Advanced Industrial Science and Technology) established the FREA (Fukushima Renewable Energy Institute) in Koriyama, Fukushima Prefecture in April 2014, to promote R&D into renewable energy in this project (amongst other initiatives).

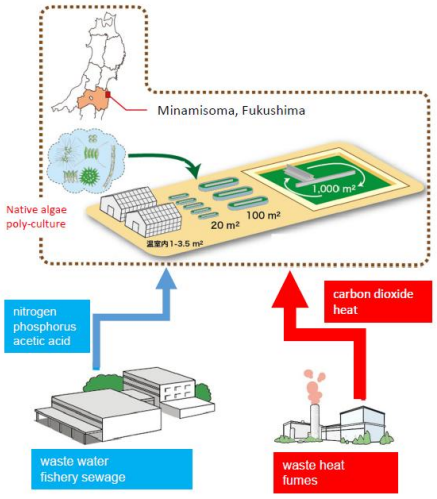


Figure 45. *Demonstration project in Fukushima.*

Figure 46. *Algae Biomass Production R&D Center, Minamisoma, Fukushima*

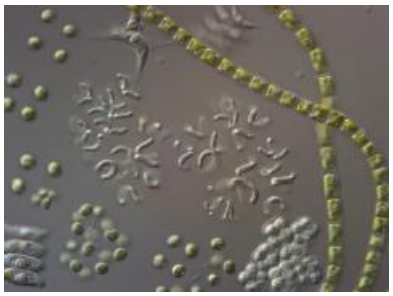


Figure 47. *Fukushima's native algae(1).*

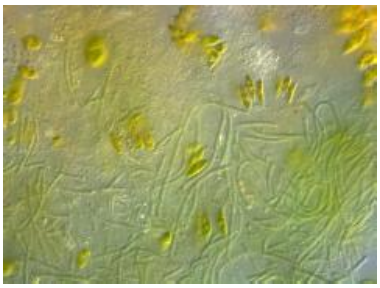


Figure 48. *Fukushima's native algae(2).*

2.1.7. Tsukuba System of International Strategic Zone

It aims to contribute to serious current problems such as a rapid decline in birth rates, an aging society and governmental energy policy-making.

Tsukuba International Strategic Zone
つくば国際戦略総合特区

Figure 49. *Logo of the Tsukuba International Strategic Zone.*

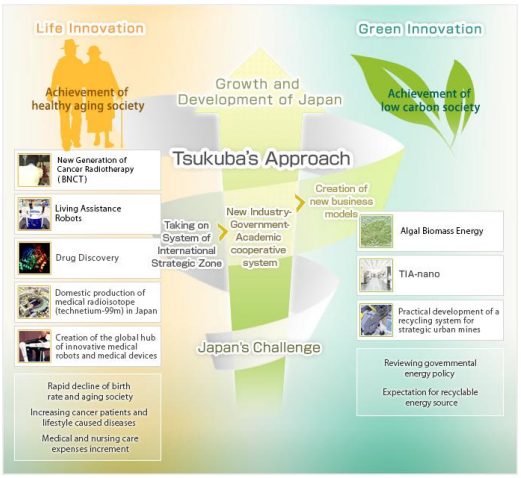


Figure 50. *Main goals.*

The Scientific Technology field holds core values which can provide a resolution for these problems. The Tsukuba System of International Strategic Zone works as a new hub for academic-industrial alliance which constantly renovates itself.

Several species of algae can produce oil efficiently. For example, the potential of hydrocarbon-oil production of Microalgae, Botryococcus braunii is estimated to be 118 t per 1 ha per year, which is much greater than 0.2 t for maize and 6.1 t for palm. Aurantiochytrium has only one third of hydrocarbon content of Btryococcus braunii, but grows 36 times faster and thus produces 12 times more hydrocarbon than Botryococcus braunii. These bio-fuels will contribute to the low oil self-sufficiency of Japan and help to mitigate global warming.

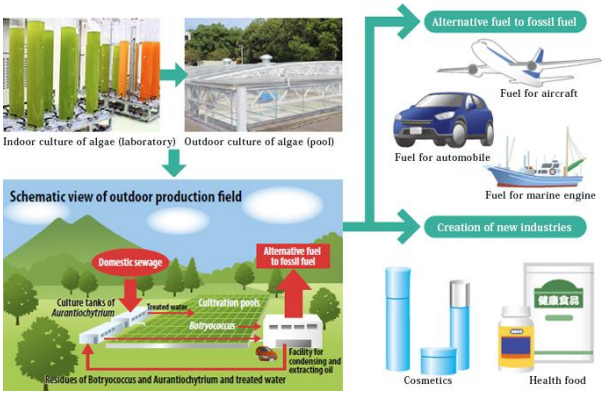


Figure 51. *Process of production of bio-oil through the Tsukuba System of International Strategic Zone.*

2.1.8. Core Laboratory for Algal Biomass and Energy System

Figure 52. *Logo of the Core Laboratory for Algal Biomass and Energy System.*

The research unit made a team with experts in chemical conversions from the Faculty of Pure and Applied Sciences. The experts in energy were members of the Faculty of Engineering, Information, and Systems. The university approved Strategic Initiatives support and established a "Core Laboratory for Algal Biomass and Energy System". The scientific research grants were used to build the research base. The funds were received from CREST (Core Research for Evolutional Science and Technology) and NEDO (New Energy and Industrial Technology Development Organization).

The company has been able to move towards more business associations internationally for the research bases, particularly in United States, Australia, the Netherlands, Thailand and India. The company established the Algae Industry Creation Consortium to be associated with industry-academia. The major project for the Tsukuba Special Zone of International Strategy made the company recognized overseas. It gives the opportunity for further studies in Next-Generation Energies for Tohoku Recovery projects. To promote and strive for better business, must stick to the basic laboratory base.

2.1.9. Initiatives for Next Generation Aviation Fuels (INAF)

The Center for Aviation Innovation Research is an inter-disciplinary organization within the University of Tokyo, established in August 2009.

Figure 53. *Logo if INAF.*

Japan is one of the largest countries that commenced a government-backed project to explore the possibility to develop an aviation bio-fuel industry domestically. All over the world, about 30 companies have come together to form a group named Initiatives for Next Generation Aviation Fuels (INAF).

These companies belong to the industry of the aerospace, fuel, engineering, and finance as well as the research sector. This committee will develop a plan to make use of the aviation bio-fuels by 2020. It was considered for the Olympic and Paralympic Games that will take place in Tokyo, Japan. The airline companies include Japan Airlines, All Nippon Airways, Nippon Cargo Airlines and Boeing, which came together as an association in 2009. They tested their first flight with bio-fuels. The bio-fuel was demonstrated and created from melina, jatropha and algae blended by Honeywell UOP. These were supplied by the Japanese venture of UOP and JGC Corporation, Nikki-Universal as well as members of the INAF.

Japan Airlines, Nippon Cargo Airlines, Narita International Airport Corporation and Japan Petroleum Exploration and Boeing formed a steering party with an initial meeting arranged in May. The research was facilitated by the help of the University of Tokyo. The outcome of the meetings are to be observed under the direction of four government ministries that are responsible for the sector of agriculture, land, transport, environment and trade.

Roadmap on microalgae bio-fuel

The report to the concerned party was titled “Roadmap for Establishing Supply Chain for Next-Generation Aviation Fuels ~ aiming to Commence Utilization by the 2020 Tokyo Olympics and Paralympics”. It was released in July 2015. It observed that establishing a supply chain will require fuel production for next-generation aviation fuels by 2020. This fuel will be produced by consuming raw materials: municipal waste, microalgae, natural oils, food waste oil, non-edible biomass and woody biomass. It will formulate a roadmap..

In other countries, the fuel production has been done through microalgae. This is because the productivity rate per unit is high, and the competition among foods will be

prevented. In the meantime, the production can be innovative and the technology can be established to improve microalgae's cultivation. It will help the supply over the time.

The Tokyo Olympics and Paralympics are scheduled to take place in 2020. The Mitsubishi Regional Jet (MRJ) is the Japan's foremost locally manufactured passenger aircraft in use for over 50 years. It is planned to take flights via Japan throughout whole world. The manufacture and establishment of this next-generation aviation fuel will help Japan to commence and promote the supply of alternative aviation fuel. This is a better opportunity for the country to attract more tourists. The environment and innovation in the industry will increase the prestige and standing of the company and country, with the consequent acceleration of business.

A supply chain flow for the next-generation aviation fuel has been proposed (Table 13).

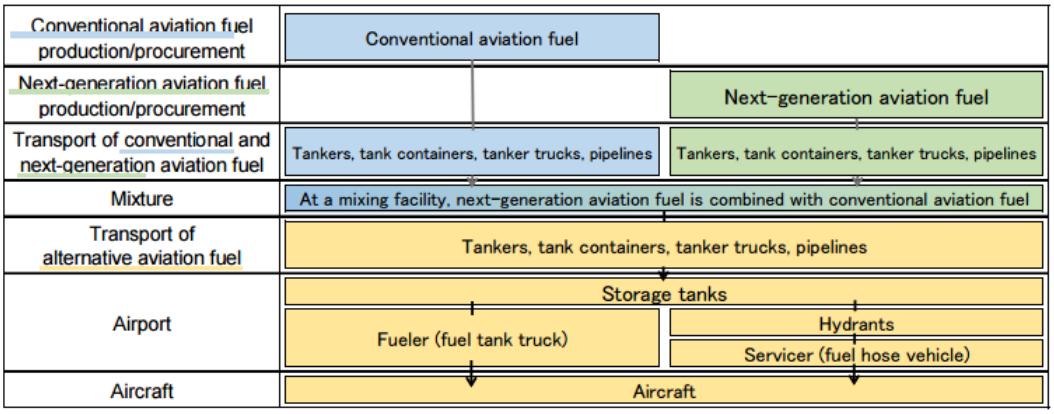


Table 13. *Proposed supply chain for the next-generation aviation fuel.*

The international standards of quality given by the certified ASTM (American Society of the International Association for Testing and Materials) have to be met by production companies. For example, the traditional aviation fuels follow D1655. D7566 is a standard that has been used for alternative aviation fuels. They have to be met by companies in the industry.

Nonetheless, a roadmap has been created to make companies able to utilize the innovative technology in Japan and to establish next-generation aviation fuels. It will commence the use of alternative aviation fuel by the creation of a post-production supply chain. The projects planned will give a demonstration in 2020, and commercial use will be established by 2021.

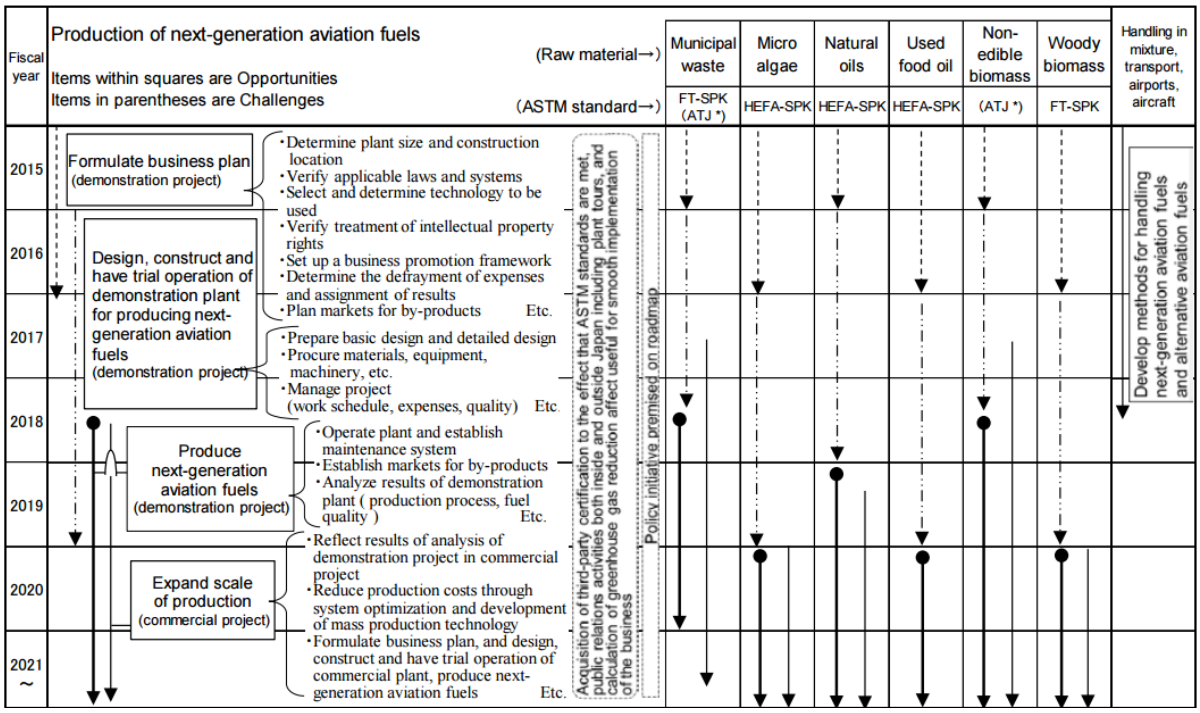


Figure 54. *Planned roadmap for production of next-generation aviation fuel.*

Business Overview

Algae oil has been used to produce Next-generation aviation fuel. This is gained through hydro-refining oil content that is produced by microalgae. The project will focus on the continued procedure of growth of microalgae to the production of next-generation fuel. The business will be progressed with other companies collaborating to continue the research as part of the NEDO project. The ASTM standards do rule for the usage of production technology and innovation (HEFA-SPK).

Path Leading to Achievement of Goal

Fiscal Year	Opportunities	Challenges
2015	< Formulation of business plan > ● Select multiple candidate raw materials ● Conduct simulation of next-generation aviation fuel production process using UOP technology	■ Selecting raw materials that can be stably procured ■ Determining implementing enterprise
2016	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Conduct trials for producing fuel from selected candidate raw materials (oversees implementation anticipated) ● Prepare basic design for demonstration plant	■ Concluding licensing and engineering agreement with UOP
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Prepare detailed design for demonstration plant	■ Appropriately managing project
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) > ● Construct and have trial operation of demonstration plant	■ Appropriately managing project
2019	< Production of next-generation aviation fuel (ongoing from 2019) > ● Operate demonstration plant, and produce next-generation aviation fuel < Increase in production scale (1) > ● Commence basic design for commercial plant	■ Narrowing down raw materials to ensure operational stability of plant ■ Commencing plant operation, appropriately managing and maintaining operations ■ Reflecting results of demonstration plant operation
2020 ~	< Increase in production scale (2) > ● Prepare basic design, detailed design for commercial plant, construct and operate	■ Increasing scale of demonstration plant production capacity by 3~5

Figure 55. *Roadmap for Supply of Next-Generation Aviation Fuel Using Natural Oils as the Raw Material.*

Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

Position of this Path will be considered to form large-scale production while the quantity of the fuel will be limited in 2020. After 2020, the technology will lower in cost following the next-generation fuel. This will be kept parallel to the rising demands with the help of increased acquired materials.

There are various issues concerned with microalgae regarding production mass. The productivity of oil is high, and the competition among the food may be prevented. So the former meeting held in 2012 had great concerns for the fuel productions by the use of raw materials, and it is considered same as today. A longer run perspective shows that the next-generation aviation fuel production is considered to be both feasible and sustainable in the segment enabling the process.

INAF Members:

IHI Corporation
ITOCHU Corporation
Japan Aerospace Exploration Agency
Kawasaki Heavy Industries
Green Earth Institute
Advanced Industrial Science and Technology
JFE Engineering Corporation
Shell Japan

Sumitomo Corporation
Japan Petroleum Exploration
All Nippon Airways
Sojitz Corporation
Chiyoda Corporation
University of Tokyo
Toyo Engineering Corporation
Toyota Central R&D Labs
Narita International Airport Corporation
JGC Corporation
Nikki-Universal
Japan Asia Investment Company
The Institute of Energy Economics, Japan
Nippon Cargo Airlines
Japan Airlines
Neo-Morgan Laboratory Incorporated
Nomura Research & Advisory
Hitachi Zosen Corporation
Phoenix Business
The Boeing Company
Mitsui Engineering & Shipbuilding
Mitsui Global Strategic Studies Institute
Mitsubishi Research Institute,
Mitsubishi Heavy Industries/Mitsubishi Hitachi Power System
Euglena Corporation

Table 14. *INAF members.*

INAF Observers:

Ministry of Agriculture, Forestry and Fisheries
Ministry of Economy, Trade and Industry
Ministry of Land, Infrastructure, Transport and Tourism
Ministry of the Environment
Japan Maritime Self-Defence Force
New Energy and Industrial Technology Development Organization (NEDO)

Table 15. *INAF observers.*

The initiation and expansion of the production process of next-generation aviation fuel that is both feasible and sustainable is a great opportunity. It is a commitment to the nation to increase tourism. It will also help the industry to promote better technology and aid the environment.

2.1.10. Newest Trends on Microalgae in Japan

In 2014, a scientific research paper was published which showed that Microalgae and aquatic plants can eliminate radioactive caesium, iodine and strontium from the radio-polluted aquatic environment, as well as provide an important strategy for decreasing radiopollution in the Fukushima area. Some species could absorb up to (1) 89,2% of caesium; (2) 41,3% of strontium and (3) 65,9% of iodine [44].

The New Energy and Industrial Technology Development Organization of Japan (NEDO) released [45] a report in June 2015 highlighting the importance of using Microalgae for bio-fuel production, using the energy of sunlight to convert carbon dioxide into fuel as a renewable resource. The efficiency of conversion is greatest among the species of plants. The report outlines that *"in the future, in order to lower the production cost, improvement in productivity per unit area, lower cost... it will be completed the development of a system for harvesting, oil extraction and purification"*, it also stated that "jet-fuel" for aircraft will be produced (Figure 56).

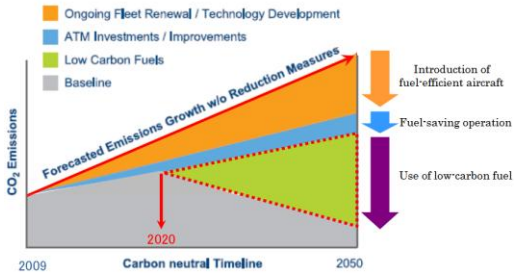


Figure 56. *Technology roadmap [44].*

The percentage of oil that is included in the dry algae (biomass) is 50% or more of the total weight which makes it a large productivity per unit area. It is also noticeable the current tests and achievements regarding bio-fuels Microalgae in outdoor large-scale algaculture (Figure 57) carried out by *IHI Corporation*, the *University of Kobe* and the *Chitose Institute*, in association with the NEDO.

Figure 57. *Achievements by IHI Co., the University of Kobe and the Chitose Institute, in association with the NEDO [45].*

The following picture (Figure 58) illustrates the real dimensions of the outdoor plant in *Kagoshima*.

Figure 58. *Plant of Kagoshima [45].*

Finally, this report depicts that in the future, in order to lower the production costs and enhance improvements in productivity per unit area, it will develop a system of algaculture of harvesting, oil extraction and purification as follows (Figure 59).

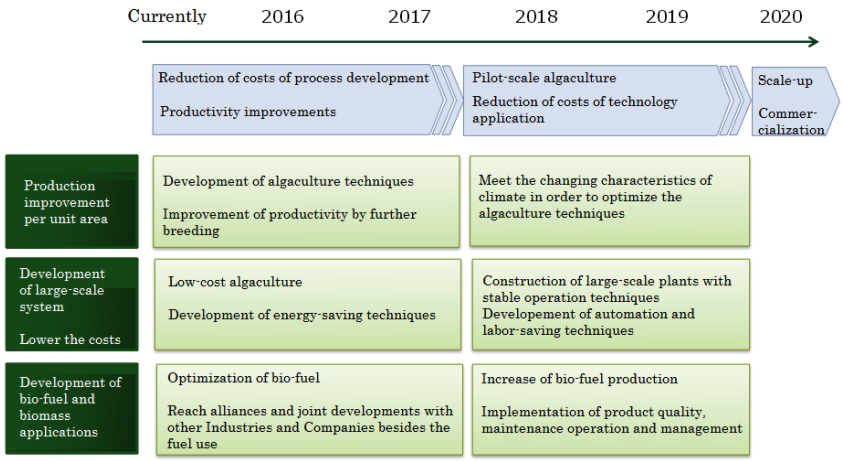


Figure 59. *Expected roadmap on Microalgae by the NEDO [45].*

The Agency for Natural Resources and Energy of the METI released a report [46] in June 2015 detailing what should be the future roadmap to follow in order to tackle the reduction of CO_2 emissions through Microalgae, *"using the recovered CO_2 such as alternative fuels and chemical raw materials to produce a value product"*. Besides, big Companies like IHI, J-POWER, DENSO (i.e. with the biggest (20,000m^2) test plant for the culture of *Pseudochoricystis ellipsoidea*, a patented oil-producing Microalgae) and DIC are already working with different species of Microalgae, and producing algae-based products, mainly, bio-fuels. Finally, the paper illustrates the roadmap for CO_2 emissions reduction to follow until 2030.

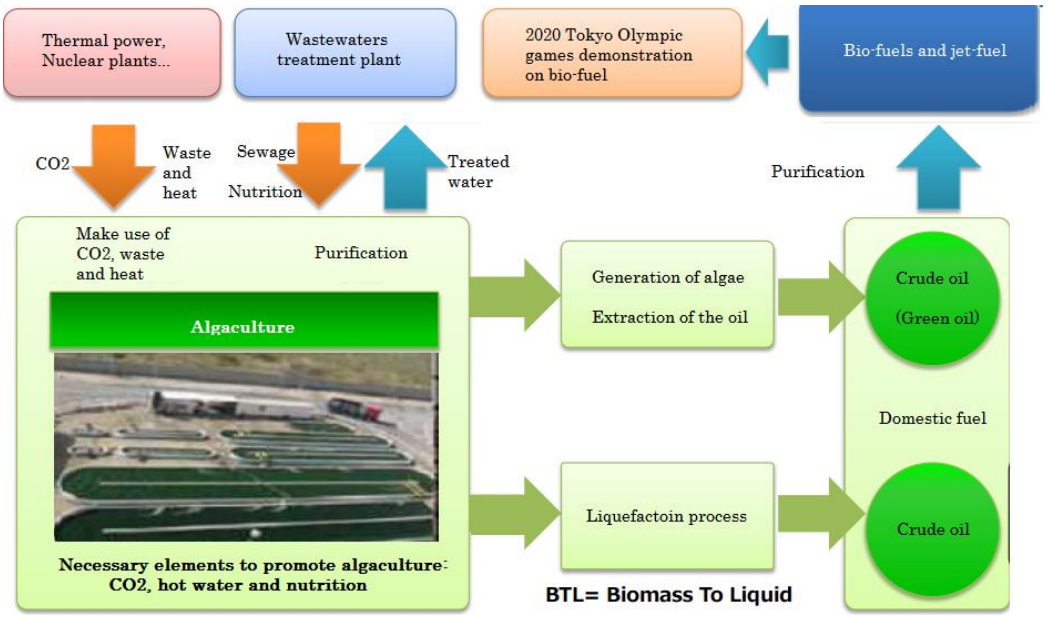


Figure 60. *Example of technology applied to Microalgae [45].*

There are various Japanese Companies (Table 16) working on various promising projects using different types of Microalgae, such as:

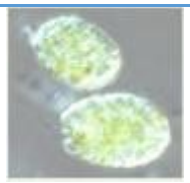
	IJI	J-POWER	DENSO	DIC
Application	Jet-fuel	Jet-fuel	Jet-fuel and Bio-fuel	Jet-fuel
Microalgae				
Plant				
Size	1.500m^2	Circular, 10m^2	60m^2	25m^2

Table 16. *Various Japanese projects.*

In two different reports in 2015 [47-48], the NEDO studied how a consortium of Japanese Companies could be able to produce jet-fuel obtained from Microalgae concluding that it would be necessary to produce at least 100.000m^2 of Microalgae production in 2020 to obtain jet-fuel. Furthermore, in an Achievement Report released by the NEDO in February 2016, it was stated that *"there is a chance to enter the market as health food due to increasing health awareness in the region. In each case, processing produced water requires cost, but thanks to the high profitability in Microalgae production, combining the two results in profitability. Moreover, power generation with wastes and utilization of exhaust heat enable further cost cuts as well as energy savings"* [49].

As it was previously depicted, the METI has a bio-related budget with a slight increase of around 1%, this is, from 21.85 billion yen in 2015 to 22.04 billion yen in 2016. This budget includes the initiative named *"strategic next-generation biomass energy utilization technology development projects"*, with an investment of 4.0 million yen (1.12 billion yen). This depicts that it will promote the biomass gasification and liquefaction (BTL), as well as the development of next-generation technologies to use bio-fuel derived from Microalgae. It will also undertake the development of technologies for putting into biogas purification technologies, within the existing city gas infrastructure [38].

2.2. PROFILE OF BIOMASS IN JAPAN

Currently there is a process of market liberalization [29] which encourages new entrants by opening up the power market to competition (Figure 61).

The government has come up with many measures to increase competition in the market for renewable energy resources. This means that they have to provide leverage for biomass producers to support the overall biomass utilization. Efforts have been made to increase biomass raw material so as to enhance the market further. Since Japan has a strong timber market, with its supply far exceeding its demands, policies are formulated to use excess timber for wood-based biomass production. Systems are being designed to reduce waste by utilizing food, waste, animal and industrial waste as raw materials for biomass production.

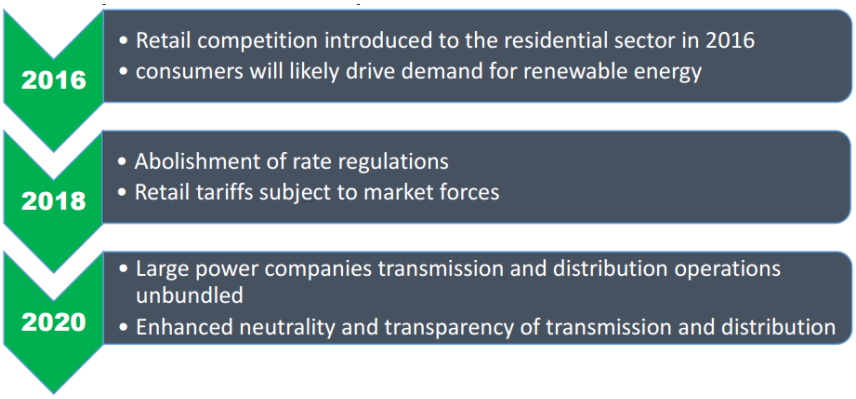


Figure 61. *Biomass market trends in Japan [29].*

The Biomass utilization program was developed in 2002 and the Basic Act was implemented in 2009 [30], this is summarized in Table 17.

Year	Policies	Outline
2002	Biomass Nippon Strategy	• Providing basic national strategy to realize sustainable society with full biomass utilization • Begins to create Biomass Town in 2004
2005	Kyoto Protocol Target Achievement Plan	• Promoting widespread use of biofuels including fuel for transportation (500,000 kL by 2010) • Building Biomass Towns and developing biomass energy conversion technologies
2006	Biomass Nippon Strategy (Revised)	• Aims to use biomass energy, including fuel for transportation • Fortifying Biomass Town creating. (Goal: 300 Biomass Towns by 2010)
2009	Basic Act for the Promotion of Biomass Utilization	• Aims comprehensive and planned promotion of biomass utilization policy • Drawing up the National Plan for the Promotion of Biomass Utilization • Setting up the National Biomass Policy Council
2010	Basic Energy Plan	• Introducing renewable energy in 10% primary energy supply by 2020 • Increasing biofuel at a volume equivalent to 3% cut of gasoline demand nationwide by 2020
2010	Act Concerning Sophisticated Methods of Energy Supply Structure	• Requiring oil refiners to produce a certain amount of biofuels (FY2011: 210,000kl → FY2017: 500,000kl (crude oil equivalent))
2010	National Plan for the Promotion of Biomass Utilization	• Setting targets for 2020 • Setting basic policies on the development of technologies for biomass utilization
Great East Japan Earthquake and Fukushima nuclear power plant accident (2011.3)		
2012	Biomass Industrialization Strategy	• Specifying the targeted conversion technologies and biomass for realizing biomass industrialization • Setting principles and policies for realizing biomass industrialization

Table 17. *Summary of the Japanese Biomass policies from 2002 until 2012.*

Listed below are the newest Biomass Policies in chronological order:.

1. *Basic Act for the Promotion of Biomass Utilization (2009).*
2. *The National Plan for the Promotion of Biomass Utilization (2010).*
3. *The Biomass Industrialization Strategy (2012).*
4. *Assistance for research and development.*
5. *Tax systems related to biomass.*
6. *Feed-in tariff scheme.*
7. *Credit system for CO_2 emission reduction.*
8. *Personnel training.*
9. *Waste Management in Japan.*

1. Basic Act for the Promotion of Biomass Utilization (2009)

The Basic Act of Biomass Utilization developed in 2009 states the guidelines for biomass utilization, *"the Basic Biomass Utilization Promotion Plans"*. These guidelines included the basic plans and duties of related personnel as well as measures, and *"the National Biomass Policy Council"*.

The main aim of the Act was to enhance a society for a sustainable economy by shaping principles and fundamental national instruments on biomass promotion and utilization.

Summary of the Act

The act included numerous important rules and guidelines regarding biomass utilization and its safety. It outlined the duties of all the stakeholders involved i.e. the government, and other parties. It developed the Biomass Utilization Promotion Plans and took necessary measures for their completion. It also included the complete infrastructure of how projects would be created to effectively produce biomass energy, the related research and technological support that is required, training of employees, and promoting the generation of biomass products. Another important feature of the Act was to serve as a liaison between public and private bodies and their joint activities regarding biomass utilization as well as to develop research regarding the national and international energy sources.

- Set up *"the National Biomass Policy Council".*
- Define the *principles* for the promotion of biomass use as follows:
  - *"Comprehensive, Uniform and Effective Utilization of Biomass".*
  - *"Mitigation of Global Warming".*

- *"Development of Recycling-based Society".*
- *"Promotion of industrial Development and International Competitiveness".*
- *"Revitalization of Rural Areas".*
- *"Fully Utilization of Different Types of Biomass".*
- *"Diversification of Energy Sources".*
- *"Promotion of Community-based Voluntary Actions".*
- *"Raise of Social Awareness for Biomass".*
- *"Consistency between Stable Food Supplies and Biomass Utilization".*
- *"Considerations for Environment Preservation".*

The Act is further categorized into three levels to ensure the establishment of the biomass utilization Plan. The three levels are:

- **National level:** the Government's duty to make policies and plans for Biomass utilization. Three plans are further proposed in this category:
  - Basic Policy on Biomass Utilization.
  - Define targets of how biomass utilization can be achieved.
  - Definition of new strategies to ensure new and technological advancements with regard to Biomass Utilization.
- **Prefectural level:** different states and provinces develop biomass utilization plans in correspondence with the national plans.
- **Municipal level:** municipalities create plans for biomass utilization in accordance with the national and prefectural plans.

The Act sets up the "**National Biomass Policy Council"** comprised of seven government bodies. Its purpose is to serve as a coordinated bridge between the country's ministries to promote the activities of biomass utilization. Its members consist of the vice ministers or state secretaries from the seven ministries.

Seven ministries are involved in biomass policy:

- *"Cabinet Office, Government of Japan (National Strategy)".*
- *"Ministry of Agriculture, Forestry and Fisheries (Agricultural and Forest Policy)".*
- *"Ministry of Internal Affairs and Communications (Regional Development)".*
- *"Ministry of Education, Culture, Sports, Science and Technology (R&D)".*

- *"Ministry of Economy, Trade and Industry (Energy and Industrial Policy)".*
- *"Ministry of Land, Infrastructure, Transport and Tourism (Infrastructural Policy)".*
- *"Ministry of the Environment (GHG Reduction Policy)".*

2. The National Plan for the Promotion of Biomass Utilization (2010)

A set of basic policies were established based on the Basic Act for the Promotion of Biomass Utilization.

Outline of the National Plan:

- The main purpose of the plan was to take effective measures to promote biomass utilization in various sectors of the country including the agricultural sector, fishing sector and other government, private and public bodies.
- To define national goals (for 2020) keeping in view three outlooks: enhance rural participation, industry development and lessening of global warming.
- To introduce effective government measures that facilitate activities to utilize biomass, use it in industries, supply its by-products to other industries and to assist in research and development.
- To define technological goals and national policies that have to be met in the short term and long term plans.

Objectives of the National Plan

- Expand biomass utilization – expand the industry so it is able to utilize 26 million tons of carbon per year. It also included the usage rates of various biomass resources.
- Introduce the 600 Municipal Biomass Utilization Promotion Plans in 600 municipalities of Japan.
- Create Biomass Industries that are worth 500 billion Japanese Yen.

The targets also include the average utilization of each type of biomass that must be carried out and the necessary measures that have to be taken at the national level to ensure that this target is met.

Type of biomass	Amount generated annually	Present and target utilization ratio 2009 → 2020
1 Animal waste	Approx. 88 million tones	90% → 90%
2 Sewage sludge	Approx. 78 million tones	77% → 85%
3 Black liquor	Approx. 14 million tones	100% → 100%
4 Waste paper	Approx. 27 million tones	80% → 85%
5 Food waste	Approx. 19million tones	27% → 40%
6 Sawmill wood residue	Approx. 3.4 million tones	95% → 95%
7 Wood waste from construction	Approx. 4.1 million tones	90% → 95%
8 Non-edible parts of food crops	Approx. 14 million tones	85% → 90%
9 Forest off-cuts	Approx. 8 million tones	0% → 30%
Note: 1 Black liquor, saw mill wood residue, forest off-cuts are dry-weight, all others are wet weight. 2 Target for energy crops is 400,000 carbon tones produced by 2020.		

Table 18. *Target of biomass utilization by type (2020).*

Policies for the Research and Development of Biomass Utilization

Policies were formulated regarding how the research (Table 19) of biomass would be carried out in all its stages: collection to transportation, to conversion and final usage of biomass resources.

1. Waste biomass	(1) Animal waste • Development of technologies to use digestive liquids as liquid fertilizer after bio-gasification and technologies to adjust composition of digestive juices (2) Sewage sludge • Development of technologies to ensure efficient bio-gasification and conversion into solid fuel (3) Waste paper • Advancement of energy collection technologies, including ethanolization and bio-gasification (4) Food waste • Promotion of ethanolization and bio-gasification technologies (5) Wood waste from construction • Development of technologies for efficient wood waste sorting by type after demolishment
2. Unused biomass	(1) Non-edible parts of crops • Establishment of efficient collection and transportation systems (2) Forest off cut • Development of high performance forestry machine • Establishment of low-cost, efficient collection and transportation systems

Table 19. *Policies to the research and development for effective biomass utilization.*

The policies formulated the way in which technological advancement could be made in biomass utilization. The policies also facilitate the long term research (Table 20) related to biomass and its newer resources **like Microalgae** and its proposed and efficient use.

3. Mid-term technical issues	(1) Cellulosic biomass glycolysis and fermentation • Development of technologies for effective glycolysis of celluosic biomass, including non-edible parts of crops, grasses, and woody biomass • Development of fermentation technologies to produce a variety of materials other than ethanol (2) Next-generation biofuels • Development of next-generation biofuel technologies, such as BTL,i.e. (3) Thermal reaction-driven gasification • Development of technologies to efficient use by-product (tar) generated during gasification (4) Biomass plastic • Development of technologies to reduce production costs and improve heat resistance and durability (5) High value-added products • Development of technologies to manufacture a variety of high value-added products, such as carbon fiber and highly-functional resin (6) Remove of hazardous substances during thermal reaction • Development of technologies to remove hazardous substances in a low-cost and efficient manner (7) Effective collection and storage systems of biomass • Establishment of collection systems and storage networks integrated into agriculture and forestry
4. Long-term technical issues	(1) Generation of new biomass resources • Development of technologies for breeding, growing and extraction of usable substances for new and promising biomass, such as microalgae and perennial grasses (2) Development of biomass refineries • Development of technologies to refine and convert biomass into usable chemical ingredients

Table 20. *Policies for long term research such as for Microalgae.*

3. The Biomass Industrialization Strategy (2012)

After the great East Japan Earthquake and the Fukushima nuclear accident, Japan had to come up with some alternative to its current energy resources. A National Plan was developed based on these objectives. Later on, the Biomass Industrialization Strategy was developed to help achieve the targets set by the National Plan. The main purpose was to be self-sufficient in energy supply systems while preventing further global warming.

- **Biomass Industrialization Strategy**
  - To achieve the targets outlined in the National Plan for Biomass Utilization.
  - Exploration of renewable energy resources using biomass utilization especially after the Great earthquake and Fukushima accident.
  - Shifting to an environment-friendly energy supply using biomass resources.
- **Targets of Biomass Industrialization Strategy**
  - Introducing biomass technologies in various industries.
  - Creating such policies and guidelines so as to ensure that all activities are carried out without any adverse effect to the environment or climate.
  - Development of renewable and green industries.

Table 21 below illustrates the biomass energy potential for 2 cases:

Annual (Sustainability is not considered)	Case 1 where 2020 targets is achieved by energy use	Case 2 where all unused biomass are utilized for energy.
Electricity potential	About 13 billion kWh (equivalent to the needs of 2.8 million households)	About 22 billion kWh (equivalent to the needs of 4.6 million households)
Fuel potential (crude oil equivalent)	About 11.8 million kl (equivalent to the needs of 13.2 million gasoline cars)	About 18.5 million kl (equivalent to the needs of 20.8 million gasoline cars)
Greenhouse gas reduction	About 40.7million t-CO_2 (equivalent to 3.2% of total greenhouse gas emission in Japan)	About 63.4million t-CO_2 (equivalent to 5.0% of total greenhouse gas emission in Japan)
Note: Japanese greenhouse gas emissions are calculated at 1.256 billion tones (2010 estimate) with electrical power consumption per household of 4,734 kWh/year, and gasoline consumption per vehicle of 1000 L/year		

Table 21. *Biomass energy comparison potential.*

Biomass Conversion Technology Roadmap

Switching to new technology of biomass meant that the previous industries and activities had to change in order to start using biomass instead of other resources. A roadmap was developed to check what technological difficulties and problems arose during this transformation period. Intense research was done by related ministries and technical institutions in this regard. Different types of biomass resources were assessed to check for the most practical application in given conditions (Table 22).

Targeted conversion technologies and biomass for industrialization	
Technologies	● Methane fermentation & composting ● Combustion ● Solid fuel conversion (pellet, bio-coke, RPF, etc.) ● Liquid fuel conversion (First generation technologies for ethanol and biodiesel)
Biomass	● Woody biomass, food waste, sewage sludge, animal waste, etc.

Table 22. *Targeted conversion technologies and biomass for industrialization.*

The Industrialization Strategy

This strategy has seven main components, namely:

- Basic Strategy – this strategy reviews the process by which biomass industrialization can take place. This involves:
  - Creating industries that use biomass resources and technologies.

- Establish a concrete system through which raw biomass material could be collected, transported, used in manufacturing and the selling of final biomass products.
- Create a system that ensures a non-toxic and green environment in the energy supply system.
- Making efforts to attract foreign business related to biomass technologies and products.

- Technological Strategy – to enhance the technological studies so as to come up with newer biomass resources such as woody biomass that is achieved through forest woods, as well as the appliance of the feed-in tariff (FIT) system. Through this strategy, the wood waste from construction is used as raw material for constructing paper, wood boards and chips are to be used in energy production. Another example is that of food waste and sewage sludge. Biomass products can be used in recycling by employing methane gasification and solid fuel conversion. In case of animal waste, this is carried out through methane fermentation, combustion and combining it with other biomass resources like food wastes.
- Entrance Strategy – this strategy involves the various ways in which raw biomass material can be collected and fed into the system to produce energy.
- Exit Strategy – this strategy involves collecting the final biomass products and putting them into use for domestic energy requirements or selling them to foreign investors.
- Specific Strategy – the use of bio-ethanol to produce domestic energy. Develop systems to use biodiesel fuel as an alternative that cuts costs whilst being able to produce high efficiency products. The use of biodiesel can further be assisted by reducing taxes so that biodiesel usage can be encouraged.
- Comprehensive Support Strategy – this strategy involves establishing a link between the Biomass Industrial communities and the regional sustainable utilization system. The purpose of this link and correspondence is to allow for better performance among all steps of biomass utilization: collection, transport, production, use and selling.
- Overseas Strategy – the primary focus of this strategy is to define next generation models and techniques related to biomass and sell them in foreign countries. The main market focus would be Asia.

Biomass Industrial Community

The main purpose behind the creation of a biomass industrial community is to create a green industry that uses biomass raw materials and other waste products. This is done by

using solar as well as hydroelectric power generation systems. The focus is to create a biomass industry that works in an environment friendly manner and ensures the safety of involved personnel.

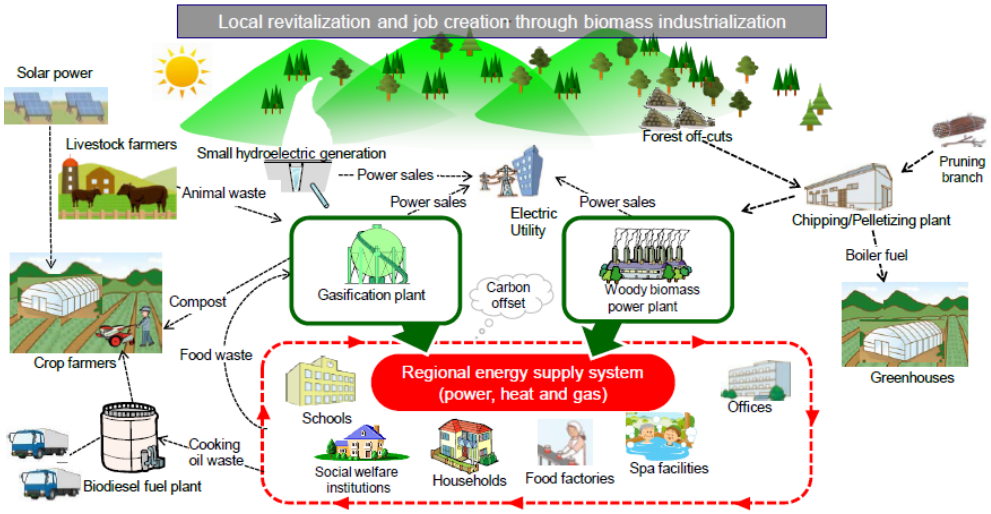


Figure 62. *Biomass industrial community.*

4. Assistance for Research and Development

It also facilitates new technologies and their usage at different steps of biomass utilization (Figure 63) (Table 23).

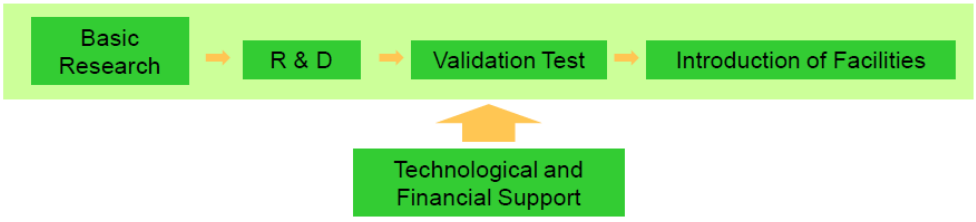


Figure 63. *Stages of the Assistance for research and development.*

Basic research phase	
Comprehensive approach	➢ Developing advanced low-carbon technologies ➢ Basic research into biomass refinery ➢ Basic research for efficient technologies of biofuel from microalgae
Research and development phase	
Biofuel	➢ Developing glycation and fermentation technologies from cellulosic biomass ➢ Development of technologies for cultivation and extraction of microalgae to gain usable resources.
Comprehensive approach	➢ Development of technologies for thermal usage of biomass, such as heat supply to greenhouse ➢ Developing Biomass-to-liquid technology

Table 23. *Stages of the Assistance for research and development explained.*

This includes woody biomass collection and production as well the production of bio-ethanol fuels from crop wastes.

Validation phase	
Woody biomass	➢ Validation test for introduce of integrated system for woody biomass utilization (collection & transportation systems, heat supply plant and power plant)
Sewage sludge	➢ Validation test for power generation and/or methane gasification technologies using sewage sludge.
Biofuel	➢ Validation test for bioethanol plant operating using farm surpluses and by-products ➢ Validation test for introduction of integrated system for biodiesel production and distribution.
Comprehensive approach	➢ Validation test for heat supplying system using methane gasification.

Table 24. *Validation tests.*

It also supports bio-fuel production and biomass power generation plants.

Introduction of biomass plant	
Woody biomass	➢ Construction of biomass power plant using woody biomass ➢ Lumber cutting and transportation, and improvement of forest road networks
Food waste	➢ Introduction of highly-efficient waste treatment power generation plant
Sewage sludge	➢ Introduction of biomass power plant using sewage sludge
Biofuel	➢ Introduction biofuel manufacturing facilities by refiners
Comprehensive support	➢ Establishment of Biomass Industrial Communities

Table 25. *Practical technologies of a biomass plant.*

5. Tax systems related to biomass

Another step towards providing better support to the biomass industry is to reduce taxes so that more renewable energy power generation plants could start functioning. Efforts are made for tax reduction on gasoline as well so that bio-ethanol could be used in the biomass industry.

Item	Tax category	Method	Note
Bioethanol blended gasoline (E3, E10)	Gasoline tax (58.0 JPY/L)	Tax reduction for bioethanol	–
Manufacturing facility for biofuel (*1)	Property tax (1.4% → 0.7%)	50% reduction of property tax (3 years)	Certification required based on the Act on Agricultural, Forestry and Fisheries Biofuel
Manufacturing Facility for bioethanol	Income tax, corporate tax	Special depreciation of 30% facility cost (first year)	Green investment tax reduction
Renewable power plant (*2)	Property tax (1.4%→0.7%)	One-third reduction of property tax (3years)	–

Table 26. *Tax systems applied to biomass.*

6. Feed-in tariff plan

In 2012, the Feed-in tariff (FIT) scheme was formulated in Japan to helps achieve a biomass renewable energy system. In this scheme, any biomass producer could sign a contract with the electricity departments through which they could request an electricity connection at some fixed price for long periods of time. This would promote biomass utilization (Figure 64).

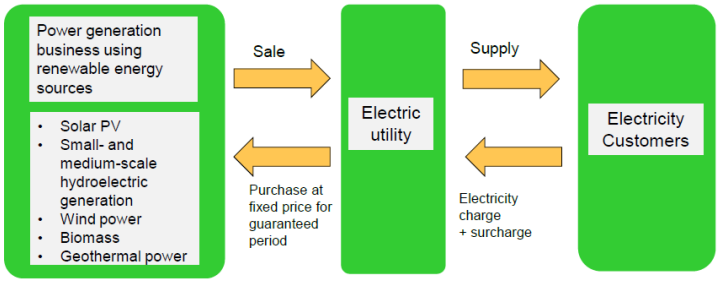


Figure 64. *Diagram of the Feed-in tariff.*

The FIT for biomass is categorized among five categories (table 27).

Energy source	**Solar PV**		**Wind power**	
Category	>10kW	<10kW	>20kW	<20kW
Tariff (per kWh - tax included)	42 yen	42 yen	23.10 yen	57.75 yen
Duration	20 years	10 years	20 years	20 years

Energy source	**Geothermal power**		**Small and medium-scale hydroelectric generation**		
Category	>15kW	<15kW	3 MW-1 MW	1 MW-200kW	<200kW
Tariff (per kWh - tax included)	23.7 yen	42 yen	25.2 yen	30.45 yen	35.7 yen
Duration	15 years	15 years	20 years		

Energy source	**Biomass**				
Biomass type	Biogas	Wood-fired power plant (timber from forest thinning)	Wood-fired power plant (other wood)	Waste (excluding wood waste)	Wood-fired power plant (recycled wood)
Tariff (per kWh - tax included)	40.95 yen	33.6 yen	25.2 yen	17.85 yen	13.65 yen
Duration	20 years				

Table 27.*Types of tariff applied to biomass.*

7. Credit system for CO_2 emission reduction

To develop a green industry with environmentally friendly systems, two mechanisms (CDM and J-VER) were devised. Both of these systems were stopped temporarily when Japan withdrew from the Kyoto Protocol Treaty in 2012. However, they were later reviewed and integrated in 2013, namely:

- Domestic Clean Development Mechanism (CDM) – domestic CDM system ensures that green house gas (GHG) emissions are reduced as domestic credit. Large enterprises provide different industries with capital and technology which is used as domestic credit to reduce GHG emissions. After the large industries have provided the small industries with capital and technology, these small industries employ various certified techniques and approaches to reduce GHG emissions. The large enterprises, consequently, gain credits for reduction in GHG emissions. Credit is then used by these enterprises to achieve their goals.

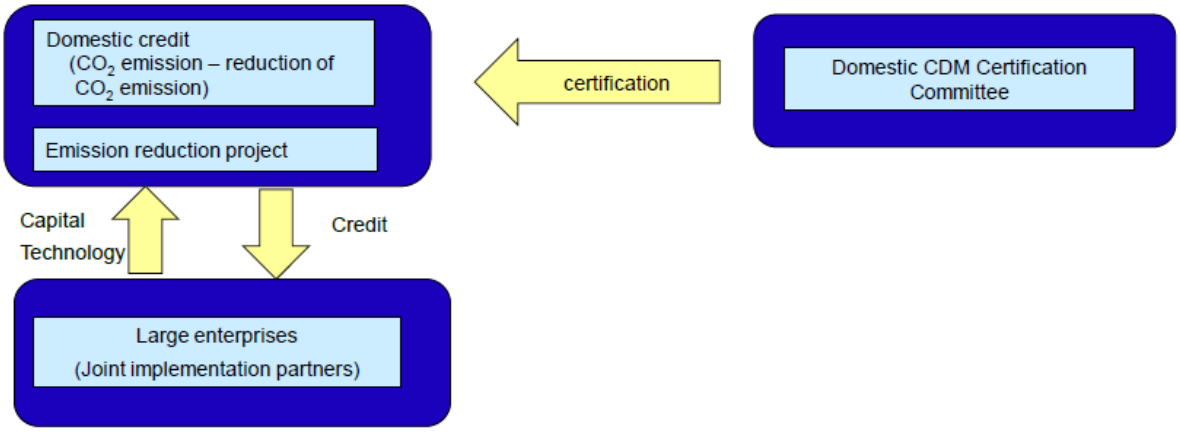


Figure 65. *Life cycle of the Credit system for CO_2 emission reduction.*

- Japan Verified Emission Reduction System (J-VER System) – in this system, a mechanism is devised through which carbon offset is utilized. The aim is to offset one Company's GHG emission goal and balance it with the GHG emissions reduction of another Company. This promotes absorption or reduction of GHG emissions. This can be done by one Company who wishes to offset some or all of its GHG emissions J-VER made by some other Company. This results in an efficient system where GHG emission reduction is achieved through J-VER.

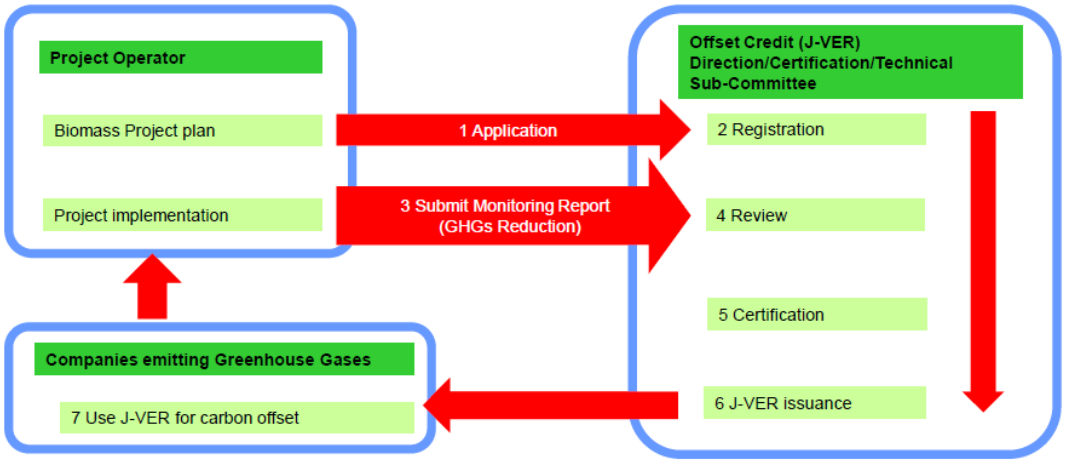


Figure 66. *Life cycle of the J-VER.*

8. Personnel training

To train the people of the municipalities with respect to biomass production and utilization, two types of training courses were organized by the Japanese government:

- Biomass Town Advisor Training – this training was specific for private operators and was functional from 2006 to 2010. Its main task was to train the personnel of the private sector so that they are able to formulate the Biomass Town Plan, do the associated advertising and public awareness. The program was able to train 170 advisors during the 5 years that it ran.
- Municipal Staff Training – this training was specific to the personnel of municipalities and it operated from 2006 to 2009. Specific training and education was provided to the personnel of municipalities to assist them in implementing their Biomass Town Plans.

Biomass Town Advisors

Biomass Town advisors are the personnel that support the Biomass Town plan created by the Government and coordinate efforts for biomass utilization. The tasks of biomass advisors include the following:

- Make efforts to implement the biomass plans made by municipalities.
- To plan and implement biomass projects in their regions.
- Plan and implement biomass utilization and support processes that create awareness regarding biomass utilization.

The Japan Organic Recycling Association (JORA) is a private body that registers biomass town advisors. Currently, there are 170 town advisors registered with JORA. Theses advisors belong to different professions but majority of them are members of private consulting Companies. When the municipalities have created the Biomass Town plan, they request JORA to provide them with one or more town advisors for the implementation of biomass town plans. JORA then selects the town advisor that best fits the requirements for that particular municipality and dispatches them. All these services are offered without any compensation.

9. Waste Management in Japan

In 1956, Minamata disease broke out in Japan. It is a neurological disease that is caused by mercury poisoning. The cause for the breakout of this disease was pollution caused by inefficient waste management. Thus, the Waste Regulation was started in 1956 [30].

Figure 67 illustrates the history and current state of waste management in Japan with the Legislation and Policies to Create a Recycling-Oriented Society [31-32].

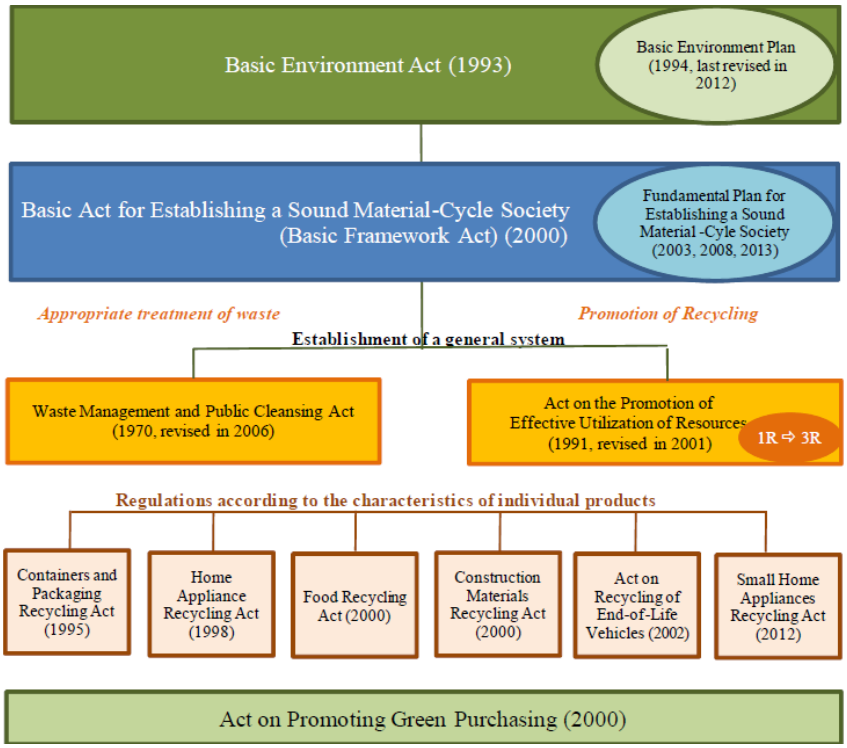


Figure 67. *Legal system for establishing a "Sound Material-Cycle Society".*

The Basic Act for the Establishment of a Sound Material Cycle Society was formulated with the main aim of efficiently utilizing natural resources while lessening harmful effects on the environment. It was developed as a five-year plan by the Government in 2003. The first plan defined what a sound-material society is and formulated ways in which this society could be established. After 5 years, the second plan was introduced in 2008. It focused on creating a low-carbon society. The third plan was initiated in 2013, whose main aim was to fulfill the Reuse-Reduce concept. According to this, resources and waste should be reused to reduce dependence on new resources.

For this purpose, the waste management and Public Cleansing Act were introduced highlighting four main tasks:

1. Provide proper procedures for the management of waste generated.
2. Reuse waste or recycle it.
3. Provide proper facilities where waste is managed and treated.
4. Define standard for waste treatment.

In the year 2000, Japan initiated the 3Rs (Triple R). The R's stand for reduce, reuse and recycle. Its aim is to provide a better environment for people, Earth and the sky. Its logo is composed of three colours with each colour representing one of these three entities; orange for people, green for Earth and blue for the sky.

According to Japanese legislation, thermal recycling could be carried out if material recycling is not possible. In any case, waste has to be properly taken care of if it can't be recycled. According to this legislation, Design for Environment (DfE) [33] has been proposed to put the concept of the 3Rs (Figure 68) into practice. This is implemented through the complete production and life cycle of every product: from designing to using recycled materials for manufacturing, to recycling and disposing off those products when they have completed their purpose.

Figure 68. *Logo of the 3Rs.*

"Cradle to grave" principles as precursor of a Circular Economy

A related concept to this 3Rs plan is the Cradle to Grave (also known as life-cycle assessment, LCA) [34] (International: ISO 14040:200615, Japan: JIS Q 14040:201016). The purpose of this plan is to assess the effects that each stage of the product lifecycle will have on the environment. This means from designing to manufacturing to distribution to usage and repair to recycling and disposal. LCA helps to achieve the following goals [35]:

- Keeping a record of material inputs and their potential effects on the environment.
- Evaluating those potential negative effects.
- Using those results to help make the process better and more environmentally friendly.

The main concept behind this is to ensure that each stage of the product life cycle is evaluated against any potential harmful effects on the environment and to minimize them as much as possible, from the delivery of unprocessed materials to the discarding of the remaining waste through manufacturing, transport, supply and use. This also helps to evaluate newer measures like incineration as opposed to recycling in certain cases, as a tool for decision-making.

In Japan [36] the 3rd Fundamental Plan mentions that *"in promoting such recycling, we need to give importance on the view point of LCA (Life Cycle Assessment), where recycling would not end up with heavier environmental loads through a substantial increase in the consumption of required energy, with due considerations to the balance with global warming measures"*.

2.3. Support Provided by the Japanese Government

This section depicts various Japanese institutions that provide support to Companies in different forms, such as for partner searching, advice on funding opportunities or general procedures for avoiding barriers prior to business.

Table 28 summarizes relevant local projects that received support by governmental institutions such as the NEDO or the MAFF.

Operator	Size of the outdoor cultivation pond	Experiment location	Microalgae	Supporting organizations
IHI Corporation, Kobe University, Neo-Morgan Laboratory Incorporated	1,500m^2	Kagoshima City, Kagoshima Prefecture	Botryococcus	NEDO
J-POWER, JGC Corporation, Tokyo University of Agriculture and Technology	10m^2 × 20, circular	Kitakyushu City, Fukuoka Prefecture	Marine microalgae Fistulifera family	NEDO
JX Nippon Oil & Energy, Euglena Corporation, Hitachi, Ltd., Keio University	25m^2 × 2, raceway configuration	Ishigaki Island, Okinawa Prefecture	Euglena	NEDO
Smabe Japan Co., Ltd.	Total of 7 of varying sizes in a raceway configuration 2,600m^2	Model farm in Kiyosaki, Ishinomaki City, Miyagi Prefecture	Nannochloropsis	Ministry of Agriculture, Forestry and Fisheries
University of Tsukuba, Tsukuba City, Ibaraki Prefecture	Raceway configuration 2,800m^2	Kurihara, Tsukuba City, Ibaraki Prefecture	Botryococcus	Ministry of Land, Infrastructure, Transport and Tourism, Cabinet Office
Sendai City, Tohoku University, University of Tsukuba	[Plan] Botryococcus: 200m^2 (cultivation field) Aurantiochytrium: 360L (90L cultivation tanks × 4)	Minamigamo, Sendai City, Miyagi Prefecture	Botryococcus, Aurantiochytrium	Reconstruction Agency, Ministry of Education, Culture, Sports, Science and Technology
Denso Corporation	33,000L	Nishio City, Aichi Prefecture	Pseudochoricystis	Ministry of Agriculture, Forestry and Fisheries

Table 28. *Local projects that received support by governmental institutions.*

Other projects are shown in the following Figure 69.

Other projects in MAFF and other Ministries and Agencies

MAFF

○ A scheme to revitalize agriculture and fisheries in disaster area through deploying highly advanced technology
○ Integration research for agriculture and interdisciplinary fields
・Promotion of R&D Cellulose nanofibers from rural resources
○ Science and technology research promotion program for agriculture, forestry, fisheries and food industry

Other Ministries and Agencies

○Strategic basic research programs 【MEXT】
○Project for promoting the utilization of biomass waste 【MOE】
○Cross-ministerial Strategic Innovation Promotion Program 【Cabinet Office】
○Strategic development of next-generation bioenergy utilization technology / Development of efficient elemental technologies for biofuel production 【METI(NEDO)】

Figure 69. *More examples of funded projects.*

Collaboration with other Ministeries and Agencies (Figure 70).

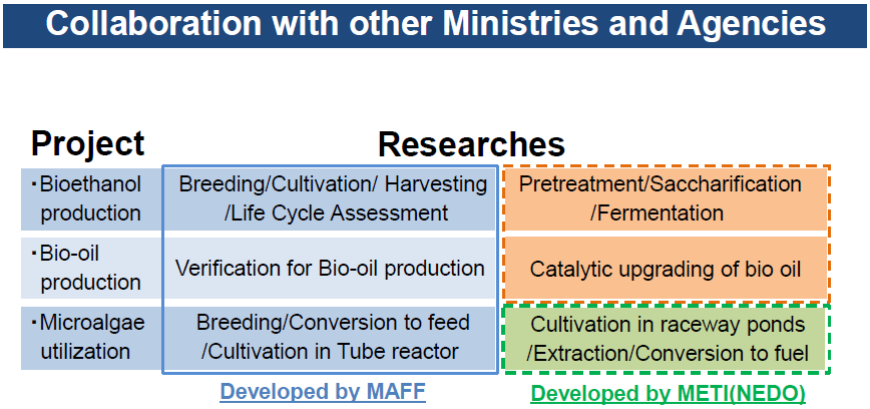


Figure 70. *Collaboration with other Ministries.*

The EU Japan Centre for Industrial Cooperation

"Established in 1987, the EU-Japan Centre for Industrial Cooperation is a unique venture between the European Commission (Directorate General for Growth - Internal Market, Industry, Entrepreneurship and SMEs) and the Japanese Government (Ministry of Economy, Trade and Industry) (METI). The mission of the EU-Japan Centre, a non-profit organization, is to enhance all forms of industrial, trade and investment cooperation between Japan and the EU, and to strengthen the technological capabilities and the competitiveness of the European and Japanese industrial systems. The Centre was founded with a view to contributing to industrial cooperation between the Community and Japan, as specified in the Council Decision which constitutes the Centre's legal basis" [37].

Being more specific, the EU Japan Centre for Industrial Cooperation provides guidance for preparing projects such as H2020 that can be related to Microalgae (e.g. like the existing topic "water in the context of the circular economy") for the tasks of partner search, preparation of proposal or dissemination tasks. The Centre collaborates with various organisations that will be addressed next, such as the EEN, the NCP or the METI.

METI National funding for the development of next-generation technologies to use bio-fuel derived from Microalgae

The METI has a bio-related budget with a slight increase of around 1% (from 21.85 billion of yen in 2015 to 22.04 billion of yen in 2016). This budget includes the initiative named *"strategic next-generation biomass energy utilization technology development projects"*, with an investment of 4.0 million yen (1.12 billion yen). This will promote the biomass gasification and liquefaction (BTL), as well as the development of next-generation technologies to use bio-fuel derived from Microalgae [38].

EEN

"Since January 2011, Enterprise Europe Network (EEN) - Japan is coordinated by the EU-Japan Centre for Industrial Cooperation with the support of the Japanese Ministry of Economy, Trade and Industry (METI). It promotes all forms of industrial, trade and investment cooperation, to facilitate exchange of experience and know-how between EU and Japanese businesses as well as preparation of seminars, managerial training programmes, student internships, information desk and matchmaking activities" [40].

For instance, when searching for jobs related to Microalgae for finding possible partners, there are 14 results found.

Title of Profile	Country	Type	Publish Date
Microalgae production for applications in agro-industry and environment, including services for biotech companies and...	Spain	Tech. Offer	2015-06-30
Israeli company with a novel infrastructure/process for cultivation of microalgae is looking for a manufacturer of...	Israel	Tech. Offer	2016-07-11
Efficient cultivation and harvesting of microalgae	Spain	Tech. Offer	2016-03-09
Diagnostic kit for toxic microalgae to help forestall harmful toxic blooms in water	France	Bus. Offer	2015-05-27
Microalgae and cyanobacteria identification, isolation, culture and development of derived products	Spain	Tech. Offer	2016-07-20
Bulgarian company specialized in production of patented health supplements for stimulation of stem cells and optimal...	Bulgaria	Bus. Offer	2015-11-03
Scalable microalgae biomass production & harvesting system to get biofuel, food & feed feedstock for competitive price	Israel	Tech. Offer	2016-04-21
In-silico design and optimization of microalgae based biorefineries through mathematical models	Italy	Tech. Offer	2016-02-22
Producer of bioreactors for the production of transgenic microalgae looks for financial cooperation	Germany	Bus. Offer	2015-04-30
Wastewater bioremediation coupled with energy production via photosynthetic microorganisms	Spain	Tech. Offer	2015-08-25
Bulgarian company is looking for distributors of its innovative healthy food additives	Bulgaria	Bus. Offer	2016-05-10
Microalgae photo-bioreactor using sun and LED light source for stimulation and tuning in wastewater engineering	Greece	Tech. Offer	2015-09-15
Renown Czech university is looking for various partners for H2020 SFS-10-2017 call to work research in plant secondary...	Czech Republic	R&D Request	2016-05-20
Marine Biocides – Natural sea-based biocidal agents offering strong anti-fouling properties for paints, cosmetics and...	France	Tech. Offer	2016-06-13

Table 29. *Results after searching for "microalgae".*

When selecting (for instance) the proposal from July 2016 named *"Microalgae and cyanobacteria identification, isolation, culture and development of derived products"* it displayed the following information *(incomplete)* (Figure 71).

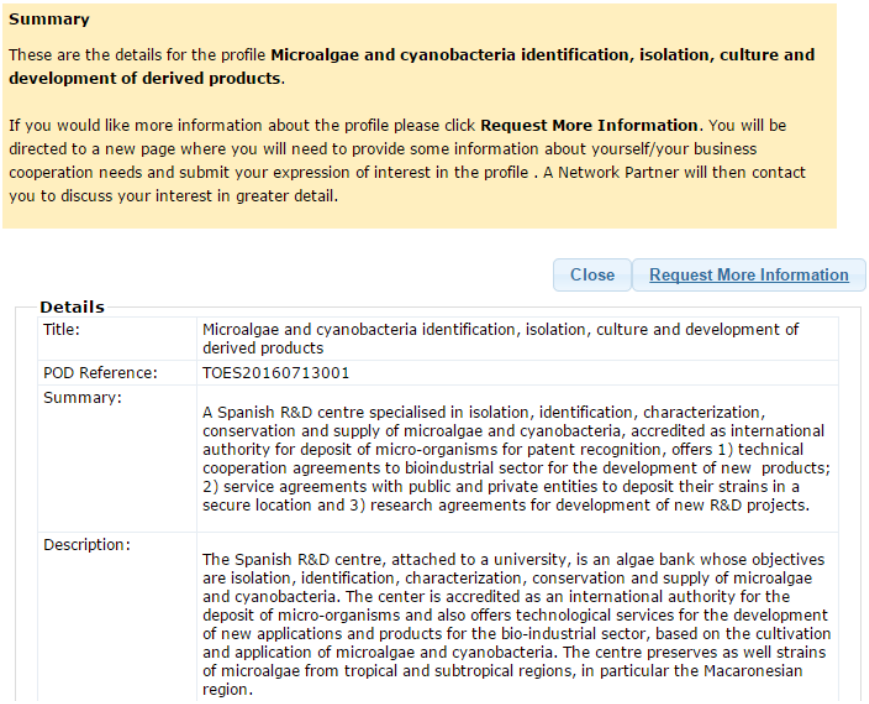


Figure 71. *Details displayed of a certain partner (incomplete).*

It is possible to directly contact the stakeholders by clicking in *"Request More Information"*. Then, the following contact form is displayed to be filled in (Figure 72).

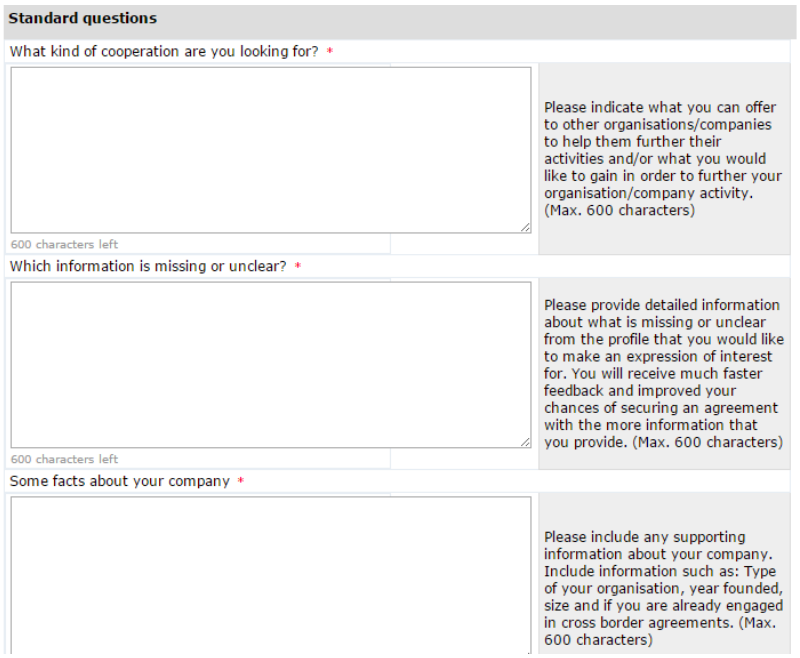


Figure 72. *Contact form for partner/proposal search.*

JETRO funding

Japanese External Trade Organization (JETRO) is a national-level government agency dedicated to promoting Japanese Companies in the worldwide market and, at the same time, increase the interest of the foreign Companies. With 16 offices in Europe, European firms can easily approach for assistance regarding connections to businesses and helping in administrative processes [39].

For instance, JETRO participated in promotion activities of Japanese Companies in the Microalgae sector of Japan, such as Euglena, in diverse events related to business in Bangladesh.

NCP (National Contact Point) for Horizon 2020

"EU-Japan Centre for Industrial Cooperation was formally appointed as NCP in November 2013 with governmental funding. Its main tasks are to disseminate information on the Horizon 2020 programme in Japanese via its portal and handouts, such as an overview of the programme, call information, reference documents and success stories. The NCP also promotes participation to Horizon 2020 through dissemination seminars and public events such as exhibitions and trade fairs. The main target of the service is researchers and industry within Japan. The NCP in Japan is collaborating with the Enterprise Europe Network (EEN) in Japan" [41].

The NCP can be used as guidance for finding partners, likewise for the same purpose than using the EEN, it also provides examples of successful EU-Japan projects.

European Interest Group (EIG) CONCERT-Japan (EIG CONCERT-Japan) programme

"The European Interest Group (EIG) CONCERT-Japan is an international joint initiative to support and enhance science, technology and innovation (STI) cooperation between European countries and Japan" [42]. The initiative provides funding opportunities for joint calls focused on sustainable research cooperation between EU-Japan actors. Aims of EIG Concert-Japan:

- Cooperation between the two countries.
- Improving research.
- Creating successful partnerships.
- Knowledge exchange.

For instance, to date [43] there is a Call related to Microalgae and biomass that was recently reopened, titled *"Food Crops and Biomass Production Technologies"*.

2.4. ANALYSIS OF 7 NOTABLE INITIATIVES (EXTRACTED FROM INTERVIEWS)

This section includes 7 ongoing cases (*extracted from interviews*) of successful examples of Microalgae-based, biomass-based products and recycling in Japan. The first three cases are from Euglena (1-3), the next two are from the University of Tsukuba (4-5), and the last one from a joint project between ISUZU Motors and Euglena:

1. Euglena bio-fuels.
2. Euglena Farm.
3. Euglena Cosmetics.
4. Waste waters treatment.
5. Algae Industry Incubation Consortium (AIIC).
6. DeuSEL project (ISUZU and Euglena).
7. Euglena and ANA

Euglena's strategy is ultimately to expand the use of the euglena Microalgae strain to five different fields. In line with the concept of the 5 *"F"*s of Biomass Model, they will aim for the continued cultivation of euglena to expand into the respective businesses (in descending value-added order) of **Food, Fiber, Feed, Fertilizer** and **Fuel.**

Moreover, through continuous changes and the advancement of development innovation, Euglena is expecting to decrease the prices of the Microalgae strain. Of late, Euglena has begun to research wastewater purification and CO_2 diminishment innovation.

1. Euglena bio-fuels

Table 30 summarizes the actions carried out regarding of bio-fuels.

City of Yokohama (local government)	Support for development and operation of the plant in Yokohama.
Chiyoda (EPC Company)	Designing, obtainment and development of the plant.
Itochu Enex (energy trading Company)	Supply of renewable jet and diesel fuel feedstock other than the Microalgae "Euglena", research on supply/interest and conveyance of items.
Isuzu (diesel engine maker)	Assessment and usage of cutting edge renewable diesel energy.
ANA (airline Company)	Proposition on operations, (i.e. refueling) in airports.

Table 30. *Summary of the actions carried out in matter of bio-fuels.*

In recent years, a lot of research is being done regarding the use of bio-fuels in jets. In July 2015, a Committee for the study of a process leading to introduce jet-fuel (derived from Microalgae) for the 2020 Summer Olympics Games and Paralympic Games in Tokyo was established. Euglena Co initiated its research to use bio-fuels in commercial flights and cars in Japan. The Company is currently building a demonstration plant of bio jet/biodiesel fuels in Yokohama which is planned to start functioning by 2018.

Figure 73. *Consortium of Companies participating with Euglena.*

Under the studies conducted by Euglena since 2010, the bio jet fuel produced from Microalgae is named Euglena as well. Euglena also signed a joint collaboration with Isuzu to research the next generation bio diesel fuels in 2014. Another joint research program was signed between Euglena and *Chevron Lummus Global LLC* and *Applied Research Associates* in 2015. Under this collaboration, a biodiesel demonstration production plant is being built with the aim of providing biodiesel fuels to the commercial industry by the year 2020. This is being done in collaboration with the *City of Yokohama, Chiyoda, Itochu Enex, Isuzu* and *Ana.* This plant is being built at the *Keihin Plant of Asahi Glass Company Ltd* and is expected to be completed by 2017. The biodiesel production is likely to start in 2018. After the successful demonstration of this plant and its bio-fuels, the Company is likely to start supplying commercially by 2020.

This will make it Japan's first demonstration plant that could produce biodiesel and bio-fuels from Microalgae and provide these fuels for commercial and domestic purposes. Their aims include:

- To produce biodiesel Euglena from Microalgae.
- Invest in the demonstration plant and make it operational.
- To produce and supply biodiesel for commercial use in the city of Yokohama.
- To make necessary research regarding supply/demand and distribution of bio-fuels.
- Construction of a demonstration plant for the engineering, procurement and production of bio-fuels obtained from sources other than Microalgae.
- To make proposals and evaluate the possibility of supplying bio-fuels to airports and airlines.

Plan details	Data
Location	1-1, Suehirocho, Tsurumi-ku Yokohama-shi, Kanagawa, Japan (the KEIHIN plant of Asahi Glass Company, Limited)
Site area	9.000m^2
Start of Construction	Summer 2016
Completion of construction	Winter 2017
Start of operation	1H 2018
Feedstock	Domestically-produced/-procured feedstock, such as Microalgae "Euglena" and unedible plant oil
Product	ASTM-compliant biokerosene, next-generation biodiesel, bionaphtha
Production Capacity / volume	5 barrels per day / 125 kiloliters per year

Table 31. *Data of the planned plant.*

The following figure 74 illustrates the plan upon construction.

Figure 74. *Overview of the future plant.*

2. Euglena Farm

"Healthcare market is still growing" – said *Ms. Kawano* (PR and IR Section Management Strategy Department at Euglena Co.,Ltd.) -. As the euglena strain has both plant and creature properties, it contains both plant and creature supplements including the folic corrosive and vegetable fiber often found in plants and DHA, EPA, vitamin B-1, often found in animals.

Another major biological characteristic of the euglena strain is that it does not contain any of the cell walls usually found in plants, and its cells are separated only by a membrane. As human beings lack the compound cellulase which is required to break down the cell walls, digestion of nutrients from vegetables with cell walls proceeds slowly. However, in the case of Euglena, cells are surrounded only by a membrane, so nutrients can be absorbed efficiently. This means that vegetable nutrients which are normally absorbed poorly can be thoroughly taken into the body by consuming euglena, achieving a digestive ratio of 93.1%. The best-selling product is "*Midorijiru*" green juice (Figure 75).

Figure 75. *The "Midorijiru" green juice.*

There are various other products that are very popular, such as the *"PLUS+"* nutraceutical (Figure 76). This product contains alpha-carotene, beta-carotene, vitamin B1, B2, B6, B12, C, D, E, K1, niacin, pantothenic acid, biotin, folic acid, DHA, EPA, palmitoleic acid, oleic acid, linoleic acid, linolenic acid, eicosadienoic acid, arachidonic acid, docosatetraenoic acid, docosapentaenoic acid, dihomo -γ- linolenic acid, manganese, steel, iron, zinc, calcium, magnesium, potassium, phosphorus, sodium, paramylum, chlorophyll, lutein, zeaxanthin, GABA, spermidine, putrescine, palin, leucine, isoleucine, alanine, arginine, lysine, aspartic acid, glutamic acid, proline, threonine, methionine, phenylalanine, histidine, tyrosine, tryptophan, glycine, serine and cystine.

Figure 76. *Euglena Plus+ nutraceutical product.*

3. Euglena Cosmetics

The market for all-natural algae-based cosmetics is over $12 billion USD globally. Average growth in this market from 2000-2012 was approximately 9% per year. Most estimates show further growth in the next 5 years of over 10% annually, with the luxury segment growing above 20% annually. Market growth in the entire sector in key regions: - 7% in North America – 9% in Europe – 13% in Asia

Euglena created *Rejuna™*, a restorative concentrate made through the hydrolysis of euglena Microalgae. Research has demonstrated that *Rejuna™* has different distinctive impacts. For instance, it expands generation of dermal fibroblasts which gives a more grounded guard against bright light and strongly affects the making of the young looking skin. *Rejuna™* can be utilized for the creation of an assortment of various beauty care products including purifying specialists, facial wash, skin moisturizer, serum, cream and sunscreen.

B.C.A.D. - a Company brand created by combining the B.C. and A.D. eras - is a skincare brand which uses *Rejuna™*, a cosmetic extract created through hydrolysis of euglena. Additionally, there is an available series of anti-aging products that provide comprehensive, effective care for aging skin

Figure 77. *B.C.A.D. products.*

4. Wastewater treatment in the Fukushima plant

The next generation renewable energy development program for Fukushima reconstruction and revitalization is bio through crude oil production using native algae population.

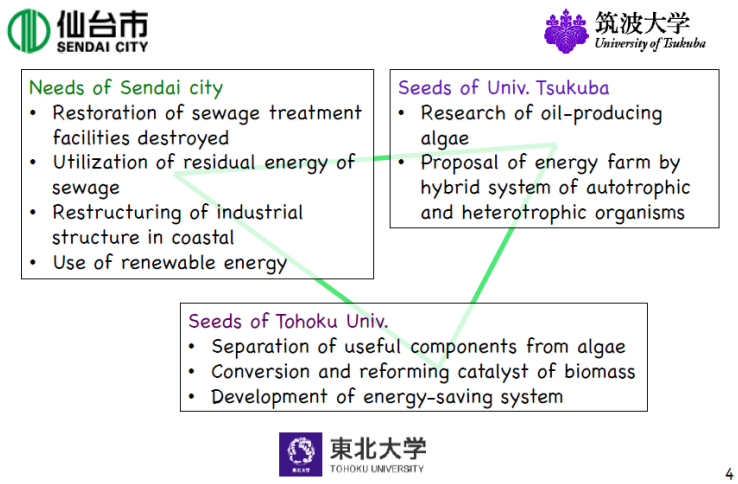


Figure 78. *Public-private collaboration.*

This project funded by the METI uses native algae population adapted to the climate and environment in Fukushima. It contains ammonium acetate to enhance mixotrophic native algae in order to overcome the bottlenecks of low temperatures and low sun light irradiance experienced from middle autumn to early spring.

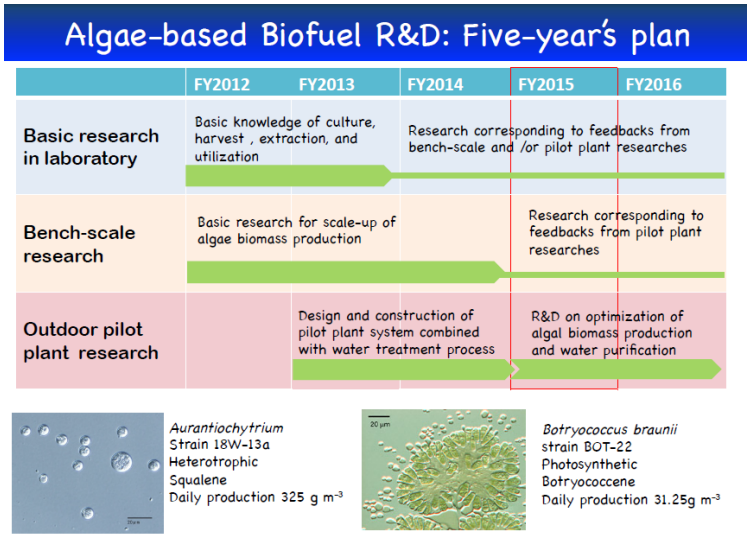


Figure 79. *5-year plan on algae-based bio-fuel R&D.*

The technologies used follow the next Figure 80.

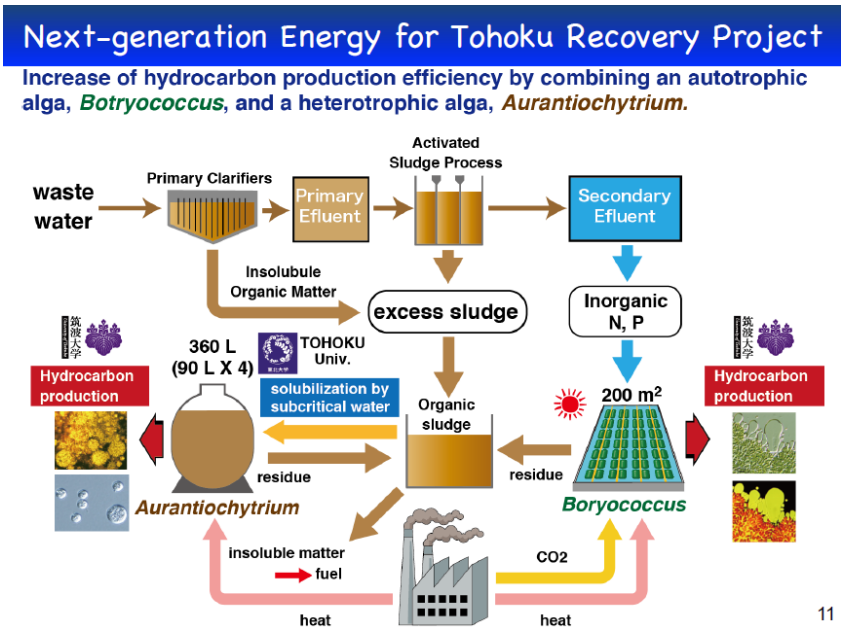


Figure 80. *Next-generation Energy for Tohoku Recovery Project.*

Figure 81. *Algae pilot plant in Fukushima.*

By adding ammonium acetate it was possible to significantly increase how deep can grow up the Microalgae (Figure 82), obtaining a biomass production of 29g/m^2/day.

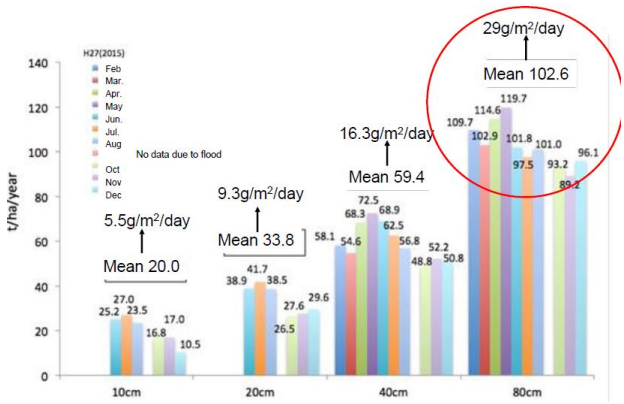


Figure 82. *Comparison of algae production when using ammonium acetate.*

The resulting biomass is processed with coagulants and Drum Hydration techniques (Figure 83).

Figure 83. *Drum hydration machinery.*

Then, the compacted biomass can be treated for extracting bio-oil (Figure 84) considering the Hydraulic Retention Time (HRT), which indicates the average length of time that a soluble composite remains in a photobioreactor

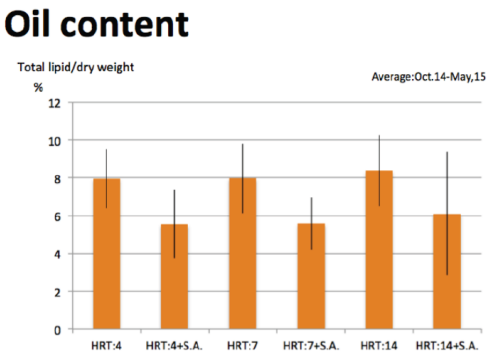


Figure 84. *Bio-fuel production comparison when using HRT.*

Figure 85 compares the crude oil productivities with HHVs (higher heater value) by algae HTL (hydrothermal liquefaction).

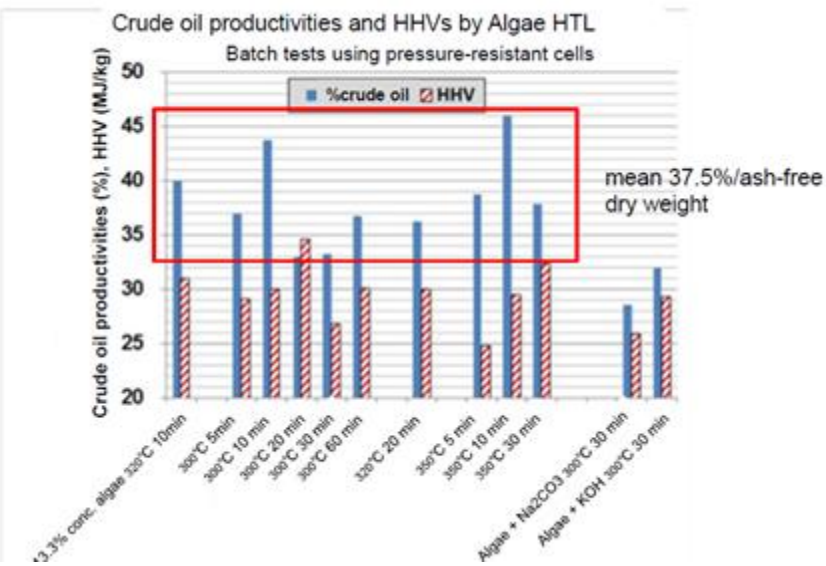


Figure 85. *HTL conversion of algae samples to bio crude oils and their higher heating value (HHV: MJ/kg).*

Figure 86 illustrates the generating efficiency of 59%, while the minimum pre-requisite set by the METI was a 35%.

Energy balance

（100,000m² x 0.8m、HRT=4、Mixing speed =45cm/s、Boimass productivity =30g/m²/day、Conversion rate into bioclude oil =26%、Uses of Fertilizer 、Acetic acid + Ammonia、and Concrete-type raceway ponds）

プロセス	Energy consumption (MJ/kg・biocrude oil)		
	Generating efficiency (100%)	**Generating efficiency (59%)**	**Generating efficiency (35%)**
Raceway pond culture	4.14	**7.02**	**11.83**
Harvest and concentration (25% concentration by coagulation and dewatering)	1.45	**2.46**	**4.14**
HTL and refinery	4.5	**7.63**	**12.86**
Whole process	10.39	**17.11**	**28.83**
EPR(34.12MJ /kg biocrude oil)	3.28	**1.99**	**1.18**

Figure 86. *Comparison between the energy production.*

Figure 87 illustrates the initial costs of the algae-based bio-fuel, without any improvements.

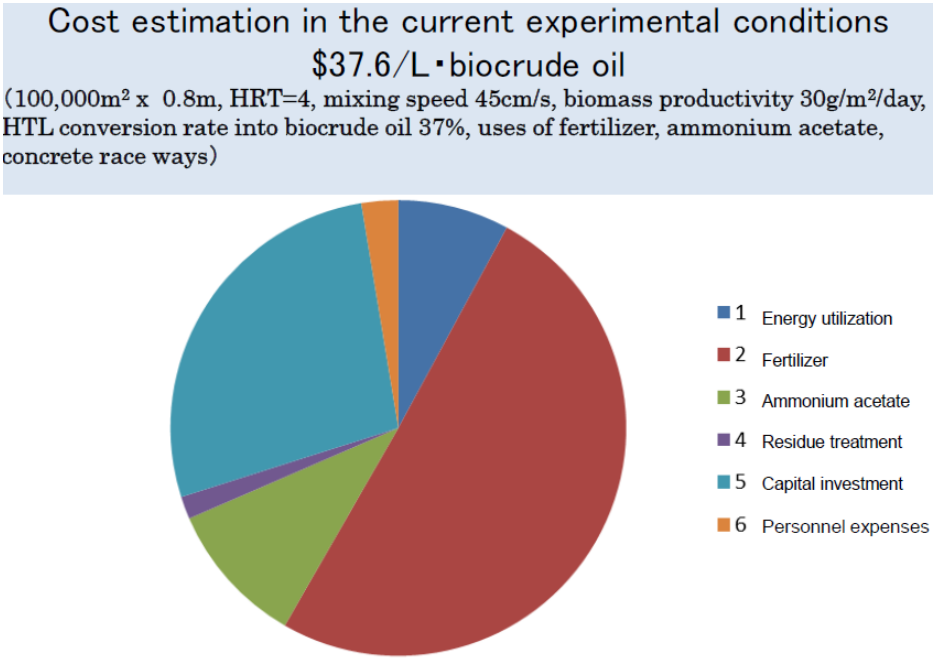


Figure 87. *Costs of production of algal bio-fuel.*

There were 4 possible scenarios (Figure 88) with the developed improvements.

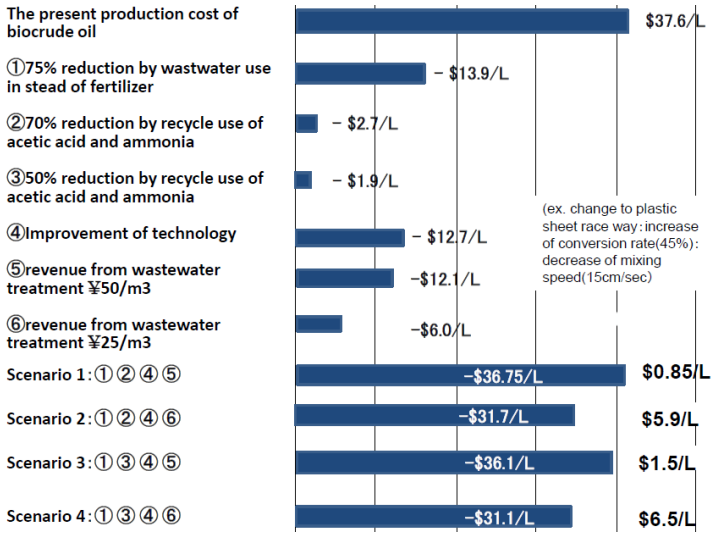


Figure 88. *Comparison with the 4 possible scenarios of bio-fuel production.*

The first scenario is the ideal one; using wastewater as an alternative for nutrients which can reduce the costs of fertilizers by up to a 75%, and 70% reduction in the costs by recycling acetic acid and ammonia. This is due to an improvement of the existing technology and increasing the revenue of wastewater treatment up to 50 yen per cubic meters. With this scenario it is possible to compete with fossil oil prices. The rest of the scenarios are less favourable since bio-fuel prices are higher than fossil fuels.

Finally, with first 3-year stage recently ending, the 2nd stage has begun and will last for another 3 years and will focus on commercialization. This Business Model represents the establishment of advanced technology of algae fuel production from native algae.

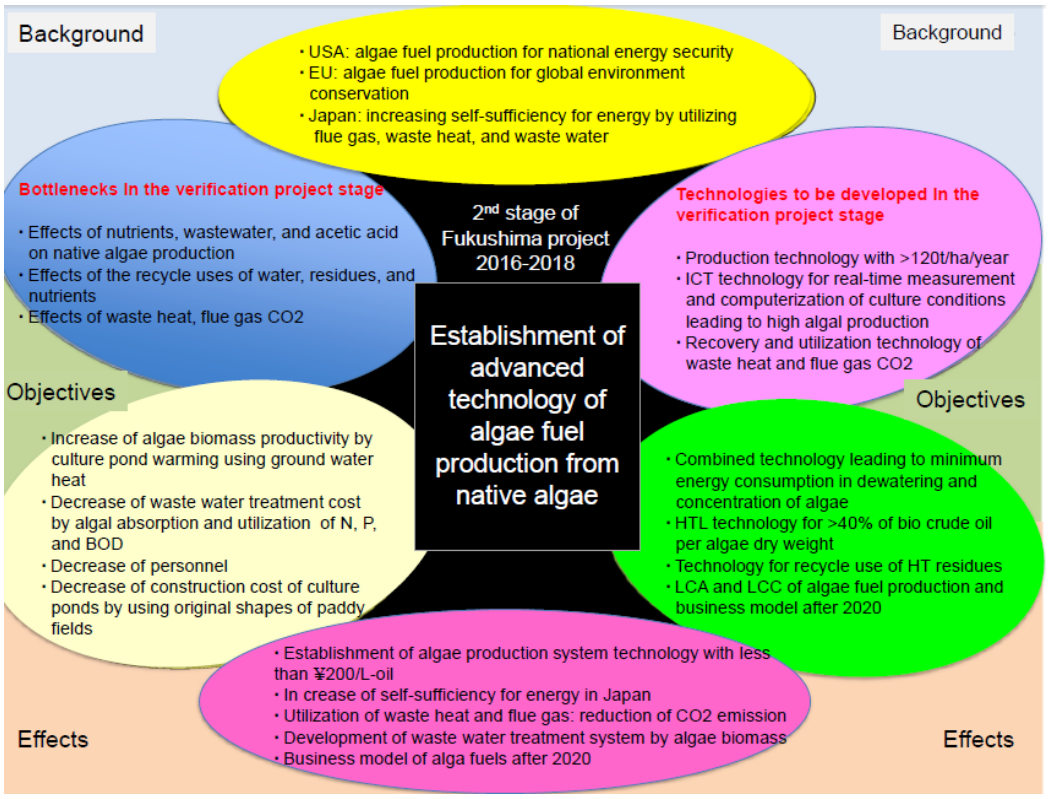


Figure 89. *Diagram with the Background, objectives and Effects.*

4. Initiatives by the Algae Industry Incubation Consortium

This section includes various initiatives by the Algae Industry Incubation Consortium of JAPAN (AIIC) (Figure 90) as a contribution to the actualization of a low-carbon society (which the Japanese government is promoting), by sharing information and improving technology about algae and encouraging growth and mutual development of various algae industries [50]. The consortium aims to *"imagine the algae-based future"*.

Figure 90. *Logo of the AIIC.*

A group of 7 research scholars and 15 businesses came together in June 2010 to launch the AIIC organization. By the 30th October 2015, over 75 businesses, 3 government bodies from the local sector and 25 scholars from different universities and educational institutions were involved. The AIIC has a set of roles and functions, to name:

1. Data regarding the use of algal biomass across the world is collected, coming from research, market trend analysis, investments made in the sector and policies released on this regard. The details are shared with the consortium.

2. Workshops are conducted on algal taxonomy, collection and ways to culture it. This is done with the intention of promoting commercial use of algae by developing the human resource.

3. The basic aim is to promote the algae production sector so, towards this goal, R&D ideas are proposed in a well planned framework and presented to the specific government sectors and businesses.

4. Enhancing joint projects worldwide in order to contribute to the algae-based future society.

Figure 91. *Activities carried out by the University of Tsukuba and the AIIC.*

The AIIC has already collaborated with international institutions:

Event	Date	Location
1st AOAIS	2010	Tsukuba - Japan
2nd AOAIS	2012	Bangkok - Thailand
3rd AOAIS	2014	Daejeon - Korea
4th AOAIS	**2016**	**Wuhan - China**
Roadmap for Algal Biomass Energy Development	February 2012	Tokyo - Japan
International Symposium on Algal Biomass (ISAB)	September 2013	Tokyo - Japan

Table 32. *International project in which the AIIC participated.*

Next, 4 initiatives will be highlighted: (1) R&D roadmap for incubation of profitable algal biomass industry in Japan, (2) Fukushima Next Generation Algae Energy Project, (3) Fukushima Innovation Coast and (4) Business Model of Circular Economy of Microalgae.

R&D roadmap for incubation of profitable algal biomass industry in Japan

This project received support from the Ministry of Agriculture, Forestry and Fisheries (MAFF) projects (FY2011), and consisted of 2 main pillars, (1) Revolutionary technology development for sustainable green and water environment, and (2) integration by a feasibility Study on the Development of Algal Biomass Farm in Japanese Rural Areas. 65 Companies of the Consortium members that took part in 6 task forces (TF):

- *TF1: Algal Biomass Resources*
- *TF2: Algal Biomass Mass Production*
- *TF3: Concentration and Harvesting Algal Biomass*
- *TF4: Extraction and Bio-refinery of Algal Oil and Other Co-Products*
- *TF5: Commercial Use of Algal Biomass*
- *TF6: Life Cycle Assessment and Evaluation*

The roadmap follows the following diagram (Figure 92).

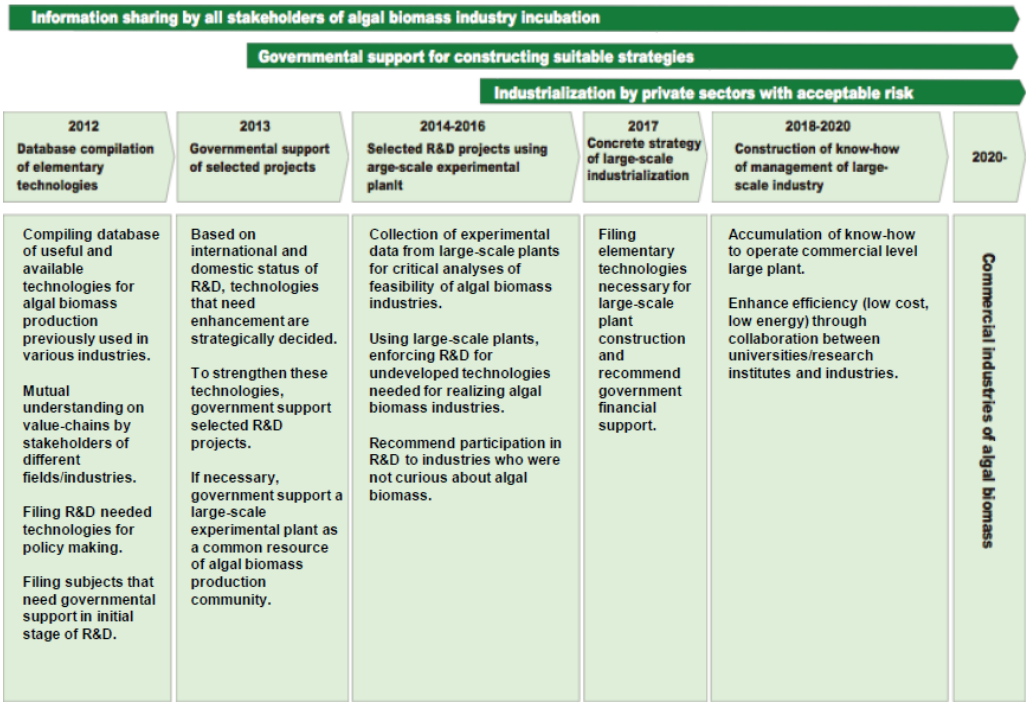


Figure 92. *The biomass R&D roadmap.*

The summary of this algal biomass R&D roadmap is as follows:

- AIIC created the first R&D roadmap of algae-based biomass in Japan.
- The hidden capability of Japan to be able to use technology for algal biomass production was revealed.
- Japan has a well-structured water supply system and this can prove beneficial for the development of algal biomass production.
- A proper database of the technologies which are available but not established yet has to be created so that the stakeholders are able to access the information.
- The decision was made to set 2017 as the marking year to set up pre-commercial algal biomass plants and to develop it into a profitable industry by 2020. This target was evaluated after considering the current international situation of the R&D in algal Biomass sector.

Project 3 is the major attraction of the roadmap which was completed in 2015 with support from the government. The agenda of this project was to replace fossil fuel with algal biomass fuel. It was also decided to increase production of algae to huge volumes through technological advancements in the area by the year 2015 which will help solve the current power supply and energy issues faced by the country and also promote the development of energy production from algae.

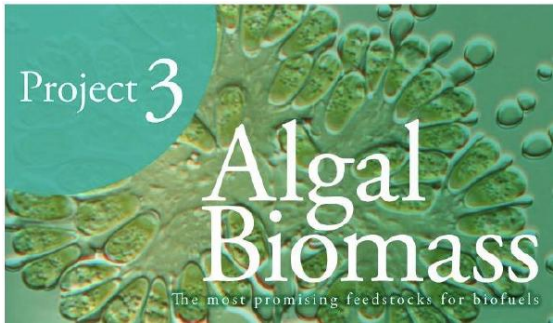


Figure 93. *Logo of the "Project 3 Algal Biomass".*

Project 3 also collaborated with 3 National Institutes and 5 Companies (Figure 94).

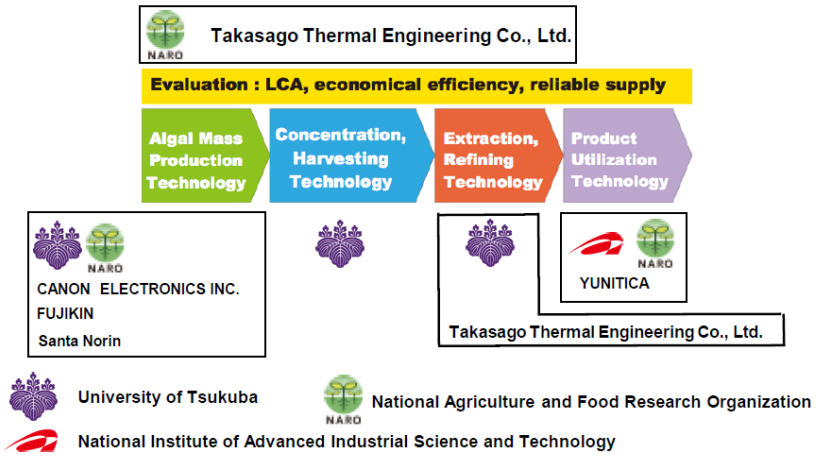


Figure 94. *Companies that conform the Consortium.*

This project used an algae biomass test plan (Figure 95).

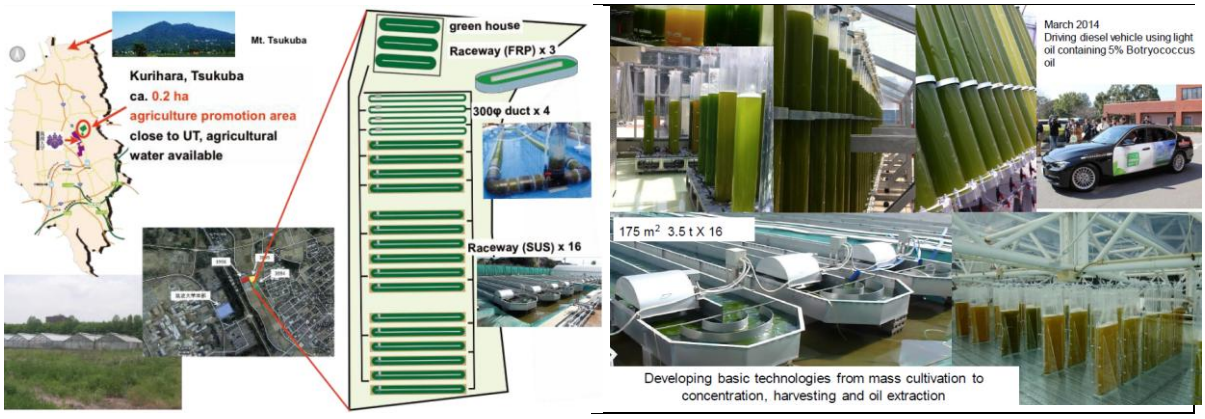


Figure 95. *Overview of the project.*

Fukushima Next Generation Algae Energy Project

The project is based on a model construction for biomass production with natural algal population in temperate region.

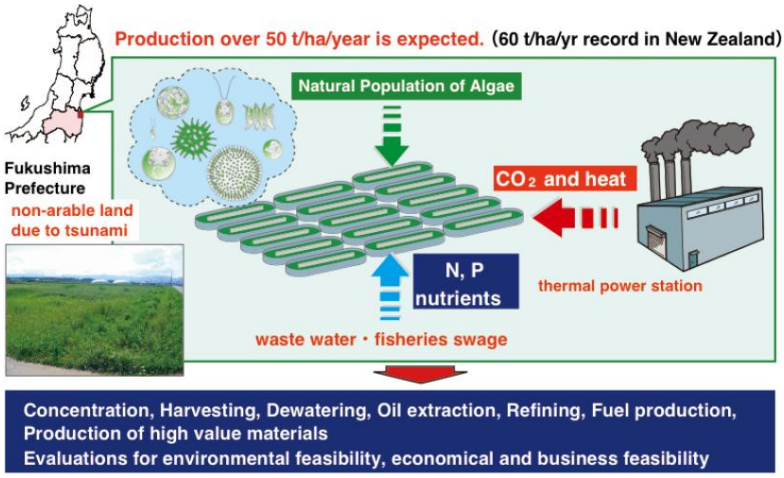


Figure 96. *Overview of the Fukushima Next Generation Algae Energy Project.*

Up to 40 Companies took part in the project, split between 4 task forces:

- *TF1: Facility construction and management (9 Companies).*
- *TF2: Overseas Research (6 Companies).*
- *TF3: Examination and improvement of technologies 17 Companies.*
- *TF4: Mile Stone (Achievement requirements) 8 Companies.*

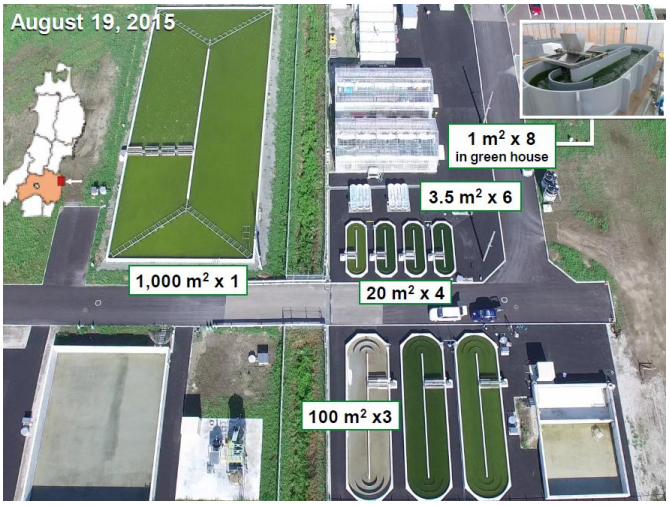


Figure 97. *Aerial view of the plant.*

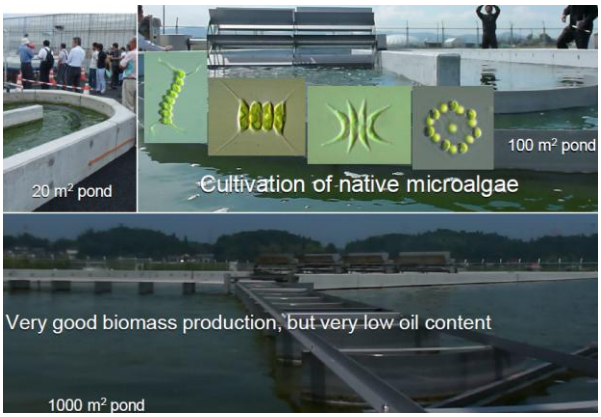


Figure 98. *Variety of native algae.*

A model was constructed which depicted how algal biomass could be produced by natural means from naturally occurring algae in temperate regions. But there was some interference from the native micro algae population which led to a reduction in the volume of oil production. There are numerous micro algae species which are capable of producing more oil, but they were not utilized in the place of the temperate region algal species. The reason is because these native Microalgae are highly adapted to the temperature and nutrients available in the natural state and providing these conditions optimally (by artificial methods) was not feasible. With oil production reduced more than expected, it was found necessary to include the process of optimization of Hydrothermal Liquefaction (HTL).

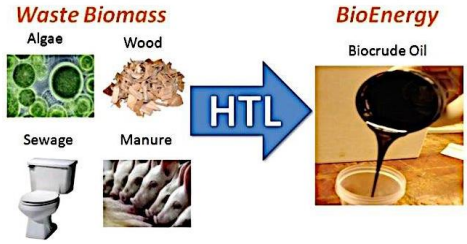


Figure 99. *The HTL process can be used for obtaining bio-crude oil from various sources.*

Fukushima Innovation Coast

The region known as Fukushima *Hama-Dori* will have different kinds of energy production units, including Microalgal biomass.

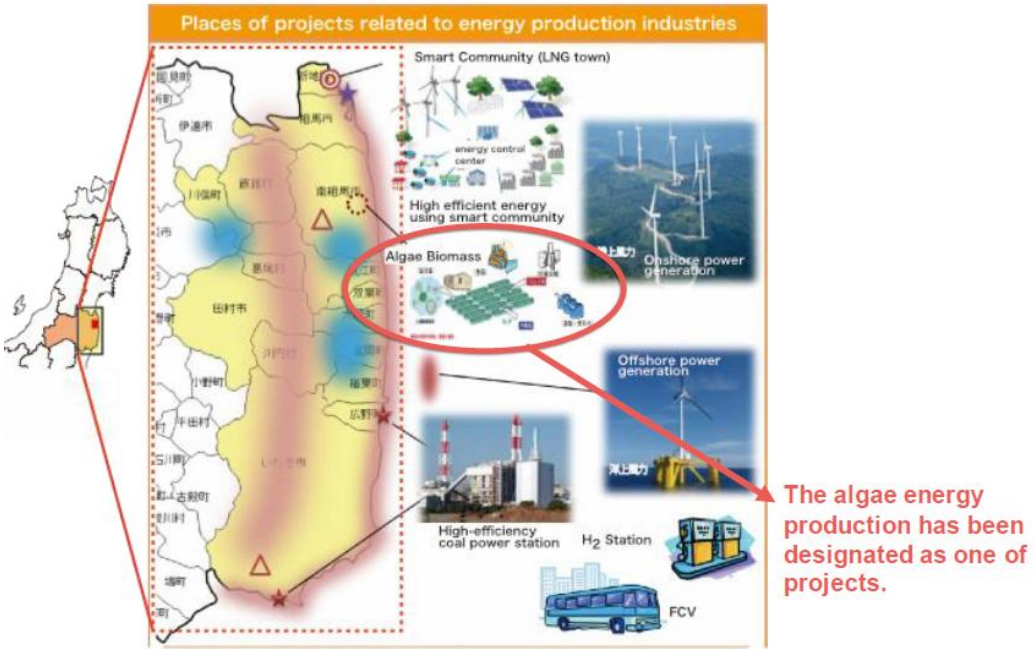


Figure 100. *Algae biomass settlement with different projects in the Fukushima area.*

It is important for the project consider exporting this technology in the overseas.

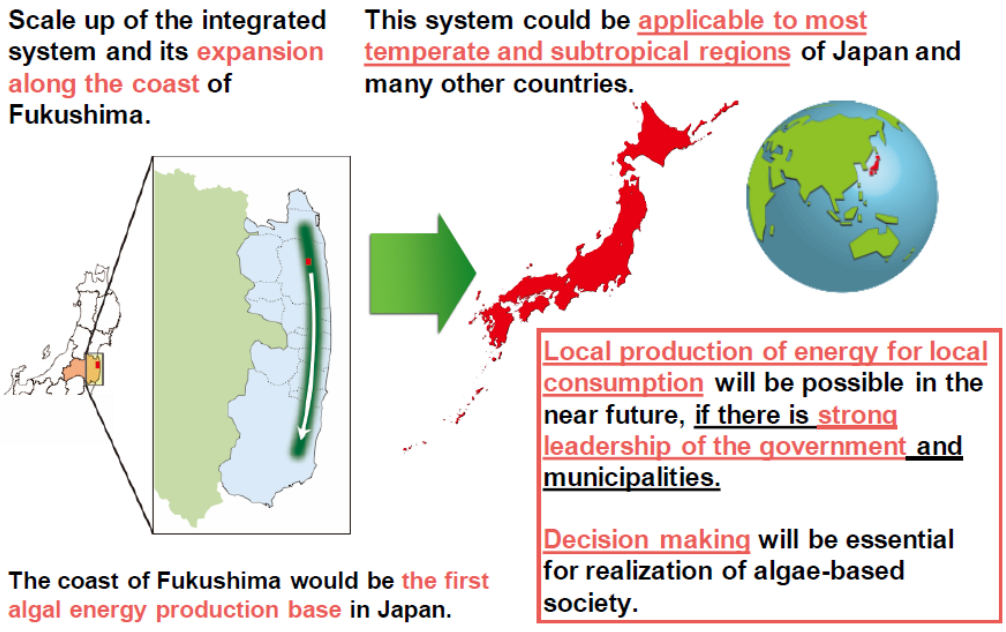


Figure 101. *Potential expansion of the system overseas.*

A Business Model of Circular Economy through Microalgae

The University of Tsukuba, in Collaboration with the AIIC of Japan, is already developing a Business Model of Circular Economy by creating loops Microalgae-biomass-wastewater management, by recycling not only the **bio-crude residues but also wastewater** (therefore, purifying it for human consumption) in the form of new nutrients for the Microalgae.

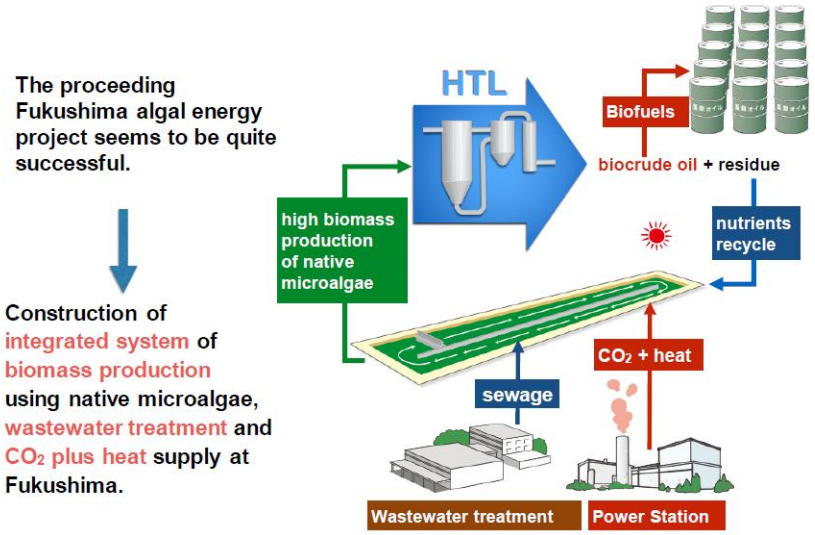


Figure 102. *Example of Circular Economy through Microalgae.*

6. The DeuSEL project

ISUZU MOTORS Co. Ltd. and EUGLENA Co. Ltd. are joining efforts in the joint project DeuSEL [51] aiming at the practical use of the next generation bio-fuel in 2018 (not necessarily to be released to the markets). The project is divided by 2 main different roles depending on the Company, and various stages:

- **EUGLENA Co. Ltd.:** R&D for cultivating the euglena Microalgae strain, its treatment for obtaining dried biomass and process for extracting the Midorimushi bio-fuel.
- **ISUZU MOTORS Co. Ltd.:** logistics and distribution of the Midorimushi bio-fuel in service stations, and specially, the validation of the Midorimushi bio-fuel using diesel-based buses.

Figure 103. *Stages of the "DeuSEL" project.*

The project consists of a series of tests using the Midorimushi bio-fuel on the DeuSEL bus. To date, the project successfully passed a two-year experiment with a mileage of over 40,000 km. DeuSEL can use the existing diesel infrastructures such as (1) storage tanks, (2) the regular service stations for diesel vehicles and (3) trucks for transportation of fuel.

By using the Midorimushi bio-fuel there are 4 main assets; (1) it helps to tackle the current high dependence on fossil oil imports by enhancing the production of local Microalgae-based bio-combustibles, (2) the CO_2 emissions are significantly reduced when compared with conventional fuels [52-53], the energy security is improved [54] and it is shaped as a sustainable business model through Microalgae as is depicted in the next carbon cycle (Figure 104).

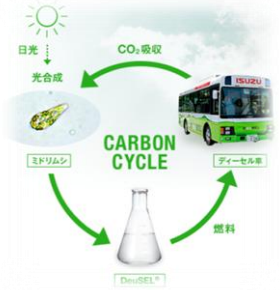


Figure 104. *The carbon cycle of the project.*

Furthermore, the DeuSEL project created an interactive “HaKoBu” [55] community web in order to (1) enhance the awareness among the potential future customers about the importance of using the Midorimushi bio-fuel and (2) for detailing how the proposed carbon cycle works, as 2 keys for success.

7. Euglena and ANA

However, the Japanese Microalgae company Euglena planned on Thu 17 Dec 2015 to announce the foremost demonstration plant to manufacture jet bio-fuel from algae. The refinery will be established in Yokohama with the association of Chevron Lummus Global that will cost 3 billion yen ($24m) approximately. The operations will be started in 2018. It will be able to produce an estimate of 33000 gallons of jet fuel. All Nippon Airways (ANA) and Euglena will receive the fuel. In 2018, a commercial plant will be established.

The Engineering companies like Chiyoda, Isuzu Motors, and Itochu Enex are the procurement, construction and commercialization partners.

Euglena is used to extract oil that will be refined to make fuel. It is the algae which give the company its name and has almost the same characteristics as traditional jet kerosene.

ANA EVP Kiyoshi Tonomoto addressed the users about the algae-based fuel that it will be mixed 10% blend with traditional jet fuel. It will be able to permit one round-trip a week among the airports of Tokyo, Haneda and Osaka.

The demonstration plant will refine the algae sources and cooking-oil if the Euglena is not available for sufficient use.

The major challenge observed by Euglena President Mitsuru Izumo is the commercialization of the fuel particularly the premium price. But the fuel will become competitive over time. The fuel will be used to make cosmetics and nutritional supplements.

The research firm Fuji Keizai anticipates that the demand for the fuel internationally will increase by a factor 16 from 2016 by 2030. It will reach the worth of 11.88 trillion yen ($95bn).

3. THE MICROALGAE INDUSTRY IN THE EU

3.1. OVERVIEW OF RELEVANT EU PROJECTS

This section will enumerate the existing ongoing projects in the EU, and will explain 5 relevant ones, such as the *"Algae-cluster"* (Bio-fat, All-gas and InteSuSal), *"Algae Park"*, *"Algadisk"*, *"CO2Algaefix"* and *"Enalgae"*.

Ongoing projects (to date: 6th of April 2016) [56-57]

Acronym	Website	Remarks
PUFA-Chain	www.pufachain.eu	In the process of increasing the value of the product in the production process, it is necessary to make use of the best possible Microalgae species.
BISIGODOS	www.bisigodos.eu	The chemicals and bio resins used in the algal production units are made from CO_2 emissions from factories.
D-Factory	www.d-factoryalgae.eu	The breakthrough was made by the D-Factory which stepped into the algal biomass production with industrial large scale bio-refinery unit.
InteSuSal	www.intesusal-algae.eu	The prime aim of the InteSusAl was set to provide an example for producing bio-fuel from algae culture in a controlled environment.
AllGas	www.all-gas.eu	Sustainable and large scale production of low-cost bio-fuels based on Microalgae cultures.
BIOFAT	www.biofatproject.eu	The intricate steps to value addition was demonstrated in detail right from the stage of controlled growth, increasing starch and oil production and the final processing stage (biorefinery) towards bio-fuel production.
MIRACLES	www.miraclesproject.eu	R&D project initiated by the industries and laid its aims on producing different products to be used in food, aquaculture and non-food products from Microalgae using different processing techniques.
SPLASH	www.eu-splash.eu	A new kind of biologically oriented industrial system was suggested by this project. The techniques suggested the extraction of hydrocarbons and exo-

		polysaccharides from Microalgae and the usage of these by products for the production of complex polymers.
FUEL4ME	www.fuel4me.eu	The basic aim is to replace fossil fuels and for this is it necessary to ensure a continuous Microalgae chain which produced bio-fuels on a consistent basis so that the 2nd generation bio-fuels would be able to fulfill this goal.
AlgaeBioGas	www.algaebiogas.eu	Biogas digestate is processed with algae which were widely accepted as a prominent and efficient method to increase the quality of the digestate liquid fraction, better feedstock and control over CO_2 emissions. The excess heat produced from the biogas plant and also the odor produced could be controlled efficiently using Microalgae. The nutrients thus produced was later extracted at the plant itself.
PHOTOFUEL	www.photofuel.eu	Photofuel was developed to help in the research of better production methods for solar fuels and to know how this new invention will impact the fuel composition and engine performance in the coming years.

Table 33. *Ongoing projects.*

Algae-cluster

To support the strategy of gaining renewable energy, The EU Commission has aligned itself with 3 large-scale industry projects directed towards a bio-fuel production framework. A demonstration will describe all the sections of the value chain right from the beginning stage of selecting the algal strain, cultivation of the specific strain, production and extraction of oil and finally bio-fuel production and testing [58].

Cluster is composed of 3 different sub-projects: (1) BIOFAT; (2) All-Gas and (3) InteSuSal.

1. BIOFAT project

BIOFAT was a FP7 project that describes the value chain process from the beginning with Microalgae to the bio-fuel production and extraction. It demonstrates optimization of algal growth, production of starch and excess oil and bio-refining process. This section of the project brings together and increases the measure of additive technologies from each partner to form a project report that covers all the areas.

The activities that add value to the final product are tested on several aspects: (1) Energy efficiency; (2) Economic viability; and (3) Environmental sustainability.

Sustainability is the key for bio-fuel derived from algae production, taking into consideration both environmental sustainability (such as usage of marine strains to limit freshwater use) and cost-effectiveness (low energy consumption) (Figure 105).

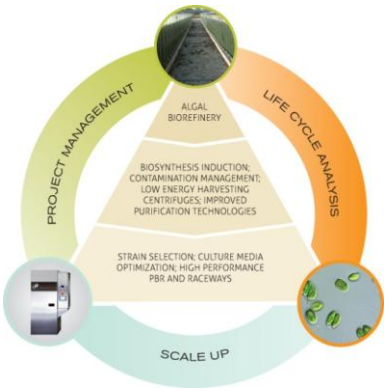


Figure 105. *The BIOFAT project diagram.*

2. All-gas project

This project aims to demonstrate how wastewater and other by-products released through the process of bio-fuel production from algae can be re-utilized in a low-cost environmentally friendly framework. This project focuses on the production of carbon dioxide from the waste water, production of energy and reutilization of the nutrients. The waste water acts as the first raw material in the demonstration where it is treated before the process in oxygen-deficient condition which will help to increase the biogas and CO_2 production. The treated waste water is then subjected to algal biomass production and thus purified. The algae that proliferate is removed and used for oil and other residue extraction. The biomass from the algae is converted to biomethane, CO_2 and minerals.

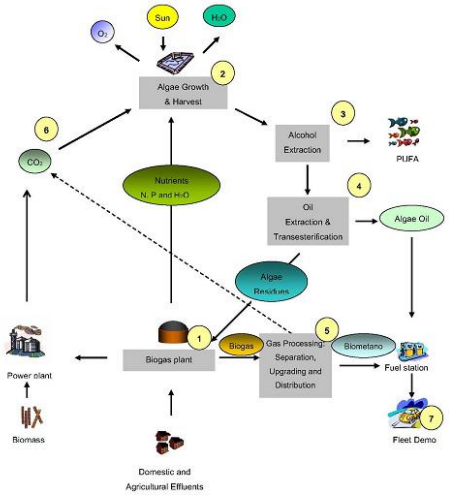


Figure 106. *The All-gas project diagram.*

3. InteSusAl project

This project aims to demonstrate the whole process of the production of bio-fuels from algae in an eco friendly and continuous manner on a large-scale basis. The success of this project lies in the ability to demonstrate the maintenance of the economic and ecological factors during the process. It also ensures that the algal biomass is produced in optimal conditions and maintained correctly so as to enable commercial production.

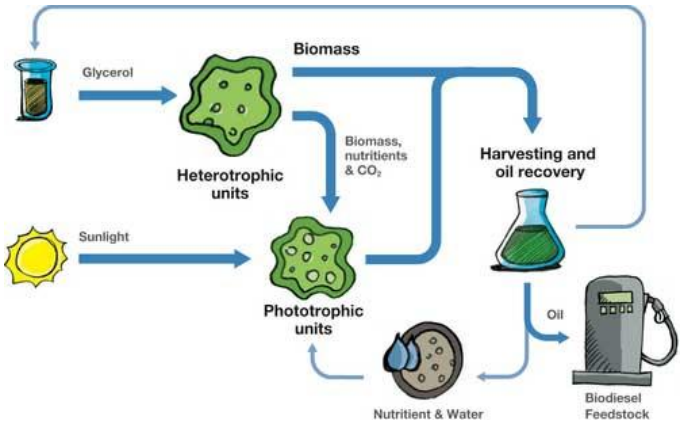


Figure 107. *The InteSusAl project.*

Algae Park

A research program by the name of Algae Park was initiated and conducted studies on the whole processing of cyanobacteria and Microalgae and their value addition along the production process. The whole value chain is evaluated differentially to get proper data on profitability and environmental factors. The research program then uses this data to analyze the bioengineering features of the algal cultivation and refining. The technology is then developed in a lab and then moved to a large-scale production where the beginning idea is implemented as a large-scale pilot scale production. This move produces high-quality, new and advanced products. The basic research and its applications are thus connected to the pilot scale production [59].

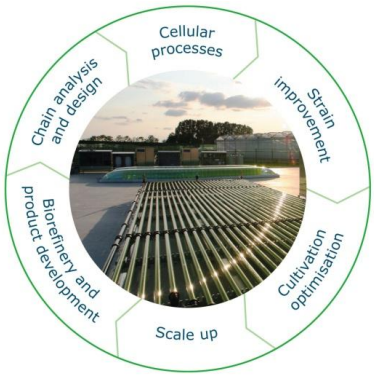


Figure 108. *The Algae Park business model.*

Algadisk

The aim was set on a wider basis that would allow the creation of a biofilm reactor which could reduce setup and process cost and increase efficiency at the same time. This reactor for biomass production has to be compact, self-operational and scalable. The carbon dioxide released from industrial processes is utilized in the production of valuable products. According to the project the algae will be cultivated in the liquid on the surface, which will allow for the utilization of CO_2 emitted in the aqueous and gas phase. By cultivating the algae in both phases, the efficiency can be increased immensely and the water required for the process will also be reduced. In this system, the algae will replicate automatically and harvested continuously, producing biomass efficiently and better utilization of CO_2. This system makes use of an easily-adjustable system and therefore scaling of the ALGADISK will not be a matter of major concern. The space taken up for installation will also be less when compared to other systems in the industry [60].

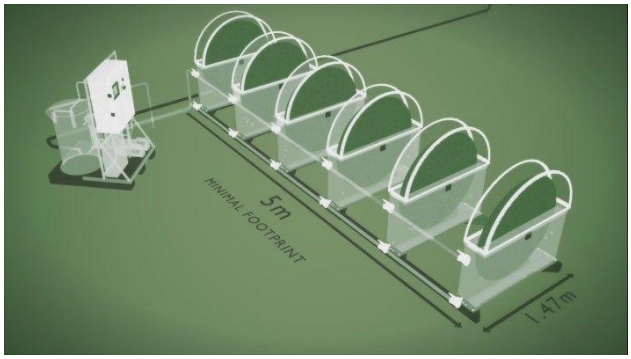


Figure 109. *The Algadisk device.*

CO2Algaefix

This project focuses on the growing of Microalgae for the purpose of absorption of CO_2 emitted from the electric power units. The CO_2 captured using a vertical bioreactor is utilized by the algae to produce biomass and energy. With the immense amount of CO_2 generated from these plants the approximate value of biomass production is estimated at 100,000 kg/year proving to be a great potential source for industries like health, cosmetic, food and fertilizer [61].

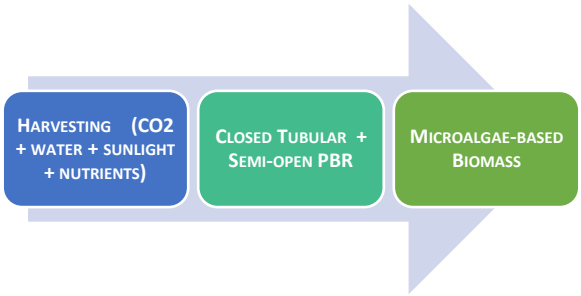


Figure 110. *Life cycle sequence of the project.*

Enalgae

This project aimed at producing products like biomass from algae, energy production with decreased greenhouse gas (GHG) production in pilot plants and then working on this to take it to large scale production.

Over the area assigned for the sample pilot facilities, nine of them would be created and shared to reduce the cost and accessibility factors. This also gives the advantage for the sample plants to realize the effect of the different physical conditions from rural to industrial areas.

The associates involved in the project can attain funds and political benefits and can even share the project models to come up with beneficial changes. The combined working system to create a best-practice model can be then reflected in their policies [62].

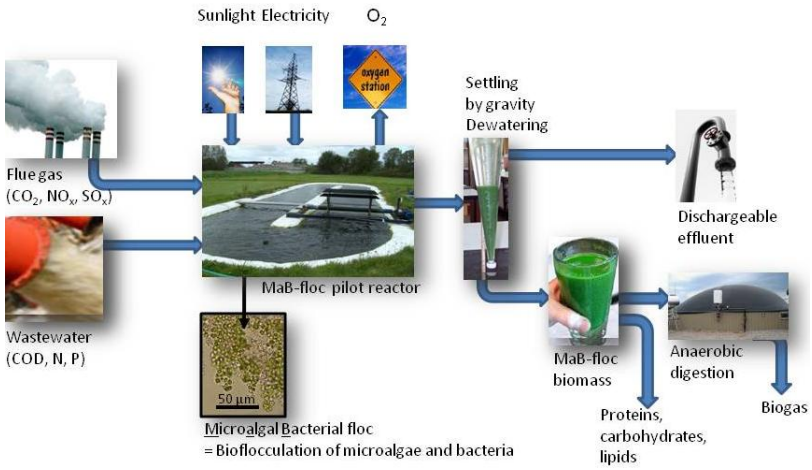


Figure 111. *The Enalgae project.*

3.2. LIST OF EU COMPANIES

This section will enumerate **the most relevant EU Companies** (related to the Industries participating in the Business Model) as a *good starting point* for finding potential partners and building EU-Japan alliances. It is important to note that the Companies listed in this section will be represented in the virtual map (*Annex 2*).

Microalgae

Table 34 enumerates 10 of the most relevant European Companies of the Microalgae Industry. It is important to note that several of the Companies shown also produce additional biomass-based products other than the ones that are highlighted.

Company	Website	Remarks
A4F, S.A	a4f.pt	*Coordinator of BIOFAT project. The aim of BIOFAT project is to create a model, implement it and product Microalgae in a large scale at production plants with the help of large plants.*
Fotosintetica & Microbiologica S.r.l.	femonline.it	*Partner of BIOFAT. A spin-off Company of the University of Florence, has created an algae culture collection (950 strains) and develops low-cost photo-bioreactor designs.*
Algosource Technologies	algosource.com	*Partner of BIOFAT. University of Florence along with its subsidiary Company had created 950 strains for algal cultures with their cost efficient bioreactor model.*
Subitec	subitec.com	*Subitec is the Company which has the prime and accepted technology for industrial scale production of microalgal biomass.*
Algaelink NV	algaelink.nl	*Coming up with a efficient photobioreactor for the production of algae is the prime necessity.*
Algaenergy	algaenergy.es	*A technology-based Company specialized in the field of Microalgae biotechnology that, with substantial R&D programs, managed by a team of entrepreneurs and scientists with solid track, has solid track record.*
Archimede Ricerche	archimedericerche.com	*One of the Italian industries has been producing premium quality Microalgae in its four modules. Each module has several*

		bioreactors and the industry has been set up in a 1000 sq m area and it's the biggest plant of the kind. These bioreactors enable the production of various different algal strains.
Algenuity	algenuity.com	*The Company by the name of Algenuity, has been dealing with all processes based on algal biology. The Company aims to produce an economy that is dependent on algae for cost effective, eco friendly and efficient system.*
Algalimento	algalimento.com	*The Canary Islands serve as the best location for algal propagation due to the wonderful climatic conditions all through the year. Their interest derives from composition, rich in protein and highly digestible carbohydrates and a fat fraction can reach 70 % of its dry weight, which makes them particularly interesting from a nutritional standpoint.*
Svandid	svanvid.com	*placed in the top five list of the Company's in Europe and was awarded recognition by Commissioner Carlos Moedas and Europa BioPolish.*

Table 34. *EU Microalgae Companies.*

Biomass-based Products: Energy

Table 35 highlights 10 of the most relevant Companies that are producing bio-fuel or jet-fuel by using biomass obtained from Microalgae.

Company	Website	Remarks
Evodos	evodos.eu	*The SPT or Spiral Plate technology for algal cultivation which makes use or lesser energy compared to other systems and there is no chemical processing involved in this dry separation method developed by a partner of BIOFAT agenda.*
Cellulac	cellulac.co.uk	*The UK and Switzerland facilities have been able to provide its registered fluid processing reactors and also the technology to breakdown molecules into atomic state. These new technologies have increased the cost efficiency and also has made it possible to be implied in different industrial processes.*
Neste Oil	neste.eu	*The Fuel4Me project has its partner Company operating in 15 countries with its aim set to produce*

		good quality inexhaustible diesel fuel.
Algenol	algenol.eu	*The project also keeps a watch on the newer applications that can be made to the program "DIRECT TO ETHANOL" to attain the goal. Some innovations towards this goal have already been proofed to a greater extent.*
BDI-Bioenergy	bdi-bioenergy.com	*With the goal of "Waste to Value", waste products and by products have been utilized in the production of energy keeping the resources protected. BioDiesel and Biogas facilities have been set up with state of the art technologies.*
Bio-oils	bio-oils.com	*When operations had begun, the R&D program also rolled out at the same time and this has made it possible to produce premium bio-fuels from different oils. All the oil courses are made use of the plant at present to process different residual materials.*
Elin	elin.gr	*The plant in Volos has been producing premium biodiesel with innovative technologies.*
Fermentalg	fermentalg.com	*There has been an increased fight over land sharing between bio-fuel production units and the agricultural land. With the Algae-sourced bio-fuel also known as algofuel, this competition can be reduced as the third generation bio-fuel is produced efficiently using lesser area giving higher yields.*
Biopetroleo	biopetroleo.com	*With this technology it has been able to release a new kind of crude oil, and carbonated products like proteins, lipids etc. This is the outcome of the effort laid out by a group of dedicated scientists, engineers and technical people who have made it possible to speed up the natural process of change that has been happening over several hundred years.*
Proviron	provirion.com	*Proviron designs has 22 plants set across US and Belgium providing chemicals to smaller markets and it has the credit of being the leading market position for their produces. It has its role on FUEL4Me project and takes part in the associated research.*

Table 35. *Biomass-based Products related to Energy Companies.*

Biomass-based Products: Nutritional

Table 36 enumerates 10 Companies that produce foods, feeds and fertilizers.

Company	Website	Remarks
Wageningen ur-food & biobased research	wageningenur.nl	*Coordinates FUEL4ME and participates in the fundamental research.*
Algaspring	algaspring.com	*Micro-algae successfully applied in hatcheries and aquaculture feed Companies around the world, "simply the world best quality for the best price".*
Simris Alg	simrisalg.se	*Pioneering agribusiness harvesting algae in Sweden. Algae farmers aiming to empower healthy and eco-friendly lifestyles, delivering superior quality products derived from algae. The main target is to be a landmark business for bio-based economy Business Model.*
Buggy power	buggypower.eu	*Produces microalgal biomass wit premium quality and develop new products supplemented with marine Microalgae that can be used as a supplement in animal feed (FEED) and human (FOOD) and distributed by the different marketing channels.*
Metabolium	metabolium.com	*Works on the process to add the benefits of Selenium to the specific benefits of Microalgae (proteins, amino acids, pigments, vitamins, lipids, ...).*
Ecoduna	ecoduna.com	*Ecoduna is the global technology leader in the construction of algaculture systems. A continuous industrial-scale production of biomass with the greatest possible conservation of resources and the environment.*
Algomed	algomed.de	*Pioneers in the field of advanced Microalgae farming. With our unique and patented photobioreactor technology together with long-term experience in algae cultivation, provide to costumers an outstanding quality of products.*
Neoalgae	neoalgae.es	*Born in 2012 with the objective of bridging the gap between laboratory scale and industrial processes in the field of applications of Microalgae.*
Phytolutions	phytolutions.de	*Advances in the Production of High-Value*

		Products by Microalgae Marine Microalgae used as food supplements and their implication in preventing cardiovascular diseases.
Olmix SA	olmix.com	*Offers natural health and nutrition solutions for animals plants and people, to ensure a complete, consistent food and health chain.*

Table 36. *EU Biomass-based Products related to Nutritional Companies.*

Biomass-based Products: Other Applications

Table 37 features 10 other relevant applications of Microalgae-based products, such as plastics, cosmetics and wastewater treatment.

Company	Website	Remarks
A&A Fratelli Parodi S.p.a.	fratelliparodi.it	*Is a green chemistry oriented Company that supplies products for cosmetic and pharmaceutical applications and boasts experience in establishing and operating production plants for vegetable oils, third generation bio-fuels and green solvents.*
Feyecon	feyecon.com	*Member of Fuel4me. Develops products and processes based on compressed CO_2. The CO_2 technology has been applied to diverse processes, such as the extraction of natural products, the precipitation of proteins, the production of polymer foams, and their products are used in the pharmaceutical and food industry.*
Fitoplancton Marino	fitoplanctonmarino.com	*To improve the health of society by providing healthy products and functional ingredients. For this, generate high value-added products derived from Microalgae, committed to sustainable development and economic viability.*
Microphyt	microphyt.eu	*Biological & functional benefits of Microalgae-based products have been known for years in cosmetics Industry with several commercial products already on the market: skin care products (anti-aging cream,*

		refreshing or rejuvenating care products, emollient and anti-irritant in peelers) Sun protection (UV filters) and Hair care products.
Monzón BIOTECH S.L.	mznbiotech.com	*Production of Microalgae for aquaculture, animal feed and cosmetics.*
Phytobloom	phytobloom.com	*Microalgae are naturally designed to resist several environmental aggressions. They produce pigments as sun-blockers; several metabolites to fight bacteria and virus; polysaccharides to protect themselves from outer menaces. Cosmetologists have long exploited these benefits in cosmetic formulations.*
Aquaflor	aquaflor.no	*Aqua Flor always strives to offer the very best dietary supplements and cosmetics. Cosmetics are free of parabens and are dermatologically tested.*
Neoalgae	neoalgae.es	*Production of different species of Microalgae for use in sectors as diverse as human and animal food, cosmetics, or pharma-cosmetics.*
Algen	algen.eu	*AlgEn is committed to be an active participant in the blooming area of algal technologies. Internal research and development activities are being complemented by components and know-how of partners into effective solutions.*
I-PHYC	i-phyc.com	*Industrial Phycology is an award-winning Company that offers sustainable water recycling and nutrient recovery solutions. Applying cutting-edge technology, the I-Phyc system uses Microalgae at an industrial scale to treat wastewater from agricultural, industrial and municipal sources.*

Table 37. *EU Biomass-based Products related to other applications Companies.*

3.3. SUPPORT PROVIDED BY THE EU

This section briefly summarizes the EU programmes that support the economic activities of European Companies (mainly) in form of funding.

Horizon 2020 (H2020) programme

This funding is not open to the Japanese industries directly. The funds will have to be sourced by the organizations themselves, either with their own funds or taking help from the Japanese funding authorities. The calls sent over funding have been spread over various sections like biological technology development, economy factors, bio-fuel, water recycling and other biological products and their role in maintaining a circular economy.

To date, there are 3 Calls divided across various topics highly related to the scope of this paper, such as biotechnology, bioeconomy, biomass, biorefineries, waste/wastewater management, bio-based products and Circular Economy of biological materials. Next, 1st *call is open, 2nd/3rd are forthcoming*:

CALL: BIO BASED INDUSTRIES PPP (H2020-BBI-JTI-2016)
BBI-2016-D01: Improve sustainability of value chains based on forest biomass and increase productivity and profitability on supply side by adapting forests to Climate Changes.
BBI-2016-D02: Improvement and adaptation of industrial crop varieties and novel sources of biomass to diversify biomass feedstock for biorefineries.
BBI-2016-D03: Valorisation of lignin and other side-streams to increase efficiency of biorefineries and increase sustainability of the whole value chain.
BBI-2016-D04: New and optimised biorefinery approaches enabling the creation of local value chains in underdeveloped or unexploited areas.
BBI-2016-D05: Bio-based polymers/plastic materials with new functionalities for medical, construction, automotive and textile industries.
BBI-2016-D06: Valorisation of the organic content of Municipal Solid Waste and contributing to the renewable circular economy.
BBI-2016-D07: Optimise technical production routes to bio-based chemicals in bio- or chemo-catalytic processes.
BBI-2016-D08: New sources of proteins for animal feed from co-products to address the EU protein gap.
BBI-2016-D09: Biomass production on unused land for conversion into added-value products while 'boosting rural and industrial development'.
BBI-2016-F01: Valorisation of by-products or waste-streams from the food processing industry into high added-value products for market applications.
BBI-2016-F02: Converting bio-based feedstocks via chemical building blocks into advanced materials for market applications.
BBI-2016-R01: Valorisation of the organic content of wastewater as feedstock, contributing to the renewable circular economy.

BBI-2016-R02: Develop consolidated bioprocesses for direct fermentation into bio-compounds for chemicals and materials.
BBI-2016-R03: Improve control over microorganism growth in bio-catalysis operations in order to reduce/avoid contamination without antibiotics.
BBI-2016-R04: Flexible biorefining technologies able to handle different feedstock, leading to new value chains or enlarging existing ones by using the same processing plant.
BBI-2016-R05: Advanced biomaterials for smart food packaging.
BBI-2016-R06: Bio-based alternatives to improve protection of human health and the environment.
BBI-2016-R07: Biopolymers with advanced functionalities for high performance applications.
BBI-2016-R08: Emerging technologies for conversion of the organic content of Municipal Solid Waste and improving waste-to-chemicals value chains.
BBI-2016-R09: Exploiting algae and other aquatic biomass for production of molecules for pharma, nutraceuticals, food additives and cosmetic applications.
BBI-2016-R10: Industrial biotransformation for the production of bio-based chemicals.
BBI-2016-R11: Recover and reuse enzymes to reduce costs of existing industrial processes.
BBI-2016-R12: Emerging technologies for separation and purification of fermentation products to obtain high grade bio-based molecules at industrial level.
BBI-2016-S01: A roadmap for the chemical industry to a bioeconomy.
BBI-2016-S02: Bioeconomy related open access research infrastructure and assessing its capabilities for industry driven development projects.
BBI-2016-S03: Open-innovation Platform strengthening cooperation and joint development of bio-based industries and downstream sectors.
BBI-2016-S04: Clustering and networking for new value chains.

Table 38. *Topics of the Call H2020-BBI-JTI-2016.*

CALL: BIO-BASED INNOVATION FOR SUSTAINABLE GOODS AND SERVICES - SUPPORTING THE DEVELOPMENT OF A EUROPEAN BIOECONOMY (H2020-BB-2016-2017)
BB-02-2017: Towards a method for the collection of statistical data on bio-based industries and bio-based products.
BB-03-2017: Adaptive tree breeding strategies and tools for forest production systems resilient to Climate Change and natural disturbances.
BB-05-2017: Bio-based products: Mobilisation and mutual learning action plan.

Table 39. *Topics of the Call H2020-BB-2016-2017.*

CALL: INDUSTRY 2020 IN THE CIRCULAR ECONOMY (H2020-IND-CE-2016-17)
CIRC-01-2016-2017: Systemic, eco-innovative approaches for the circular economy: large-scale demonstration projects.
CIRC-02-2016-2017: Water in the context of the circular economy.
FOF-06-2017: New product functionalities through advanced surface manufacturing

processes for mass production.
FOF-07-2017: Integration of unconventional technologies for multi-material processing into manufacturing systems.
FOF-08-2017: In-line measurement and control for micro-/nano-enabled high-volume manufacturing for enhanced reliability.
FOF-09-2017: Novel design and predictive maintenance technologies for increased operating life of production systems.
FOF-10-2017: New technologies and life cycle management for reconfigurable and reusable customised products.
FOF-12-2017: ICT Innovation for Manufacturing Companies (I4MS).
PILOTS-03-2017: Pilot Lines for Manufacturing of Nanotextured surfaces with mechanically enhanced properties.
PILOTS-04-2017: Pilot Lines for 3D printed and/or injection moulded polymeric or ceramic microfluidic MEMS.
PILOTS-05-2017: Paper-based electronics.
SPIRE-07-2017: Integrated approach to process optimisation for raw material resources efficiency, excluding recovery technologies of waste streams.
SPIRE-08-2017: Carbon dioxide utilisation to produce added value chemicals.
SPIRE-09-2017: Pilot lines based on more flexible and down-scaled high performance processing.
SPIRE-11-2017: Support for the enhancement of the impact of SPIRE PPP projects.
SPIRE-12-2017: Assessment of standardisation needs and ways to overcome regulatory bottlenecks in the process industry.

Table 40. *Topics of the Call H2020-IND-CE-2016-17.*

LIFE programme

"LIFE promotes the implementation and integration of environment and climate objectives in other policies and Member State practice. It makes emphasis will also be placed on better governance. It has a specific link to EU priorities: resource efficiency, biodiversity loss and climate adaptation and mitigation. It is divided by 2 sub-programmes: (1) the sub-programme for Environment, including as priorities areas environment and resource efficiency, nature and biodiversity, and governance and information, and (2) the sub-programme for Climate Action, including as priorities areas adaptation, mitigation and governance and information" [63]. First sub-programme has a funding of €2,592.5 m, and the second, a grant of €864.2 m.

Update to the European Committee for Standardisation as regards algae and algae-based products or intermediates in support of the implementation of 23.3.2016 [64]

The European Committee for Standardisation (CEN) is requested to draft European standards or European standardisation deliverables in support of the implementation of Article 3 of Directive 2009/28/EC for algae and algae-based products or intermediates, as well as the Communication on *"Innovating for Sustainable Growth: A Bioeconomy for Europe"*, in order to promote energy, bio-based materials and chemicals use from renewable sources. This standardization consists of:

1. *SPECIFICATIONS FOR ALGAE-BASED PRODUCTS:*
    - ① *Classification of algae genera*
    - ② *Dry matter*
    - ③ *Ash content of primary algal products*
    - ④ *Elemental analysis*
    - ⑤ *Chemical/component analysis including: lipids, extractable oils, carbohydrates, proteins and other (anti-oxidant value, microbiological contaminants including microbial toxins, physical and chemical contaminants).*
2. *SPECIFICATIONS FOR QUALITY SPECIFICATION OF ALGAE-BASED PRODUCTS TO BE USED FOR BIO-FUEL PRODUCTION:*
    - ① *Characterisation of algal oils*
    - ② *Characterisation of solid biomass*
3. *SPECIFICATIONS FOR ALGAE PROCESSING:*
    - ① *Measurement of energy input (i.e. light)*
    - ② *Productivity of systems.*
4. *SPECIFICATIONS FOR QUALITY CHARACTERISATION OF ALGAL PRODUCTS TO BE USED FOR NON-ENERGY APPLICATIONS:*
    - ① *For use in the food and feed chains*
    - ② *For use in chemicals/materials chains*
    - ③ *For use in cosmetics*
    - ④ *For use in pharmaceuticals*
5. *SPECIFICATIONS FOR GASEOUS CAPTURE AND SPECIFICATIONS FOR SOLUBLE NUTRIENT COMPOUNDS FOR ALGAL PRODUCTS:*
    - ① *Definition of CO_2 uptake*
    - ② *Definition of nitrogen uptake.*
6. *SPECIFICATIONS FOR SOLID AND LIQUID RESIDUE STREAMS:*
    - ① *Physicochemical characterisation of solid and liquid residue streams*
    - ② *Toxicity of solid and liquid waste output*
    - ③ *Gas emissions in relation to Climate Change and end of life.*

4. POTENTIAL BUSINESS OPPORTUNITIES FOR EU COMPANIES

In general, the Industries that may find attractive investments in the **algal energy domain owing to synergistic benefits** are:

1. Sewage & water treatment companies.
2. Agriculture & farming.
3. Companies that produce waste water.
4. Companies that are major CO_2 polluters.

4.1. OPPORTUNITIES OF THE JAPANESE MARKET

Japan still has a huge dependency on fossil oil imports

1. EU Companies can contribute with their notable technologies (sometimes patented) in order to increase the bio-fuel production and to reduce costs.
2. The Japanese Government has a roadmap on biomass for producing bio-fuel in order to reduce the big dependency on exports.
3. Japan has very favourable support and weather conditions for cultivating Microalgae, as shown in previous projects (e.g. Fukushima project).

Enhancing EU-Japan collaborations with the AIIC Consortium

As was stated by the AIIC Japan, the algae Consortium are already collaborating with Companies from the USA and nearby countries (e.g. Vietnam) in various projects. However, with the current scenario in which Microalgae is a relevant topic in Europe, the attractiveness of establishing new alliances with EU Companies could be enhanced, and vice-versa.

Growing up of new markets based on products derived from Microalgal biomass

The Japanese market is continuously growing with the development of new products derived from Microalgal biomass, an example of this evolution in the market is presented by Euglena, which progressively is introducing healthy foods, feeds and cosmetic products. This tendency seems to be continuing since the Company is still releasing new product lines.

Developing cutting-edge technologies in Japan may need support from the EU Companies

There are 3 research lines that are a hot topic worldwide and still require improvements, this is, (1) wastewater treatment (2) CO_2 absorption applied to the automotive sector, and (3) jet fuel R&D/production, as it is being developed for example with the University of Tsukuba, ISUZU Motors, and Euglena Corporation, respectively.

4.2. CHALLENGES OF THE JAPANESE MARKET

There are various challenges EU Companies may face:

- The Japanese Government (METI, MAFF, JETRO…) collaborates with certain specific projects, however, the current law on National Security, social restrictions, agricultural act and wastewater management can make the process of receiving support tedious (taking a long time in most of cases).
- Finding a local partner and building solid business relationships takes considerable time. Most successful foreign Companies have first linked up with local Japanese Companies by using them as agents or distributors, and then, over time, built up a closer and more integrated business relationship.
- There are three different levels (national, prefectural and municipal) of government who often issue similar but different policies. This makes it extremely difficult to understand what are the exact rules and regulations.
- Most involved Companies are members of the AIIC (Algae Industry Incubation Consortium) of Japan, therefore the decisions made by these could be influenced collectively with conflicts of interests among different Companies from the Consortium. In this case, joining the Consortium should be a good option (there are already foreign stakeholders).
- It is important to identify the projects with **well-established roadmaps**, for instance, in the case of Euglena in association with ANA (aero lines Company) for producing jet fuel. This roadmap tends to follow a fixed number of stages with well-defined deadlines; therefore trying to join this kind of project should be more complicated.
- In most cases in Japan, it is not possible to directly approach a Company by simply sending an email to the Executives; therefore it is necessary a contact as nexus to be introduced to the Company.

4.3. RECOMMENDATIONS FOR EU COMPANIES

This section depicts recommendations for the Microalgae-related sector and subsectors.

- Having previously experience with EU Consortiums or projects should be an extra.
- Awards and international ISO certifications have very high importance in Japanese society.

Microalgae

- Should use the best innovative technologies for Microalgae harvesting as well as using the right strain for producing a specific biomass-based product or one that could be more resistant to contamination or temperatures, in order to maximize the microalgal production at the lowest cost possible.
- Since the technologies for wastewater treatment using Microalgae is still in continuous development (not being mature yet), EU Companies could take advantage of this need and participate by providing their expertise.
- Policulture (using various Microalgae strains at the same time) creates a much higher level of complication than using monoculture (just one), but it has much better results in biomass production. Therefore, expertise in policulture of Microalgae should bring up the interest from the Japanese side.
- There are numerous concluded EU projects that obtained valuable R&D outcomes (mature technologies, conclusions, methodologies, etc.) which were tested in the EU that could be also validated in Japan.

Biomass-based products

- Using advanced techniques to develop the industrial process (HTL, process to dry Microalgae, extraction...) may raise awareness from the Japanese side.
- Due to the high dependency on fossil oil imports, it is important to reduce this dependency in more sustainable forms; therefore it is necessary to reach an elevated level of production of bio-fuel and jet-fuel in order to catch the attention of the Japanese markets to become a possible provider of technologies in order to accelerate a transition to greener energy.

Wastewater treatment

- One of the highest potential opportunities is related to the creation of new business model for **nutrient recovery** (such as phosphorus), as it was (for instance) highlighted in the Horizon 2020 topic titled *"Water in the context of the circular economy"* of this year and for 2017.

- Wastewater treatment using Microalgae is very relevant when harvesting Microalgae, due to using wastewater instead of nutrients which can save up to 75% of the investment, while the purified water is returned back for human consumption.

5. CONCLUSIONS

Next SWOT diagram illustrates an overview of the Industry of Microalgae in Japan.

	STRENGTHS	***WEAKNESSES***
INTERNAL	- Helps to tackle the huge dependency on fossil fuel imports, using bio-fuel - Opening new markets of foods, feeds, energy, numerous chemicals, etc. - Environmental impacts: CO_2 emissions reduction and renewable source - Continuous development of the AIIC - Top world-class experts and R&D	- Difficult necessary involvement of various Industries on the biomass value chain - Cooperation between the AIIC members and non-members could be improved - Barriers for developing plants - Bio-fuels production still costly and not at large scale until approximately 2020 - No specific policies on Circular Economy
	OPPORTUNITIES	***THREATS***
EXTERNAL	- Funding for joint EU-Japan projects - EU R&D technologies can complement the weaknesses of the Japanese side - Global environmental business - Approach with mature EU projects - Newest trends on Circular Economy	- Volatility of the prices of fossil fuels - Modification of governmental policies - Acceptance by the society is still unclear - Questioning the fuels/foods/feeds and sustainability of biomass production - Fast implementation of alternative techs.

Figure 112. *SWOT Diagram of the Industry of Microalgae in Japan.*

It is possible to build a set of conclusions based on the previous SWOT:

Strengths

- ✓ There is now hope for a future in Japan with large scale production of domestic Microalgal-based bio-fuels. While the technologies developed are being improved the roadmap for bio-fuel production is being reduced more and more approximately to the period between 2018-2020. What can be relatively ensured is the implementation in the civil aviation market with due to pioneering initiatives such as the born from the alliance between Euglena and ANA, for jet-fuel production by 2020.
- ✓ Microalgae are excellent for opening new markets of foods, feeds, energy, numerous chemicals, as well as protein sources for **aquaculture** because their amino acid profile is similar to that of fish meal.
- ✓ CO_2 emissions reduction is always in the agenda of the Japanese organizations (AIIC, University of Tsukuba, etc.) international organizations and pursued by world leaders. In this aspect microalgae have a very relevant role due to its outstanding capacity of absorption in comparison with regular trees. Therefore the environmental possibilities for tackling this issue become business opportunities worldwide.

- ✓ The AIIC is one of the engines that moves the whole sector of microalgae in Japan, due to its contribution, it is possible to continue enhancing the developments and socio-economic progress Japan at local, regional and national level.
- ✓ Japan still leading the R&D on microalgae with pioneer initiatives such as the plant for waste water treatment in the Fukushima area, which makes a robust candidate to become a partner with international Companies or Consortium to continue developing these cutting edge technologies on microalgae.

Weaknesses

- × After conducting several interviews it was noticeable that mutual collaborations between local or regional Companies are sometimes difficult due to the microalgae sector in Japan essentially requires synergies between so very different industries.
- × It seems that the AIIC Consortium is an ideal workplace where diverse Japanese Companies can make business smoothly, however international projects with EU Companies are almost non-existent (not in the case of American Companies).
- × The legal barriers (for instance) for developing a waste water plant is still too tedious to handle, taking long time for obtaining the required authorization of exploitation. This could be (presumably) even harder for foreign Companies.
- × Bio-fuels production still costly and not at large scale; for example, Japan's agriculture greatly depends on the fossil fuel, it is important to promote efficiency for energy demand and energy transition in rural areas especially:

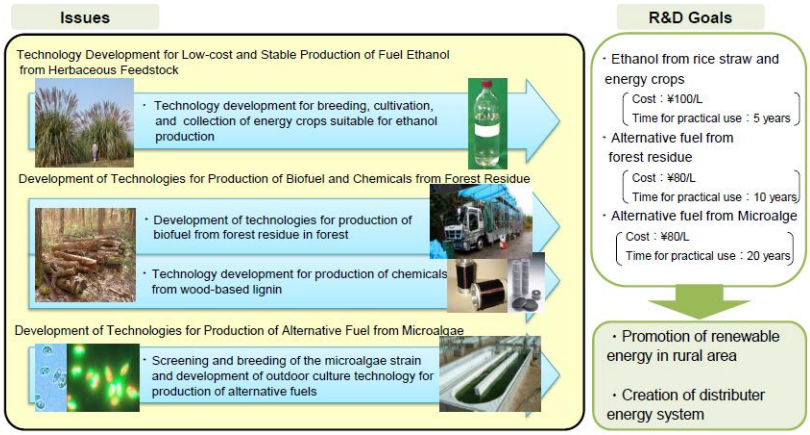


Figure 113. *R&D goals in rural areas.*

- × Circular Economy multiplies the possibilities of making business between Companies from very diverse sectors. This is for instance presented with initiatives like the waste water plant in the Fukushima area, however so far there is no specific plan for Circular Economy presented (or planned) in Japan.

Opportunities

- ✓ This report has mentioned the diverse possibilities of National funding from the Japanese stakeholders with the METI or MAFF, however the door is open also for International joint projects with Horizon 2020 as main funding programme that Japanese Companies can participate.
- ✓ The EU R&D sector of microalgae is also pioneer in the sector of microalgae as much as Japan with mature technologies and numerous funded projects and consortiums created. For this reason it should be a good complement for the Japanese SMES in order to tackle existing bottlenecks, such as the level of production or the cost of final products such as Microalgal bio-fuels.
- ✓ It is well known that reduction of CO2 emissions is a global goal. Therefore any assistance received in form of foreign investments in order to support the existing technologies should be accepted in the Japanese markets and vice-versa.
- ✓ There are diverse ongoing and finished EU projects on microalgae. These are able to provide a more or less mature "know-how" regarding problems to solve that without such collaboration may take longer to be solved from scratch.
- ✓ It is crucial for the correct socio-economic development of Japan to take seriously the business paradigm of Circular Economy more likewise the EU counterparts are doing already. For this purpose, it should be necessary to create specific plan promoted by the government, if possible including funding support and special mention to the microalgae sector.

Threats

- × To date it is not possible for Microalgal bio-fuels to become a competitor with the fossil fuels. However, due to the volatility of the prices of fossil fuels, it is not possible to predict if this difference will be greater or not in future.
- × So far the Japanese government have found appropriate to support the initiatives regarding microalgae, nevertheless the plans for every fiscal year change due to politic decisions and evolution of the markets, therefore this support could change positively or negatively in the future.
- × Japanese society seems to be positively involved in supporting the microalgae initiatives, however it seems that the microalgae sector is still unknown when compared with most of the typical sectors. This is not a matter of not having done the correct promotion; it is more a matter of the size of this very specific industry.
- × Probably the most important threat is the questioning of fuels/foods/feeds and the sustainability of biomass production. Although Companies are working against the clock, it is difficult to predict if such roadmaps will be accomplished.

- Advances in alternative sustainable technologies for producing biomass or renewables could decrease the interest or support in the Microalgal sector..

Future perspectives

1. A step from agriculture to algaeculture should be essential to tackle most of the world issues, such as to feed the (fast growth) global population, clean water access or the CO2 emissions reduction/global warming
2. Algae and biomass energy is probably the cleanest energy with essentially zero CO2 emission.
3. Therefore, algae, biomass and the energy system can significantly reduce CO2 emission and could solve the global warming problem.
4. Furthermore, algae and biomass energy can be obtained all over the world. This means that most nations in the world could have their own energy sources independently, which will greatly reduce international frictions.
5. The ABES will contribute to the eradication of environmental issues in the world in order to make the planet cleaner.
6. Algal breeding can increase from 10% to up to 10 times the biomass production in order to be “mass-produced”, similar to grains and horticultural crops.
7. Bio-imaging and “omics”. Genomes of microalgae have not been decoded in most species (omics). The microalgae irradiated with the heavy-ion beams should be selected and bred based on the quantitative data concerning their forms (bio-imaging).
8. Market cultivation (to expand algal biomass consumption) can be used to develop products across a number of markets including nutraceuticals, pharmaceuticals, aquaculture and renewable energy.
9. Standardization of processes and systems will be key to executing meaningful cultivation plants located in different areas.
10. From the technical point of view it will be necessary to (1) improve early detection of contaminants, (2) develop new strains to handle high salinity and (3) improve energy efficiency of downstream processing.
11. Carbon capture and utilization (CCU) will represent a major opportunity.
12. Policy support will be key.

13. The development of self-cloning technology is important to breed microalgae for large-scale outdoor cultivation. It is important to note that self-cloned strains are exempt in Japan from the restrictions imposed by the *Cartagena Protocol.*

14. **Waste water treatment** will be crucial with:

    ① New business models based on improving the water services and increasing public involvement.

    ② Reduction of water and energy consumption.

    ③ Interconnectivity between economic and social sectors inferring on citizen satisfaction with the water services.

    ④ New synergies between regional, national and international levels.

15. With the necessary initiatives and support Japan will become one of the most important countries in the algae industry.

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ANNEX 1: LIST OF MEMBERS OF THE ALGAE INDUSTRY INCUBATION CONSORTIUM (AIIC) OF JAPAN

Table 41 compiles the information from the members of the Algae Industry Incubation Consortium (AIIC) of Japan, to date, 93 stakeholders. It is important to note, this information will be also represented in a virtual map in the *Annex* :

Company	JGC Corporation
Person in charge	Nobuo Kakizaki
Short description	Promotes activities in diverse areas in order to attain a generation of green energy and clean energy development. The main target is to preserve the global environment
Phone number	045-682-8289
Email	kakizaki.nobuo@jgc.co.jp
Website	www.jgc.com
Location	220 0012, 2 Chome-3-1 Minatomirai, Nishi-ku, Yokohama-shi, Kanagawa-ken 220-0012
Company	Sanwa Agriculture, Forestry Co., Ltd.
Person in charge	Ryoji Shimamura
Short description	In association with the University of Tsukuba, it was possible to conduct joint research on the culture of Microalgae of freshwater (*Botryococcuas brauni*), being expected to be used as an alternative bio-fuel. Currently in development of technologies for the production of large amounts of *Lactococcus* strains
Phone number	048-769-9021
Email	shimamura@sanwanorin.co.jp
Website	www.sanwanorin.co.jp
Location	2-3-1, Minato Mirai, Nishi-ku, Yokohama 220-6001, Japan
Company	(Ltd.) Maruhishi bio engines
Person in charge	Hideo Sakuma
Short description	Contribution to the development of society through new valuable creation and biotechnology with culture devices for a variety of microorganisms, as well as equipment for concentration, purification, continuous centrifugal separation, filtration and membrane separation
Phone number	03-3866-6777
Email	sakumah17th@bemarubishi.co.jp
Website	www.bemarubishi.co.jp
Location	532-0003 Osaka Prefecture, Osaka, Yodogawa Ward, Miyahara, 2 Chome−1−17

Company	Kikkoman Corporation
Person in charge	Koji Hasegawa
Short description	Business model based mainly on soy sauce, foods, alcoholic drinks and various biochemical products
Phone number	04-7123-5555
Email	khasegawa@mail.kikkoman.co.jp
Website	www.kikkoman.co.jp
Location	550-0002 Osaka Prefecture, Osaka, Nishi Ward, Edobori, 1 Chome−9−1
Company	Idemitsu Kosan Co., Ltd.
Person in charge	Hiroto Matsumoto
Short description	Business lines focused on microbial pesticides, soil amendments, agents for environment, functional animal feeds and agri-bio business
Phone number	03-3213-9339
Email	hiroto.matsumoto@idemitsu.com
Website	www.idemitsu.com
Location	国際ビル, 3 Chome-1-1 Marunouchi, 千代田区 Chiyoda-ku, Tōkyō-to 100-0005
Company	(Ltd.) Cosmos Technical Center
Person in charge	Satoru Hashimoto
Short description	Main field is based on cosmetics, pharmaceuticals, foods, detergents, ink and other industrial products, with the target to contribute to a sustainable society in the future
Phone number	03-3966-7755
Email	hashimoto@ns-cosmos.co.jp
Website	www.ns-cosmos.co.jp
Location	174-0046 東京都板橋区蓮根 3-24-3
Company	Hamamatsu Photonics Co., Ltd.
Person in charge	Esta alta Naomube
Short description	Manufacturer of optical sensors (including photomultiplier tubes), electric light sources and other optical devices and their applied instruments
Phone number	053-584-0250
Email	takamoto@crl.hpk.co.jp
Website	www.hamamatsu.com
Location	105-0001 Tokyo, Minato, Toranomon, 3 Chome−8−21
Company	Kobelco Eco-Solutions Co., Ltd.
Person in charge	Akira Akashi
Short description	Develops a variety of ecologically-friendly solutions such as: industrial parks, water purification plants, final waste disposal sites, wastewater treatment plant, waste treatment plant,

	recycling plant, ironworks and chemical factory
Phone number	078-992-6957
Email	a.akashi@kobelco-eco.co.jp
Website	www.kobelco-eco.co.jp
Location	651-0072 Hyogo Prefecture, Kobe, Chuo Ward, Wakinohamacho, 1 Chome−4−78
Company	Taisei Co., Ltd.
Person in charge	Masahiro Okuda
Short description	Develops technologies from organic waste water treatment in food factories, machinery processing plant, inorganic wastewater treatment such as electronic device factories. On-site composting technology of harvesting material, garbage recycling technology. It was introduce the German advanced bio-technology *"livestock manure methane fermentation system"* in order to achieve the recycling of organic waste
Phone number	03-5381-5102
Email	m-okuda@msd.taisei.co.jp
Website	www.taisei.co.jp
Location	650-0011 Hyōgo-ken, Kōbe-shi, Chūō-ku, Shimoyamatedōri, 3 Chome−12−1
Company	JFE Engineering Co., Ltd.
Person in charge	Takeshi Tsuji
Short description	Business based on biomass: material handling for biomass boiler, circulating fluidized bed (CFB) boiler and waste heat recovery boiler as well as water treatment solutions
Phone number	045-505-7852
Email	tsuji-takeshi@jfe-eng.co.jp
Website	www.jfe-eng.co.jp
Location	760-0019 Kagawa-ken, Takamatsu-shi, Sunport, 2−1
Company	Kurita Water Industries Ltd.
Person in charge	Kaku AkiraKen
Short description	Provides chemicals, water treatment plants and chemical treatment processes
Phone number	0280-54-1578
Email	hirokazu.kaku@kurita.co.jp
Website	www.kurita.co.jp
Location	10-1,Nakano 4-Chome, Nakano-ku, Tokyo 164-0001
Company	DENSO
Person in charge	Hiroki Kuriyama
Short description	The Company is known for making almost all parts of automotive vehicles, such as engine components diesel, petrol, components of hybrid vehicles, systems, climate control, instrument clusters,

	airbags and other safety systems
Phone number	0566-55-0305
Email	hiroki_kuriyama@denso.co.jp
Website	www.denso.co.jp
Location	108-0075 Tokyo, Minato, 港南 2 丁目 16−2
Company	Tomoe Engineering Co., Ltd.
Person in charge	Tatsuji Natori
Short description	Develops various industrial products: decanter centrifuge, centrifuge, rotation pressure dehydrator and carbonization equipment
Phone number	03-5435-6526
Email	natori@me.tomo-e.co.jp
Website	www.tomo-e.co.jp
Location	Osaki Bright Core, 5-15 Kitashinagawa 5-chome, Shinagawa-ku, Tokyo 141-0001, Japan
Company	Kao Corporation
Person in charge	Tanaka NaruKei
Short description	The Company mainly has the Business Model based on a cosmetics and chemicals
Phone number	073-426-5045
Email	tanaka.shigeyoshi@kao.co.jp
Website	www.kao.co.jp
Location	131-8501 東京都墨田区文花 2-1-3
Company	Algae Biotechnologies Co., Ltd.
Person in charge	Shinji Chino
Short description	The Company aims to break away from dependence on oil by leveraging the power of Microalgae. The production of these algae-derived products, done in conjunction with the University of Tsukuba, obtaining functional foods, raw materials, cosmetics, chemicals and bio-fuels
Phone number	029-879-7119
Email	skayano@sobio.co.jp
Website	www.sobio.co.jp
Location	305-0821 茨城県つくば市春日 4-1-9
Company	(Ltd.) Kumagai Gumi Co., Ltd.
Person in charge	Nobuyuki Kadokura
Short description	Is a Company of construction, aiming to build a rich relationship between the people and the environment by refining the technology, creating a rich human environment
Phone number	029-847-7505
Email	nkadokur@ku.kumagaigumi.co.jp

Website	www.kumagaigumi.co.jp
Location	162-8557 Shinjuku-ku, Tokyo
Company	Usuikokusaisangyo (Ltd.)
Person in charge	Koichi Hayashi
Short description	Has their Business Model in the automotive sector with the development of brake tube, fuel tube, various processing tube such as power steering tube, single winding steel pipe, fuel injection pipe, high-pressure fuel pipe for gasoline direct-injection engine, steel pipe delivery pipe and plastic cooling fan (amongst other products)
Phone number	055-981-6007
Email	KoichiHayashi@usui.co.jp
Website	www.usui.co.jp
Location	411-8610 静岡県駿東郡清水町長沢 131-2
Company	Tsukuba City
Person in charge	Togo Kosaki
Short description	Tsukuba City
Phone number	029-883-1111
Email	pln110@info.tsukuba.ibaraki.jp
Website	www.city.tsukuba.ibaraki.jp
Location	Ibaraki 305-8555 Japan
Company	Ltd. Toyota Central R&D Labs.
Person in charge	Susumu Nagano
Short description	It is an R&D laboratory of Toyota which cooperates with the Toyota Technological Institute (TTI)
Phone number	0561-71-7120
Email	e0720@mosk.tytlabs.co.jp
Website	www.tytlabs.co.jp
Location	横道 41−1, Nagakute, Aichi Prefecture 480-1131
Company	Hitachi Construction Machinery Co., Ltd.
Person in charge	Megumi Murata
Short description	Company based on construction machinery
Phone number	029-832-7189
Email	m.murata.mb@hitachi-kenki.com
Website	www.hitachi-kenki.co.jp
Location	300-2646 Ibaraki-ken, Tsukuba-shi, Midorigahara, 4 Chome−12
Company	Toray Industries, Inc.
Person in charge	Saburo Sone
Short description	Develops innovative lightweight materials and energy-saving processes, as well as reducing greenhouse gas (GHG) emissions, non-petrochemical raw materials research and development of the

	past by technology fusion, resources and energy issues in green innovation
Phone number	03-3245-5484
Email	saburo_sone@nts.toray.co.jp
Website	www.toray.co.jp
Location	103-0022 Tokyo, Chuo, Nihonbashimuromachi, 2−1−1
Company	(Ltd.) Bethel
Person in charge	Akatsuki Kobayashi
Short description	The Company develops plastics and thermal devices, specializing in medical and nursing high-value-added products
Phone number	0299-23-7411
Email	s-kobayashi@mail.bethel.co.jp
Website	www.bethel.co.jp
Location	315-0021 Ibaraki Prefecture, Ishioka, Aragane, 3−11
Company	Nippon Steel Sumikin Engineering Co., Ltd.
Person in charge	Tsuyoshi Takahata
Short description	The Company is the world's 2nd largest steel producer by volume as of 2014. It develops the following technologies: sea biological and sludge incinerator, PCB waste treatment facilities, waste plastic processing equipment, waste tire carbonization equipment, soil and groundwater contamination investigation and cleanup, waste disposal operation and maintenance of equipment
Phone number	03-6665-2839
Email	takabatake.tsuyoshi@eng.nssmc.com
Website	www.eng.nssmc.com
Location	980-0811 Miyagi Prefecture, Sendai, Aoba Ward, Ichibancho, 3 Chome−7−1
Company	Mazda Motor Corporation
Person in charge	Sānjiǎo Masanori
Short description	Mazda Motor Corporation is an automobile manufacturer headquartered in Hiroshima, and plants in the cities of Hiroshima, Nishinoura and Nakanoseki
Phone number	045-461-1692
Email	misumi.m@mazda.co.jp
Website	www.mazda.co.jp
Location	3-1 Shinchi, Fuchū, Aki, Hiroshima, Japan
Company	(Ltd.) LIXIL
Person in charge	Seiji Shinkai
Short description	Lixil Group is a Japanese manufacturer of building materials and housing equipment with headquarters in Tokyo
Phone number	0569-44-0397
Email	shink@lixil.co.jp

Website	www.lixil.co.jp
Location	731-0113 Hiroshima Prefecture, Hiroshima, 安佐南区西原６丁目１１－８
Company	Hitachi Zosen Corp.
Person in charge	Hiroshi Sasaki
Short description	Business lines: waste incineration, power generation facility, material recycling system, AOM (after-sales service, operation management, drug sales), long-term management business, methane fermentation system, water treatment, machinery, process equipment business and precision machinery business
Phone number	03-6404-0823
Email	sasaki_hiroshi@hitachizosen.co.jp
Website	www.hitachizosen.co.jp
Location	559-8559　大阪市住之江区南港北 1 丁目 7 番 89 号
Company	Jay Phoenix Research Co., Ltd.
Person in charge	Osamu Miyashita
Short description	Centered on the research and analysis of corporate value improvement over the medium to long term. Analysis of the business structure and Business Model analysis of management philosophy and governance
Phone number	03-5532-7647
Email	miyashita@j-phoenix.com
Website	www.j-phoenix.com
Location	東京都港区西新橋 1-2-9 日比谷セントラルビル 14 階 〒105-0003
Company	Niigata Prefecture
Person in charge	Wataru Abe
Short description	Niigata prefecture
Phone number	025-280-5289
Email	abe.wataru@pref.niigata.lg.jp
Website	www.pref.niigata.lg.jp
Location	950-8570　新潟市中央区新光町 4 番地 1
Company	Canon Electronics Co., Ltd.
Person in charge	Michiyo Hashizume
Short description	Business model mainly oriented to electronic products such as digital cameras, ATM and small components to be key indispensable for various devices (for example, automatic ticket gate of the stations)
Phone number	0494-21-1620
Email	hashizume.michiyo@canon-elec.co.jp
Website	www.canon-elec.co.jp

Location	3-5-10,Shibakoen,Minato-ku,Tokyo 105-0011,Japan
Company	Sannomiya Building Maintenance Co., Ltd.
Person in charge	Sannomiya Takashi
Short description	Business in a wide range from a whole building facility management, regular replacement of garbage, repair works and interior construction of outer walls
Phone number	06-6343-5524
Email	n.sangu@sangu-bm.co.jp
Website	www.sangu-bm.co.jp
Location	530-0001 Osaka Prefecture, Osaka, 梅田 3-4-5, 毎日インテシオ 4 階
Company	(Ltd.) alpha INTEC
Person in charge	Kajiya YanagiIchiro
Short description	N/A
Phone number	048-872-6313
Email	kajitani@alfaintec.co.jp
Website	www.alfaintec.co.jp
Location	8-39-2, Aoi-Ku Shizuoka, 420-0943
Company	DIC (Ltd.)
Person in charge	Sogang Haruo
Short description	Manufacture and sale of printing ink as an organic pigment which is the basic material, as well as expanding the business of synthetic resin, related to the world top the core technology for processing, automotive, consumer electronics, food and housing
Phone number	043-498-0878
Email	haruo-nishie@ma.dic.co.jp
Website	www.dic.co.jp
Location	103-0027 東京都中央区, 日本橋 3-7-20, DIC ビル B1F
Company	Komatsu Development Industry Co., Ltd.
Person in charge	Hiroki Urata
Short description	Business basis: design, manufacture and analysis of automotive parts of packaging materials, plant construction and maintenance, through our business, such as temporary staffing, while contributing to the prosperity of tomorrow of people and society
Phone number	0566-21-5271
Email	urata-hiroki@komatsu-kaihatsu.co.jp
Website	www.komatsu-kaihatsu.co.jp
Location	444-0226, 愛知県岡崎市中島町字紅蓮 24
Company	Water ing (Ltd.)
Person in charge	Masahide Suzuki
Short description	This Company focuses on diverse lines of research related to water:

	clean water and industrial water supply equipment, industrial water treatment, but also on equipment for production of biomass
Phone number	050-3482-8235
Email	suzuki.masahide@swing-w.com
Website	www.swing-w.com
Location	108-8470 東京都港区港南 1-7-18
Company	Wago Engineering Co., Ltd.
Person in charge	Susumu Nakamura
Short description	Construction consulting Company specializing locally (Chiba) with business on facilities maintenance
Phone number	043-290-8701
Email	nakamura@wago-eng.co.jp
Website	www.wago-eng.co.jp
Location	251-0002 Kanagawa Prefecture, Fujisawa, Daigiri, 1 Chome−14−6
Company	Scan Mae blanking Japan Co., Ltd.
Person in charge	Ikuyo Ono
Short description	Aiming to lead the world in mass culture technology of micro algae, through a joint venture with Israeli engineering Company, commercial production of micro algae in Japan, processing and sales
Phone number	022-398-3827
Email	admin@smabe.co.jp
Website	www.smabe.co.jp
Location	986-2527 宮城県石巻市十八成浜清崎山 1-21
Company	Nomura Securities Co., Ltd.
Person in charge	Takanori Hamada
Short description	Japanese financial holding Company and a principal member of the Nomura Group. provides investment, financing and related services to individual, institutional and government customers on a global basis
Phone number	03-3274-0945
Email	hamada-095w@jp.nomura.com
Website	www.nomura.com
Location	1-9-1, Nihonbashi, Chuo, Tokyo, Japan
Company	Ibaraki Prefecture
Person in charge	Iizuka Shunsuke
Short description	Ibaraki Prefecture
Phone number	029-301-2529
Email	s.iizuka@pref.ibaraki.lg.jp
Website	www.pref.ibaraki.lg.jp
Location	310-8555　水戸市笠原町 978 番 6

Company	Sanyu Plant Service Co., Ltd.
Person in charge	Susumu Arai
Short description	Re-use of the collection, transportation and disposal business various waste, facility design, production and sales
Phone number	042-773-3611
Email	s.arai@g-sanyu.co.jp
Website	www.g-sanyu.co.jp
Location	252-0132 Kanagawa Prefecture, Sagamihara, Midori Ward, Hashimotodai, 1 Chome−8−21
Company	Ltd. Higashimaru
Person in charge	Masami Shimono
Short description	Noodle Company and mixed feeds for aquaculture
Phone number	0996-33-5412
Email	Shimono@k-higashimaru.co.jp
Website	www.k-higashimaru.co.jp
Location	143-0016 Tokyo, Ota, Omorikita, 2 Chome−4−18
Company	Sinanen (Ltd.)
Person in charge	Yoichi Nishimura
Short description	Petroleum products operating with different brands such as Cosmo Oil and Idemitsu Kosan Co.
Phone number	03-5470-7133
Email	yoichi-nishimura@ml1.sinanen.co.jp
Website	www.sinanen.com
Location	105-8525　東京都港区海岸一丁目 4 番 22 号
Company	Takasago Thermal Engineering Co., Ltd.
Person in charge	Masayuki Tanino
Short description	Air conditioning technology providing comprehensive system engineering
Phone number	046-248-2752
Email	Masayuki_Tanino@tte-net.co.jp
Website	www.tte-net.co.jp
Location	330-0843 Saitama Prefecture, Saitama, 大宮区, 吉敷町１丁目７５ー１
Company	Honda Engineering Co., Ltd.
Person in charge	Fukushima Nozomi
Short description	Honda Engineering Co., Ltd. manufactures and sells machine tools, equipment, and production techniques. The Company was founded in 1970 and is based in Hagamachi, Japan. Honda Engineering Co., Ltd. operates as a subsidiary of Honda Motor Co., Ltd.
Phone number	028-677-6946
Email	nozomi_fukushima@hondaeg.co.jp

Website	www.honda.co.jp/EG
Location	Tochigi Prefecture, Haga-gun Haga-machi Hagadai 6-1
Company	Nihon Suido Consultants Co., Ltd.
Person in charge	Noboru Takahashi
Short description	Nihon Suido Consultants Co., Ltd. focuses on water supply and sewerage field construction consultant Company
Phone number	03-5323-6305
Email	takahasi_n@nissuicon.co.jp
Website	www.nissuicon.co.jp
Location	901-0154 Okinawa Prefecture, Naha, Akamine, 1 Chome−4−1
Company	Tsukishima Kikai Co., Ltd.
Person in charge	Mayumi Morita
Short description	Water Environmental Business (Water Purification and Sewage Business). Biomass utilization technology, biomass conversion technology and ethanol production
Phone number	03-5560-6513
Email	mayumi_morita@tsk-g.co.jp
Website	www.tsk-g.co.jp
Location	3-5-1, Harumi, Chuo-ku, Tokyo
Company	Management Organization for Standardization (Ltd.)
Person in charge	Satoru Miyazawa
Short description	Supports through the use of various public support measures such as subsidies and funding which will be available as a certified management innovation such as aid agencies of the Ministry of Economy, Trade and Industry (certified support organizations)
Phone number	024-523-0002
Email	miyazawa@keieihyoujun.co.jp
Website	www.keieihyoujun.co.jp
Location	207-8515 tokyo higashiyamato sakuragaoka 2-137-5
Company	Sumitomo Chemical Co., Ltd.
Person in charge	Chizu Sekine
Short description	Petrochemical sector, energy and functional materials sectors
Phone number	029-864-4160
Email	sekine@sc.sumitomo-chem.co.jp
Website	www.sumitomo-chem.co.jp
Location	104-8260 Tokyo, Chuo, Shinkawa, 2−27−1, 住友ツインビル東館
Company	Fujitsu Systems West
Person in charge	Yoko Nishikawa
Short description	Consulting services, system integration services, cloud computing, outsourcing services and solution products
Phone number	06-6920-4227

Email	nishikawa.nobu@jp.fujitsu.com
Website	www.jp.fujitsu.com
Location	108-0075 Tokyo, 港区 Konan, 1−2−70, Shinagawa season Terrace
Company	Ltd. Venture Lab
Person in charge	Yamanaka YuiYoshi
Short description	The Company is active in the sectors of industrial petrochemicals, plastics production and agrochemicals
Phone number	03-6264-1861
Email	yamanaka-t@venturelabo.co.jp
Website	www.venturelabo.co.jp
Location	104-0045 東京都中央区築地 6-17-4　築地パークビル 4F
Company	Mitsubishi Kakoki Kaisha, Ltd. (stock)
Person in charge	Akira Saegusa
Short description	Manufacture of machinery involved in the chemical industry. Hydrogen generation
Phone number	044-333-5366
Email	saigusa@kakoki.co.jp
Website	www.kakoki.co.jp
Location	210-8560 川崎市川崎区大川町 2 番 1 号
Company	Showa Environment System Co., Ltd.
Person in charge	Kenichi Fukushima
Short description	Business model is set by two main areas: (1) providing clean drinking water and (2) collecting and treating waste water / sewerage water
Phone number	03-5765-1330
Email	kenichi.fukushima@sksl.co.jp
Website	www.veolia.jp/ja
Location	108-0022 東京都港区海岸 3-20-20　ヨコソーレインボータワー
Company	(Ltd.) Orca vision
Person in charge	Taiga Satoshi
Short description	N/A
Phone number	03-5919-0674
Email	o-kodo@orcavision.co.jp
Website	www.orcavision.co.jp
Location	160-0015 Tōkyō-to, Shinjuku-ku, Daikyōchō, 22−1, HAKUYOH ビル 8F
Company	(Ltd.) Sousou Environmental Improvement Center
Person in charge	Mitsumasa Sato
Short description	N/A
Phone number	0244-24-4811

Email	ss-ksc@abelia.ocn.co.jp
Website	www.ocn.co.jp
Location	879-7761 大分県大分市大字中戸次 4571-1 2F
Company	Sendai city
Person in charge	Hiroshi Kimu
Short description	Sendai city
Phone number	022-214-8467
Email	hiroshi_kon@city.sendai.jp
Website	www.city.sendai.jp
Location	980-8671　宮城県仙台市青葉区国分町 3 丁目 7-1
Company	Co., Ltd. Kureha
Person in charge	Akio Takehara
Short description	Produces household goods, industrial chemicals, synthetic resin, pharmaceuticals, agricultural chemicals as a chemical manufacturer, as well as *"krestin"*, an anti-cancer agent
Phone number	0246-63-5111
Email	takehara-a@kureha.co.jp
Website	www.kureha.co.jp
Location	103-0007 Tokyo, Chuo, Nihonbashihamacho, 3 Chome−3−2
Company	Japan Filter Co., Ltd.
Person in charge	Wada Soichi
Short description	Main business lines related to pure & ultrapure water treatment systems, wastewater recovery, precision filter, plastic cartridge filters, hyper-tonic magnetic drive pumps, metering pumps, concentration & refinement, metal recovery, concentration, oxidation, reduction and neutralization systems
Phone number	0238-28-1751
Email	hirokazu.wada@nihon-filter.co.jp
Website	www.nihon-filter.co.jp
Location	2107-3, Kamiyabe-cho, 245-0053, Japan
Company	Mountain Techno Innovate
Person in charge	Takafumi Yamauchi
Short description	Company specialized in manufacturing of 3D models at low-cost
Phone number	0296-33-5943
Email	sp@yamatechno.com
Website	www.yamatechno.com
Location	307-0021　茨城県結城市上山川 5038
Company	(Ltd.) Air, Inc.
Person in charge	Hiroyuki Sasao
Short description	Specialized in design, construction, and administration (including the manufacture, process, sales and imports/exports of peripheral

	equipment) of: freezing facilities, sanitary facilities, fire and disaster protection system, as well as waste, electric and instrumentation facilities
Phone number	046-281-3661
Email	hiro-sasao@taikisha.co.jp
Website	www.taikisha.co.jp
Location	Sumitomo Fudosan Shinjuku Grand Tower, 8-17-1, Nishi-Shinjuku Shinjuku-ku, Tokyo 160-6129, Japan
Company	Oriental screen Industrial Co., Ltd.
Person in charge	Osamu Ishii
Short description	Devices for Public sewage, community sewage, processing, drainage of chemical plants, waste water treatment of the agricultural and livestock field, waste water treatment of agricultural and fishery production processing plants, processed products of the classification and dehydration
Phone number	03-3567-2488
Email	ishii@toyoscreen.co.jp
Website	www.toyoscreen.co.jp
Location	2-10-6 kozen ikaruga-cho 636-0103
Company	(Ltd.) J-Oil Mills
Person in charge	Yosuke Isobe
Short description	Business lines based on basic oil, olive oil, sesame oil and margarine oil
Phone number	03-5148-7155
Email	yosuke.isobe@j-oil.com
Website	www.j-oil.com
Location	104-0044 東京都中央区明石町８番１号 聖路加タワー17F～19F
Company	Fujitsu Ltd.
Person in charge	Norio Hiraga
Short description	Japanese multinational on information technology equipment and services. Company headquartered in Tokyo, Japan. In 2015, it was the world's fourth-largest IT services provider measured by IT services revenue
Phone number	03-6252-2549
Email	n.hiraga@jp.fujitsu.com
Website	www.fujitsu.com/jp/
Location	108-0075 Tōkyō-to, Minato-ku, 港区 Kōnan, 1 Chome−1−2−70, Shinagawa season Terrace
Company	Nippon Filcon Co., Ltd. (stock)
Person in charge	Mr. Ohara
Short description	Business lines are industrial filters, electronic components and environment-related (water treatment business)

Phone number	042-377-3472
Email	k-obara@filcon.co.jp
Website	www.filcon.co.jp
Location	206-8577 東京都稲城市大丸 2220
Company	(Ltd.) Priss
Person in charge	Kato Shinsuke
Short description	Business is oriented to chemical equipment and device, scientific instruments and equipment, precision cleaning systems, ultrasonic generator, test and contract processing and measurement
Phone number	03-3839-4540
Email	s-kato@preci.co.jp
Website	www.preci.co.jp
Location	110-0016　東京都台東区台東 2-11-6
Company	(Ltd.) Waiandokei planning
Person in charge	Shigekatsu Endo
Short description	N/A
Phone number	043-279-4262
Email	endo@kni.biglobe.ne.jp
Website	www.kni.biglobe.ne.jp
Location	261-0004 Chiba Prefecture, Chiba, Mihama Ward, Takasu, 3 Chome−14−1, 和紅ビル 5F
Company	(Ltd.) Fukushima green farm
Person in charge	Kawarada AkiraHiroshi
Short description	N/A
Phone number	024-563-3788
Email	akihiro.kawarada@gmail.com
Website	N/A
Location	960-8055　福島県福島市野田町字道端 53
Company	Toppan Printing Co., Ltd.
Person in charge	Tatsumi IsaoIchiro
Short description	The Company provides total support for information management in the IT era with its leading-edge security technology, as well as marketing and content creating business
Phone number	03-3835-5657
Email	yoichiro.tatsumi@toppan.co.jp
Website	www.toppan.co.jp
Location	110-0016 Tokyo, Taito, 1−5−1
Company	Mitsubishi Gas Chemical Co., Ltd.
Person in charge	Tomoaki Kirino
Short description	Mitsubishi Gas Chemical Company, Inc. is a Japanese Company. It is a member of the Mitsubishi UFJ Financial Group (MUFJ) keiretsu

Phone number	03-3627-9666
Email	tomoaki-kirino@mgc.co.jp
Website	www.mgc.co.jp
Location	100-0005 Tōkyō-to, Chiyoda-ku, Marunouchi, 2 Chome−5−2
Company	Taiyo Oil Co., Ltd.
Person in charge	Takeshi Mori
Short description	Oil import-export business, refining and sales business of benzene, production of petrochemical basic products, processing and exploration of hydrocarbons such as natural gas
Phone number	03-5521-9726
Email	tk_mori@mail.taiyooil.co.jp
Website	www.taiyooil.net
Location	Hibiya Kokusai Bldg., 2-2-3 Tokyo 100-0011
Company	Helix Co., Ltd.
Person in charge	Imaizumi YoshiTadashi
Short description	Business lines focused on iron, steel, automotive, electronics, semiconductor, rubber, tires and environment
Phone number	092-472-7311
Email	imaizumi@rix.co.jp
Website	www.rix.co.jp
Location	812-8672 福岡県福岡市博多区山王 1-15-15
Individual member	(Germany), National Institute for Environmental Studies
Person in charge	Nobuyoshi Nakajima
Individual member	(Germany), National Institute for Environmental Studies river
Person in charge	land Masanobu
Individual member	University of Tsukuba
Person in charge	Shin Watanabe
Individual member	University of Tsukuba
Person in charge	Isao Inoue
Individual member	University of Tsukuba
Person in charge	Yoshihiro Shiraiwa
Individual member	Tokyo Institute of Technology
Person in charge	Kazuhiko Horioka
Individual member	University of Tsukuba
Person in charge	Suehiro MineMasashi
Individual member	(Germany) National Institute of Advanced Industrial Science and Technology
Person in charge	Yoshimura Yuji
Individual member	(Germany) Public Works Research Institute
Person in charge	Seiichiro Okamoto
Individual member	Chuo University

Person in charge	Shigeaki Harayama
Individual member	University of Tsukuba
Person in charge	Masaki Yoshida
Individual member	University of Tsukuba
Person in charge	Mr. Suzuki
Individual member	Konan University
Person in charge	Daisuke Honda
Individual member	University of Tsukuba
Person in charge	Kenichiro Ishida
Individual member	Senshu University
Person in charge	Hiroshi Sasaki Ishinomaki
Individual member	University KoRika
Person in charge	Nakajima Chubu
Individual member	Minamikyushudaigaku
Person in charge	Hideo Toyama
Individual member	University of Tsukuba
Person in charge	Mitsutoshi Nakajima
Individual member	Konan Women's
Person in charge	Mitsue Kondo
Individual member	University of Tsukuba
Person in charge	Hideo Watanabe
Individual member	Tokai University
Person in charge	Zheng Kazu 翊
Individual member	Tohoku University
Person in charge	Tsuyoshi Nishitani
Individual member	EU-JAPAN CENTER
Person in charge	Manuel Herrador
Special member	Mr. Hirose

Table 41. *List of Japanese stakeholders of the AIIC.*

ANNEX 2: VIRTUAL MAP OF THE EU AND JAPANESE COMPANIES

The virtual map below compiles the 69 stakeholders (not individuals) that participate in the Algae Industry Incubation Consortium of Japan (AIIC), available online: http://www.eu-japan.eu/publications/list-69-stakeholders-members-aiic-algae-industry-incubation-consortium-japan.

Figure 114. *Virtual map of the Algae Industry Incubation Consortium of Japan (AIIC).*

Unlike the AIIC, there is no big group of stakeholders (like a consortium) on Microalgae and biomass products derived from biomass in Europe; however the 40 most relevant ones are illustrated in the following map, available online: http://www.eu-japan.eu/publications/most-relevant-eu-stakeholders-40-microalgae-and-products-derived-microalgal-biomass.

Figure 115. *Virtual map with relevant EU stakeholders on Microalgae and products derived from biomass.*

ANNEX 3: CONTACT POINTS OF EMBASSIES IN TOKYO

This list (Table 42) is the contact point for the Embassies of Tokyo and will provide the required information for European Companies and help them in accessing the Japanese market. The list is derived from the information of the Embassies website. The details of the contact points have been listed with permission in May 2016.

Country	For EU Companies intending to invest in Japan	For Japanese Companies intending to invest in Europe
Austria	Mr. Marcel RASINGER, Commercial Section - Head of Technology Affairs T: +81-3-3403-1777 tokio@advantageaustria.org	Embassy of Austria Commercial section T: 03-3796-1331 Aba-tokyo@advantageaustria.org
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Table 42. *Contact points of Embassies in Tokyo.*

ANNEX 4. A POTENTIAL CIRCULAR ECONOMY BUSINESS MODEL BASED ON MICROALGAE

Quick facts about Circular Economy (CE)[3]

- ✓ *"Shifting towards Circular Economy (CE) could add up to $1 trillion to the global economy by 2025 and create 100,000 new jobs within the next 5 years".*
- ✓ *"The European Union (EU) could benefit from an improved trade balance of £90 billion".*
- ✓ *"A subset of the EU manufacturing sector could realize net materials cost savings worth up to $630 billion per annum by 2025".*
- ✓ *"A recent survey of nearly 300 Companies across England, France and Belgium found almost 50% had not heard of the concept of Circular Economy".*
- ✓ *"90% of the raw materials used in manufacturing become waste before the product leaves the factory, while 80% of products made get thrown away within the first 6 months of their life".*

A.4.1. INTRODUCTION TO THE CIRCULAR ECONOMY IN THE EU AND JAPAN

The Circular Economy in the EU

According to European Union policies, the circular economy has been described as a wide concept engulfing various methods and products under its discretion. It's not just about the products, but also about the processes that are involved in its production, and its value addition and actions are together taken into consideration. Different policies have been formulated and bought into effect for several stages to ensure a circular economy. There are policies relating to circular economy mentioned in the documents such as the Resource-efficient Europe Flagship Initiative and also the 7th Environment Action Program [65].

The book *"Jobs for Tomorrow: The Potential for Substituting Manpower for Energy"* was published as a report which was created after studies were done on the circular economy, and how it will be able to create more job opportunities, save current resources, and ensure waste disposal and reutilization towards an economy that is competitive. This book was released in 1982 [66].

The EU has given utmost importance to waste management and several measures have been brought into action over the 30-year period. Legislature and different action plans were introduced to implement proper waste management and thus ensure that the resources were used efficiently. Keeping the different ecological problems in mind, the EU released a document by the name of *"Innovating for Sustainable Growth: A Bioeconomy*

[3] http://www.theguardian.com/sustainable-business/10-things-need-to-know-circular-economy

for Europe" [67] in the year 2012. The subjects that were addressed included issues like the surge in world population, the reduced availability of raw materials, and also the highly-discussed climatic changes in the world and how the concept of Bioeconomy could help solve these issues, along with providing advantages such as more jobs and increased competitiveness. Over the years, several improvements have been made in the sector of waste management in EU, but every progressive step has been met with different issues, the most prominent of which has been the inclusion of the EU waste management rules into the law system. The EU waste legislation was important but the transposition of the waste directives was not efficient.

The review results were taken into consideration in 2014 and the Circular Economy Package was published by the Commission. According to this, 6 waste-related previous guidelines were altered to increase synergy with the EU waste laws. Of the several measures in the legislation, the most prominent one has been the renewed recycling aims and there were strict measures against burning and landfills. The EU commission also released communication *"Towards a circular economy: A zero waste program for Europe"*. This included the approach of the Commission towards bringing better advanced waste policies into effect and creating a roadmap for an ecological economy. It also included notes on how these measures will increase business opportunities.

By the end of 2014, the Juncker commission had taken control and in its plan for the year 2015, they announced a change in the current Circular Economy Package and that it will be replaced by a set of new rules and policies with increased legal implications.

In December 2015, the European Commission launched another ambitious strategy called *"Closing the loop – An EU action plan for the Circular Economy".* This proposal includes a set of innovative policies, to name a few, (1) a new design of product processes; (2) changes in consumption patterns; (3) waste management, and (4) recycling of resources that were previously waste streams. In terms of Industry, biomass and biomass-based products will play an important role, and the previously mentioned Bioeconomy strategy of 2012 could be revised. Nonetheless, much broader and continued dedication from all levels of government is necessary, and the European Parliament and the Council should support this action plan to actively participate in its implementation, in close cooperation with Member States, regions and cities and all the relevant stakeholders.

The current Linear Economy (Figure 116) based on the *"take-make-dispose"* approach results in massive waste, which means 90% of the raw materials used in manufacturing become waste before the product leaves the factory while 80% of products made get thrown away within the first six months of their life. This, coupled with growing tensions around geopolitics and supply risk, is contributing to volatile commodity prices. A Circular Economy could help stabilize some of these issues by decoupling economic growth from resource consumption [68-69].

Figure 116. *The life cycle of the Linear Economy paradigm [70].*

The paradigm *"Circular Economy"* was first mentioned in 1976 by *Walter Stahel* and *Genevieve Reday-Mulvey* in a research report for the European Commission. It included a brief approach to an economy in loops and its impact on new job positions, to save resources, prevent the generation of waste and economic competitiveness [71]. There are numerous definitions for CE, but this one is well-accepted.

In a few words, what is a Circular Economy? (Figure 117) "*It is an alternative to a traditional linear economy (take, make, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life"* [72].

The concept was later raised by two British environmental economists in 1989 [73], and since around 2012 is receiving a greater attention due to a report titled *"Towards the Circular Economy: Economic and business rationale for an accelerated transition"* [74]. This paper was released by the Ellen McArthur Foundation [75], which is the world reference organization regarding Circular Economy.

Finally, in 2015 an article *"Definitive Guide to The Circular Economy"* [76] was published, which caused an impact that probably led the world leaders, Companies and organizations to implement this paradigm in forms of policies, initiatives and funding programmes that will be discussed extensively in the following sections.

The approach using Microalgae represents an innovative application that has been already proposed by various scholars, although is not widely known [13].

Figure 117 illustrates how the outputs of waste of a certain business should become an input stream that connects businesses. It also depicts how there are 2 major sections depending on the materials; ***biological*** and ***technical***, this is due to the nature of how each has a different role in this CE Business Model (for instance, technical components can be refurbished or rented, while biological goods can be consumed).

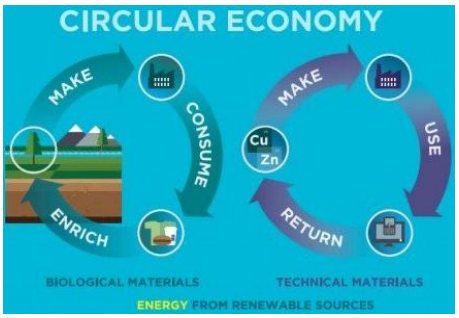

Figure 117. *The basic life cycle of the Circular Economy paradigm [70].*

This paradigm has relative complexity due to involving various interconnected stakeholders and concepts. It underpinned by **3 basic principles** and **5 characteristics** as depicted the Ellen MacArthur Foundation (Table 43) [77]:

1. *"Preservation and enhancement of the natural capital by controlling finite stocks and balancing renewable resource flows".*
2. *"Optimization of resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles".*
3. *"Foster system effectiveness by revealing and designing out negative externalities".*

1. *"Waste is designed out. Waste does not exist, and is designed by intention".*
2. *"Diversity helps to build strength".*
3. *"Renewable energy sources to stimulate the economy".*
4. *"Think in systems. Businesses, people or plants, are part of complex systems strongly linked to each other".*
5. *"Prices or other feedback mechanisms should reflect real costs".*

Table 43. *Basic principles and characteristics of Circular Economy [77].*

To date, there is growing interest *worldwide* for developing CE policies [78], strategies [79] and projects [80], with support coming from EU funding [81] programmes such as the *"Horizon 2020 Societal Challenge"* (Figure 118).

Figure 118. *Majority of requested H2020 funding in 2016 is related to CE [81].*

One of the reference institutions in Circular Economy – the Ellen Mc Arthur Foundation – highlighted in *"Towards the Circular Economy"* [82] the following 2 aspects about its business opportunities:

1. *"The circular economy takes its insights from living systems as these have proved adaptable and resilient, and model the 'waste is food' relationship very well. Waste does not exist when the biological components of a product are designed by intention to fit within a biological or technical materials cycle designed for remarketing, remanufacture, disassembly or repurposing. The biological materials are non-toxic and can easily be returned to the soil by composting or anaerobic digestion, and may also yield higher-value substances before decomposing".*

2. *"Instead of using a fossil feedstock, a bio-refinery will process organic material, such as agricultural residue and food waste into chemicals and fuels, using a range of physical, chemical, and biological technologies. From the organic feedstock, the bio-refinery will extract high-value chemicals, such as those for cosmetics or medical purposes. A well-designed refinery will not only extract these high-value components but also fuels like ethanol and methane and a set of 'platform molecules' such as succinic acid, which can be processed further into bio-plastics and many other products".*

It is important to note that **this applies to a much broader definition of CE;** however it is sufficient for introducing the next section and the objectives of this report. Nevertheless, this work will focus on the aforementioned major field of *biological materials* (Microalgae and biomass), not focusing on the CE applied to ***technological materials*** (an additional report should be needed for this case).

The Circular Economy in Japan

The Government of Japan has became recently well aware about the business opportunities of this up-to-the-minute paradigm. For instance, on the 20th of April 2016, the *"EU-Japan Business Round Table"* [83] highlighted the following recommendations regarding Circular Economy:

- *The BRT recognises the importance of measures to promote resource efficiency/circular (RE/CE) economies, and calls on the Authorities to cooperate further to promote such policies in a manner consistent with fostering economic growth.*

- *Although resource prices are declining in the short term, resource constraints are likely to inhibit economic growth over the medium to long term. This is why it is imperative to improve the efficiency of resource use. Actions to recycle or reuse for Circular Economy implemented by business sectors accelerate resource efficiency. On the other hand, the pursuit of resource efficiency through exceedingly*

regulatory approaches could inhibit economic growth. Therefore, it is desirable to choose an approach that will lead to economic growth, such as promotion through voluntary efforts by stakeholders.

- *Consumption and incentives: higher uptake of Circular Economy criteria in public procurement.*
- *Construction and demolition: give targets for the recovery of valuable resources and promote adequate waste management: 98% of all metals are recovered in Japan and more than 70% of glass is recycled in Europe.*
- *At overall, positive impression that Circular Economy involvement will create new business opportunities in both sides.*
- **EU-Japan proposals:**
  - Product design should be structured towards recyclability, high durability and easily reparable framework.
  - Materials used should have reduced effect on the environment.
  - Size and weight should be reduced.
  - Production process should not affect ecology.
  - The design should be able to be disassembled.
  - The product should have a long life and also should be recyclable.
- Although the new Circular Economy package [84] was proposed in Europe with many countries trying to adopt its various features, Japan still holds onto its own circular economy package that it proposed about 20 years ago [85].
- Since Japan has been experiencing shortage of its own natural resources, it has been developing different circular economy systems with respect to its own considerations for many years. As a result, these do not conform with the rules and guidelines of the circular economy packages being developed in Europe, such as the Horizon 2020 programme [86] (Figure 119) in which Japanese Companies can participate but not receive funding (in most of cases).

Figure 119. *Horizon 2020 programme logo.*

- It would require for efforts made in Japan by the public and private sectors, and panel discussions on matters such as the directions for cooperation between Japan and the EU, in order to revamp the existing strategies to be adapted to the newest trends similar to the ones that are already being adopted in the EU.
- Due to this huge interest worldwide in the Business Model, the necessary stakeholders are creating different business lines for increasing their profit, looking for collaborations overseas with those countries which already have the necessary infrastructure for cultivating Microalgae, producing bio-mass based products (such as bio-fuels or foods), for the recycling of biomass and for the purification of wastewater. Nevertheless, European Companies have higher expertise (to date) on this Business Model since it was promoted earlier and it is receiving bigger support and higher public funding.

A.4.2. A Potential Circular Economy Business Model Based on Microalgae

It is possible to implement a Sustainable Business Model of Circular Economy through Microalgae (Figure 120) which has 3 main actors: (1) Microalgae Company; (2) Biomass-based products Company and (3) waste/recycling Company improve their resource efficiency and financial attractiveness [87]. The participating Companies can now multiply their business opportunities by integrating input/output streams that were previously wasted, enhancing EU investments, and receiving support from the authorities with Environmental policies or funding [88].

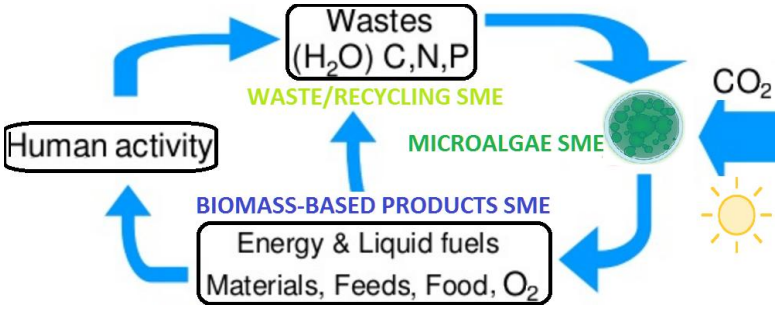

Figure 120. *Business Model of Circular Economy with interconnected Companies.*

By implementing this Business Model with Microalgae, it will be possible to tackle the upcoming essential problems*, namely:*

Issue	Solution
Sustainable Development	Circular Economy by definition is a Sustainable Business Model. Microalgae in particular provides a **renewable resource** for reserving resources for future generation without any harm [89].
Climate Change / Global Warming	Carbon Capture and Storage (CCS) techniques [90] study how to reduce the CO_2 emissions effectively. Microalgae provide a viable solution capable of capturing a considerable amount of CO_2 [91].
Clean water	A wide range of industries would benefit from the capability to treat wastewater (food, biotechnology, metal, paper, etc…). It is also a *"low-cost"* solution to sanitize water effectively [92].
Feed the world's fast growing population	30 times more productive than cereal crops, no need for agricultural land nor pesticides, just a little need of water [93].
Scarcity of resources	Provides fully renewable, recyclable or biodegradable resource inputs that underpin circular production and consumption systems. Enables a Company to eliminate material leakage and maximize the economic value of product return flows [94].
Energy	Microalgae Biomass is a renewable source of energy for producing a variety of bio-fuels that may work in conventional diesel motors, as well as for jet-fuel [95-96].

Table 44. *Summary of global issues and how can these be tackled through the implementation of the Business Model.*

It is important to note the multidimensional nature of Circular Economy through Microalgae (Figure 121) in order to tackle several of the mentioned shortcomings, for instance: *"the use of Microalgae in feed may reduce global warming rate" [97].*

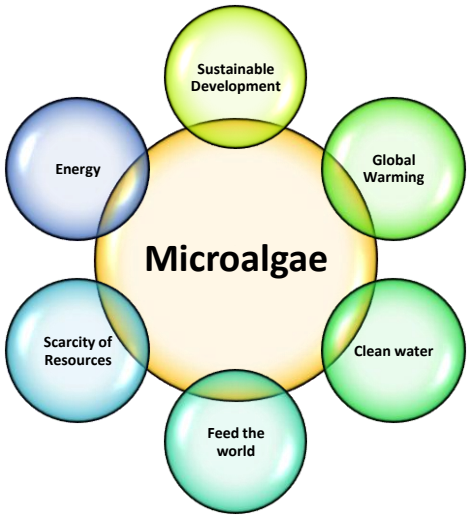

Figure 121. *How Microalgae can tackle simultaneously multidimensional issues.*

This section details the 3 necessary Company components for implementing this Business Model (Figure 122), this is (1) Microalgae Company; (2) Biomass-based products Company and (3) the Recycling Company. It is important to note this specific Industry has a relatively reduced size.

It is important to note that each stakeholder often plays various roles and follows diverse paths simultaneously, for instance, it is possible for a Microalgae Company to recycle wastewater and/or to produce a certain type of biomass-based product (Table 45).

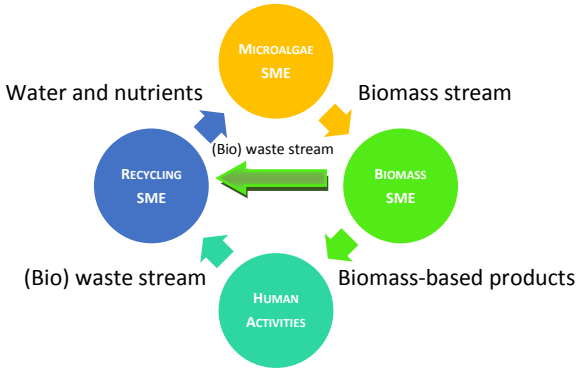

Figure 122. *Life cycle of the Business Model of Circular Economy through Microalgae with diverse paths.*

Company stakeholder	Activities
Microalgae	✓ Absorbs CO_2 ✓ Produces biomass ✓ Purifies wastewater ✓ Biomass-based products
Biomass-based products	✓ Bio-fuels ✓ Foods/feeds ✓ Other chemicals
Recycling	✓ Purifies wastewater ✓ Recycles biomass-based products to provide nutrients for Microalgae

Table 45. *Stakeholder list and their activities.*

The following example (Figure 123) helps to illustrate one of the possible applications of this Business Model. First, Microalgae are produced in renewable forms with (1) sunlight; (2) the CO_2 emissions that are being absorbed, and (3) wastewater. Second, the treated wastewater is reintroduced, and the biomass (dewatered algae) is produced. Finally, this biomass stream is transformed into bio-fuels and fertilizers products.

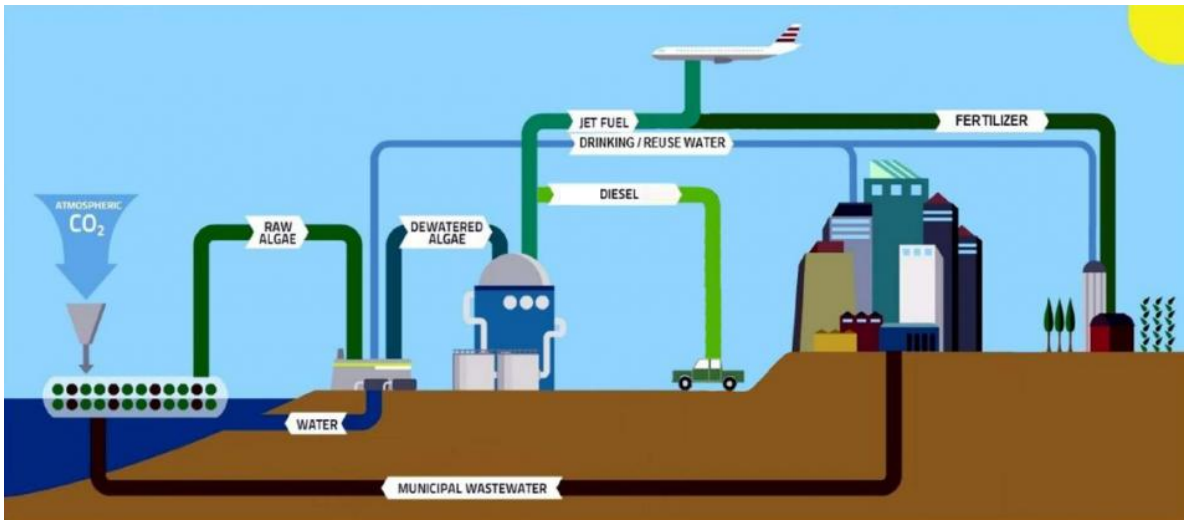

Figure 123. *A possible use case of the Business Model of Circular Economy through Microalgae [98].*

LCA in recycling is key in order to *"close the loop"* in the Business Model of Circular Economy, in this schema, it is important to note that there are 2 different approaches, (1) first, it is related to recycling the wastewater that in turn will serve as nutrients for producing more Microalgae (and therefore, biomass and biomass-based products) and (2) a classical recycle of biomass-based products. Both paths can be implemented separately or individually (Figure 124).

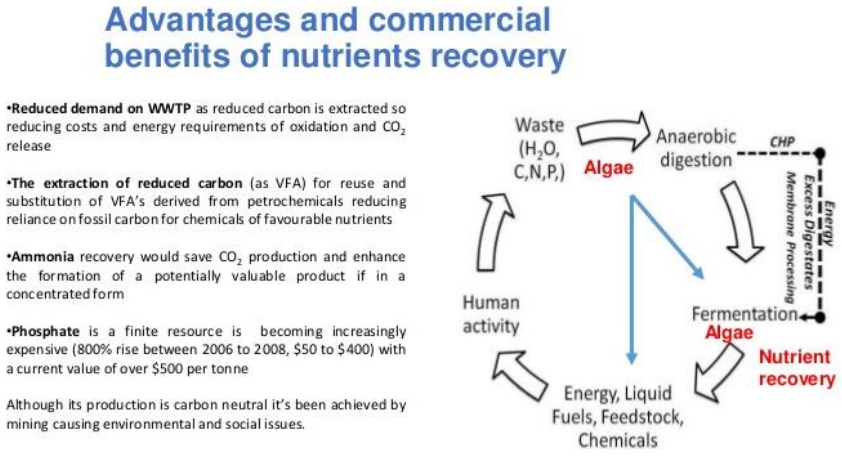

Figure 124. *Company for purifying wastewater [13].*

Although biomass products from Microalgae are a technology that have many benefits, there is the drawback of large collections of residual biomass being left over. This can be resolved through the process of anaerobic digestion (AD) [99-100] through which Microalgae can breakdown biodegradable biomass in the absence of oxygen. Thus, it creates a balance between the energy conservation and environmental impacts.

A.4.3. The Circular Economy Business Model of Microalgae in the Context of the Circular Economy Package

The biggest challenge is to make the existing Company collaborate in order to exchange waste streams and biomass streams. It is also a big challenge to enhance synergies between different Industries such as the biomass-based products and the purely Microalgae-based ones. Finally, it is fundamental to find a stakeholder in order to "close the loop", this is, to recycle wastewater through Microalgae that in turn may increase the production of biomass. Japan has the necessary stakeholders and support to carry out this complex task. The Japanese Government is aware of the national and global challenges, and the possible business opportunities with the EU.

This section includes the latest components of the Circular Economy Package consists of an EU Action Plan for the Circular Economy and it will be linked to each of the fields of Microalgae point by point (Table 46).

Summary of the EU Plan	Practical Application on Microalgae
1. Production: every economy is looking for a circular mode where by the reuse and recycle aims will be maintained. This is decided right from the production phase through design which will eventually have its impact in the source of the product, how the resource is used and also the management of the waste products.	The life cycle of the Business Model starts with Microalgae Production in water by receiving CO_2, sun light and nutrients. The nutrients and water can be received from wastewater and as part of recycling biomass. CO_2 can be received naturally from the ambience or from the combustion of any industry, such as biomass plant for generating energy. Once the Microalgae has been harvested, it is obtained raw biomass that can be used for a variety (as was already mentioned) of applications such as bio-fuel, foods, feeds, plastics, cosmetics... This production represents a Sustainable Business Model since the Microalgae can continue being harvested as long as it receives the necessary sources.
1.1. Product design: the product design should provide energy efficiency along with the adoption of an eco friendly design structure. These pertain to factors like durable design, recyclable products, lowered repairs costs and also should be easy to upgrade.	The resulting products from converting the biomass (i.e. plastics) should keep the principles of recyclability, reparability, durability, upgradability and energy efficiency, accordingly to the Ecodesign Directive [101].
1.2. Product processes: newer and more technical product processes have to be introduced which are better	Anaerobical Digestion (AD) provides an innovative solution for treating wastewater becoming nutrients for the Microalgae, while in

intended at sticking to the ecological factors. An important characteristic to be included is industrial symbiosis, whereby the waste product or the by product from one manufacturing process in an industry becomes useful in another industrial process.	turn, the wastewater is returned back purified for human consumption.
2. Consumption: optimal utilization has to ensure that the production of household waste is reduced	If the consumers choose biodegradable products the resulting biodegradable waste could be recycled, therefore reducing waste.
3. Waste management: the waste management has to follow the European Union Waste Management hierarchy.	This Business Model proposes to recycle the biomass-based products for feeding the Microalgae and harvesting new Microalgae, as well as using the wastewater for providing nutrients for the Microalgae, the resulting purified water is re-circulated for human consumption.
4. Waste to resources: for the success of an ecological economy, it is essential to ensure recycling of the by products and making use of these as raw materials for other processes. These are packed and shipped from the place of extraction. Such secondary raw materials are treated like primary raw materials.	There are **5 different streams** in the circle: ➢ Biomass stream: generated from Microalgae it is injected for generating biomass-based products. ➢ Biomass-based products: can send bio-waste remains for being recycled. ➢ Human activities: by using the biomass-based products, it generates bio-waste. ➢ Wastewaters: are used for feeding the Microalgae while water is purified. ➢ Purified water: as a result of Microalgae treatment.
5. Priority areas: some industrial sectors face certain issues concerning the following of guidelines to an environment friendly economy. This is due to the properties of the product, the footprint that it leaves on the ecology or due to the need for raw materials and resources from outside Europe.	The proposed Business Model can tackle each of the areas proposed by the Commission.
5.1. Plastics: plastic industry makes use of chemical components which pose environmental risks. Coming up with innovative ideas can be considered but there will be several concerns to	Bio-plastics generated from Microalgae provide a renewable source for producing various plastics with biodegradable capabilities.

consider including biodegradability.	
5.2. Food waste: wastage of food is a matter of immense concern that has been found to affect the environment greatly. Right from the stage of production, through distribution and storage, food products make use of natural resources. Its wastage affects the economy.	It is possible to generate Microalgae-based foods in sustainable ways. This food can be recycled instead of just being incinerated, for instance, it could be added as part of the nutrients for the Microalgae.
5.3. Critical Raw materials: raw materials which hold high importance in the European economy is classified under the critical raw material section. These even face the risk of supply disruption. But the problem arises when the extraction of such crucial raw materials impact the environment adversely.	There is no direct application for the critical raw materials since these are not organic, however, biomass-based products can become an alternative to several of the critical raw materials.
5.4. Construction and demolition: construction, renovation and demolition waste constitute a major section of total waste. Most of this bulk is reused or recycled across the European Union.	A variety of plastics can be used for construction, however (likewise the previous case), construction materials and components cannot be recycled through Microalgae due to their inorganic nature.
5.5. Biomass/bio-based products: several industries like food production, chemical etc make use of biological waste. It is also used in bio-fuel production.	Microalgae has numerous applications using the biomass generated, matching precisely with the products criteria of the European Union.
6. Innovation and investment: to ensure the development and foot hold for a circular economy it is necessary to bring about a calculated change which is reflected in every section of the processes and mainly in the top priority sectors.	The Business Model of Circular Economy through Microalgae represents a cutting edge Sustainable Business Model approach due its unique characteristics in order to tackle multidimensional global issues and for obtaining renewable resources.
7. Monitoring: with the aim of an eco friendly environment, each process is closely monitored and checked out for indicators. This ensures that the actions taken towards the setting up of a circular economy is working efficiently.	It is possible to follow-up the entire life cycle assessment if the stakeholders involved measure and trace it properly.

Table 46. *Practical application of Circular Economy on Microalgae and its biomass-based products.*

How to solve the possible barriers approaching Circular Economy

In order to explain this section, there will be 3 highlighted cases (Table 47) of linear Economy (more would be possible) that do not take advantage of the input and output streams in common, and how these can be reinvented with a CE Approach.

Use case of linear Economy	Circular Economy Solution to use case
A Microalgae Company is producing biomass and it is spending economic resources in fresh water and nutrients	The Company should invest in Microalgae technology for using wastewater as a source of water and nutrients. The invested economic resources would be amortized by adopting this sustainable solution, and the purified water could be returned back, becoming an additional income
A biomass-based products Company A is simply discarding the bio-waste from a typical industrial process of production	Company A recycles the bio-waste in 2 forms (1) Company B is recycling part of the bio-waste and provide the nutrients to a Microalgae Company, (2) Company C is incinerating the bio-waste that cannot be recycled and the resulting CO_2 in the process is injected to the Microalgae Company for its absorption
A biomass-based product Company obtains dry biomass - from Microalgae Company - which has a 50% of composition for bio-fuels and 30% for foods. This Company is specialized in producing biodegradable plastics and the rest of biomass is discarded	The Company can either (1) specialize in other biomass-based products or if the required investment is too risky (2) it can be injected to a different Company for taking advantage of this remaining biomass (therefore obtaining additional income)

Table 47. *Practical use cases.*

It is important to note how new business opportunities are being created by taking advantage of the shared input and output streams which allow alliances to be built between Companies from different Industries. Finally, decisions need to be made about which kind of investment is needed for adapting the linear Business Model into a circular one, therefore, it is key to take into account the benefits that will be obtained.

Newest legal trends on Microalgae and Circular Economy

It is important to note the measures presented will all need to be taken forward in line with the better regulation principles, including, where appropriate, an impact assessment. Table 48 illustrates CE Roadmap in form of actions to be accomplished [102]. The legislation related to biomass and Microalgae is related to the following actions.

Biomass and bio-based materials	Timetable
Guidance and dissemination of best practice on the cascading use of biomass and support to innovation in this domain through Horizon 2020	2018-2019
Ensuring coherence and synergies with the circular economy when examining the sustainability of bioenergy under the Energy Union	2016
Assessment of the contribution of the 2012 Bioeconomy Strategy to the circular economy and possible review	2016

Table 48. *CE Roadmap in form of actions to be accomplished [102].*

The European Commission released a JCR Science Report in 2015 titled "*Bio-fuels from algae: technology options, energy balance and GHG emissions"*, in which it is highlighted that *"recently, there has been a major interest in the development and validation of integrated processes employing biomass power plant supplied with agricultural residues to produce CO_2, heat and electricity for the growth of algae in ORP (Oxidation-reduction potential), in combination with WWT (wastewater treatment) effluent as the growth medium. Microalgae can be further processed into biogas that is then upgraded to compressed natural gas to be used in vehicle engines"* [103].

Pros and Cons of Circular Economy of Microalgae

The most evident obstacle for adopting a Business Model of Circular Economy is to study the pros and cons by carrying out the necessary investments; however, there are other noticeable ones to mention (Table 49).

Pros	Cons
Generates new income for the Company by taking advantage of new streams that were discarded previously	Requires to calculate the necessary investment in most of cases, and the investment itself
Companies can share *"know-how"* and best practices	Companies may be not willing to share their experience
New patents can be developed in order to take advantage of new industrial processes	Intellectual property laws may stop joint projects or agreements
Business rivals from the same Industry can understand that including new streams may increase their business benefit	Business rivals from the same sector may be reluctant to collaborate due to an existing competition
There is general positive acknowledgement and support by the Government, Society and Industry by adopting Circular Economy in order to tackle global issues such as CO_2 emissions reduction or Sustainable Development	The Government has not defined yet a clear roadmap for adopting a package of Circular Economy in Japan (i.e. funding programmes)

Implementing EU-Japan Synergies for a Circular Economy

This section addresses a set of recommendations in order to succeed to achieve EU-Japan for joint programmes, projects or consortiums.

The most common form of meeting new potential partners in the EU-Japan context of collaboration is via networking in Congresses or Conferences. Below, is a list of upcoming events in Japan and EU.

Congress (in Japan)	*Date and location*
2016 6th International Conference on Environment Science and Biotechnology (ICESB 2016)	*25th to 27th December 2016, Kyoto*

Table 49. *Congresses in Japan related to the research topic.*

Congress in Europe	Date and location
AlgaEurope 2016	13-15 December, Madrid (Spain)
European Biomass to Power 2016	5th to 6th October 2016 Seville, Spain
BIOENG '16 / 4th International Bioengineering Conference	13th to 14th October 2016 Istanbul, Turkey
1st International Conference Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability	23rd to 26th October 2016 Sitges, Spain
Venice 2016 - 6th International Symposium on Energy from Biomass and Waste	14th to 17th November 2016 Venice, Italy

Table 50. *Congresses in EU related to the research topic.*

Circular Economy is not just a fashionable trend worldwide, but a Business Model that will persist for years as it has widespread support from the EU, as specified in the annex of the *EU action plan for the Circular Economy.* Furthermore, it was recently addressed by the Japanese Government, Companies, depicted in the past *EU-Japan Business Round Table* meeting previously mentioned.

In order to take advantage of the business possibilities the Circular Economy needs additional promotion from the Japanese Government, ideally: (1) with a Circular Economy package with comparable targets with the existing EU package, including changes in current legislation, directives and policies, (2) national funding programmes similar to the Horizon 2020, (3) impulse of congresses/conferences in order to enhance the acknowledgment of best practices on Circular Economy (4) coaching/education/training and (5) platforms for promoting and establishing alliances.

It is important to note that Japan should already be implementing numerous models of Circular Economy, however the participating Companies may not be using the same terms as those with widespread use in the EU. Therefore, it is necessary to run a campaign for

the better dissemination of this paradigm and letting stakeholders know how to adapt their terminology to more adequate expressions, according to the newest worldwide trends.

Japan is one of the top countries developing Microalgae technologies, its derived biomass-based products and wastewater treatment, so it makes sense for alliances between the EU and the Japanese sides to be formed under the umbrella of Circular Economy.

The measures of the benefits of the Business Model may take several years of analysis, therefore, the existing predictions on creation of jobs and business opportunities may be different from the expectations (not necessarily worse), but in the end, the positive outcomes should be at least as noticeable as most experts depict today. Nevertheless, opponents argue that European Companies are already capturing most of the economically-attractive opportunities to recycle, remanufacture, and reuse. They maintain that reaching higher levels of circularity would involve an economic cost that Europe cannot afford when Companies are already struggling with high resource prices [105].

This paper detailed the importance of the Circular Economy for the big field of biotechnology, including biomass, biomass-based products and Microalgae, however, the other big field of Circular Economy - **technological products** - have not been explained, thus, *an additional report should be needed* for completing the study on Circular Economy.

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