The Green Gift ग्रीन उपहार

The Green Gift

ALWAYS A GREEN MOMENT AT THE ALGAE TOILET

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PREFACE

The moment our biology teacher told us about Imagine, all three of us immediately knew that it was something made for us. We all wanted to do our paper on biology and since the main focus of Imagine is on this subject, we did not have any doubts. The chance of working with scientists and developing a solution that contributes to an improvement in a third world country were our main motivation. We really liked the idea of creating a plan, only bound by a subject, but with no real limitations. It was a chance to give our creativity free reign and to combine this with a subject we are interested in. Imagine decided that the subject that we were to investigate was ‘microalgae’ and this gave us instantly a great motivation to explore all its possibilities. From there on we were constantly thinking of ways to use microalgae to solve humanitarian problems worldwide. The brainstorm sessions brought up all sorts of ideas. In one of these brainstorm sessions the link was laid between microalgae and toilets. In the end this lead to the idea of implementing the concept of microalgae in a working toilet system in India. This combination of two ideas proved to be a good method for us. Slowly on, the idea got more concrete and several parts were put in place. During the creation of our project, we have run into difficulties and questions we did not immediately knew the answer to, but after discussion we have always found a way. The whole process led to this final result. We hope this project will intrigue and interest you and will be enjoyable to read!

TABLE OF CONTENTS

Preface 2
Table of contents 3
Management summary 4
Introduction 5
The microalgae technology 6
- Species 6
- Cultivation systems 6
- Isolation of products 6
- Experiment 7
- Industrial scale 7

Global overview of India 8
- Climate 8
- Demography 8
- Infrastructure 8
- Economy 8
- Politics 9
- Culture and religion 9
- Problems 9

Current situation in Mumbai 10
Link between technology and country 11
Economic aspects 12
- Microalgae technology 12
- Toilets 12
- Cost structure 13
- Profit structure 13

Conclusion and Discussion 14
Postface 15
References 16
Appendices 17
- Appendix A: Description of species 17
- Appendix B: Different cultivation systems 18
- Appendix C: Flat plate reactor 19
- Appendix D: Waterbag 20
- Appendix E: Photosynthesis microalgae 20
- Appendix F: Experiment 21
- Appendix G: Extraction of oil 23
- Appendix H: Climatic zones of India 24
- Appendix I: Caste system pyramid 24
- Appendix J: Houres of bright sunshine worldmap 25
- Appendix K: Production of biogas 25
- Appendix L: Costs toilets 26
- Appendix M: Costs laboratory 27
- Appendix N: Costs transport 28
- Appendix O: Profit structure 29

MANAGEMENT SUMMARY

With this business plan, a link is created between the extraction of oil from microalgae and the lack of sanitation in Dharavi, the largest slum of Mumbai in India. Therefore, different aspects have been investigated: the possibilities of the microalgae technology, the global overview of India and the current situation in Mumbai.

The cultivation of microalgae requires different nutrients such as nitrate and phosphate. These nutrients appear to be in human urine and faeces. Therefore, human urine and faeces can provide the microalgae of nutrients. The substance of urine and faeces is called 'black water'.

Microalgae contain carbohydrates, lipids and proteins, which provide a wide range of possibilities and products. Since microalgae will grow on black water wherein pathogens could be present, the algae are not suitable for the production of nourishment. Therefore, the microalgae are used to produce rough oil. Under normal circumstances, the amount of lipids in microalgae is small. When the algae are cultivated with a shortage of nitrogen, the concentration of lipids increases. This expansion takes place since nitrogen is an essential element of proteins. Because of the absence of nitrogen, proteins cannot be formed anymore and the algae will switch to the production of lipids. Therefore, the algae are partly cultivated with a shortage of nitrogen to make the harvest of oil as high as possible.

In Dharavi, there is an alarming lack of sanitation. This shortage of sanitation facilities results in open defecation. Many people defecate in the local river or sea. Consequently, the hygienic circumstances in the slum are miserable and many diseases are spread. These are, however, not the only bad consequences, since the open defecation results in a risky situation for women as well. Women have to leave their homes in search for a place which they can use as a toilet, even during night. Since these women are vulnerable, they are exposed to many dangers, including the risk of being raped.

Microalgae can help to improve circumstances in Dharavi. To realize this, toilets will be placed in the outskirts of the slum and the urine and faeces will be stored. The black water will be transported to the algaeparc, the place where the cultivation and treatment of the microalgae will take place. Before the black water will serve as nutrient supplier, it is lead to a biogas reactor. This reactor is an airtight container where the anaerobic degradation of the black water takes place. During this process, biogas, a mixture of $CO2$ and methane ($CH4$), will be formed and many pathogens are inactivated. Thereafter, the microalgae will be cultivated in a water bag, a specific cultivation system, with the nutrients of the black water. The water bag will be situated outdoors because sunlight is required.
To extract the oil from the microalgae, a single-step oil extraction will be used. The method is designed by OrginOil. The extraction will produce rough oil and biomass, which could be sold separately.

By placing the toilets, the sanitation in Dharavi will improve and local people will be healthier and safer. Furthermore, the rough oil will be converted into bio fuel and biogas is formed, which can substitute fossil fuels. The products will contribute to the solution of a worldwide problem, since fossil fuels run out. Therefore, the project has many profits which will lead to a worldwide improvement.

INTRODUCTION

The aim of this project is to discover how a technology can improve circumstances in a developing country. The given technology, which is discussed in this project, is the extraction of certain products out of microalgae. This technology can be introduced in various ways, since algae contain many different products. Therefore, a decision should be made which product of the microalgae will be used and how this product can (indirectly) create a positive development. The focus of this project is the application of the technology in India. Therefore, the main question of this project is: *How can the microalgae technology contribute to a sanitary improvement in India?*

To answer this main question, various minor questions will be answered. The first sub question is: *What is the microalgae technology and what are the possibilities?*
This question will be answered in the first chapter: 'The microalgae technology'. In this chapter, different aspects of the technology will be pointed out such as the different species, the cultivation methods, how products are extracted and how an extraction method can be implemented on industrial scale.

In the next chapter: 'Global overview of India' the second question will be answered. This question reads: *What is the current situation like in India?*
In this chapter, the actual situation in India will be enlightened by looking at the climate, demography and infrastructure of the country. Furthermore, the political, cultural and religious situation will be treated. Finally, some of the present problems in the country will be named.
The third chapter: 'Current situation in Mumbai' will treat the specific circumstances in Mumbai. In this chapter, the problems in Mumbai will be explained in more detail and the precise place where the project will be implemented is discussed.

In the fourth chapter, a connection is made between the technology and the country. In this chapter, the question: *Why could India benefit the most from the microalgae technology?* is answered.
To do this, the problems which are present in Mumbai will be connected with the possibilities of the microalgae technology.

In the final chapter: 'Economic aspects', the costs and profits of the implementation of the project in India will be mentioned. This will answer the final sub question*: What are the economic aspects of introducing the microalgae technology in India?*
In this chapter, an estimation of the expected costs and profits is made by using a business model. This business model contains nine aspects and is based on the business model of the handbook made by The Business Model Generation.

All these sub questions together will answer the main question and will explain why Mumbai is the right place to implement this project.

Mumbai 2007 [1]

[1] http://lsecities.net/ua/conferences/2007-mumbai/

THE MICROALGAE TECHNOLOGY

SPECIES

To start off with, there are enormous amounts of different algae species, but only tens of thousands of the 200.000 to 800.000 species are scientifically described. All these unknown species mean that algae provide an gigantic source of opportunities. Today's species are divided into different groups: green algae, red algae, diatoms, brown algae, gold algae, yellow-green algae and blue algae or cyan bacteria[2].Green algae are with 7500 species one of the largest groups of algae. They are similar to plants. Green algae contain almost the same organelles as plants do, for example chlorophyll, a lot of proteins, the same pigments, starch as stock food and cell walls of cellulose. Green algae can be either protozoa, single cell eukaryotic organisms, or metazoans, multi-cellular eukaryotic organisms. One of the most common protozoa is Chlorella. Chlorella is grown worldwide and used for detoxifying the body.[3] Many algae produce certain substances when put under pressure and so does Chlorella. When put into a stressful situation, green algae produce a lot of oil and starch and store it in the cell.

CULTIVATION SYSTEMS[4]

Worldwide, the circumstances for producing algae differ, such as; temperature, hours of sunshine, precipitation, humidity and landscape. The best cultivation of algae is influenced by these characteristics. Therefore, scientists invented different types of cultivation systems. Algae growers currently use four different cultivation systems; open ponds or raceways, single-layer or horizontal tube reactors, three-dimensional tube reactors[5] and flat plate reactors[6]. The most productive system is, in theory, the flat plate reactor. The flat plate reactor is composed of series of flat, parallel plates. There are two benefits of this system. There is no accumulation of toxic gases and the light intensity at the surface is not too high. A drawback is the high amount of energy which is required for mixing the liquid suspension. Furthermore, it is difficult to add ingredients to the closed system and the environment has an influence on the temperature of the tubes.
A cultivation system where flat plate reactors are used is the water bag[7]. In the water bag the flat plates are surrounded by water, which keeps the temperature steady. Therefore, the water bag is the most suitable cultivation system for the variable circumstances in India.

ISOLATION OF PRODUCTS

Algae are autotrophic organisms and therefore constitute their nutrients with the photosynthesis. They use CO_2, water and sunlight to produce carbohydrates and O_2. Algae also need nutrients such as nitrate and phosphate. By using carbohydrates, algae convert these inorganic elements into organic elements such as proteins and lipids. Therefore, the cells of algae consist of different groups of molecules which can be separated and sold as individual products.[8] The composition of these molecules is different in each species and depends on the cultivation circumstances. However, there are a number of general characteristics. Cells of almost all microalgae consist of three fractions: carbohydrates, lipids and proteins. These fractions constitute 70-90% of the total biomass of the cell. Under optimal circumstances, the fraction of proteins constitutes approximately half of the biomass. When the cells do not have access to nitrate, this fraction becomes much smaller. This happens since nitrogen is one of the essential elements of proteins. In circumstances with little nitrogen, most algae switch to the production and storage of carbohydrates and lipids, which both do not contain nitrogen. The amount of carbohydrate in a cell depends on the kind of species. It can vary between 20% and 80%. The most frequent carbohydrates are the glucans, such as glycogen, starch, cellulose, laminarine and chrysolaminarine. These glucans play an important role in the deposition of energy. Because of the high amount of carbohydrates in some microalgae, these species are seen as an ideal raw material for the production of ethanol.

[2] Appendix A: Description of species
[3] http://www.seaweed.ie/algae/chlorophyta.php
[4] http://www.groenegrondstoffen.nl/downloads/Boekjes/12Microalgae_NL.pdf
[5] Appendix B: Different cultivation systems
[6] Appendix C: Flat plate reactor
[7] Appendix D: Water bag
[8] Appendix E: Photosynthesis and products of algae

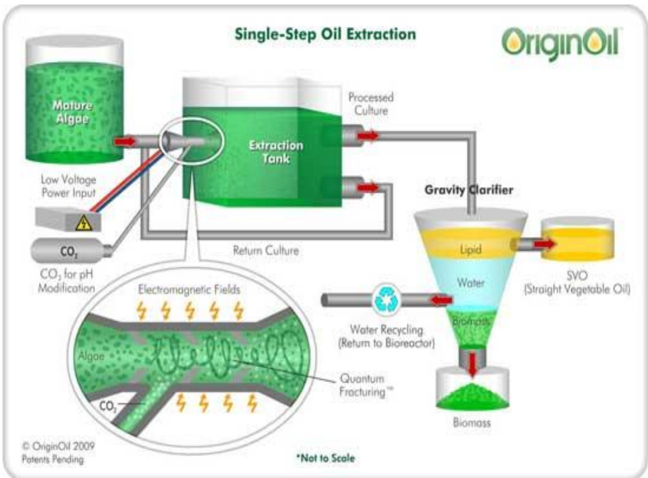
Many microalgae contain lipids. These lipids make them suitable for the production of bio fuel. The lipids which are the most suitable are triglycerides. The triglycerides could be used in nutrition, they can become bio fuel once they are converted and they can be used for the production of bio plastics. Algae do not produce many lipids under normal circumstances. However, as mentioned earlier, when algae are in circumstances with a shortage of nitrogen, the concentration of triglycerides can increase till 45% of the biomass of the cell. The remaining biomass of the cell contains pigments, antioxidants, sterols, glycerol and toxins. These substances are mostly present in tiny amounts. Exceptions are the pigments in some algae. Since pigments have a high value, the production of pigments is one of the few processes which currently are commercially feasible.

EXPERIMENT

The experiment[9] is a single-step method for rapid extraction of all lipids from microalgae. The aim of the experiment is to find out which algae produce the most oil and to find out how oil is extracted. For this experiment, the Scenedesmus Obliquus and the Chlorella Vulgaris are used as algae. The species which consist the most oil according to this experiment is the Scenedesmus Obliquus. The average oil percentage of the Scenedesmus Obliquus is: 11.21% and the average oil percentage of the Chlorella Vulgaris 5.7%. Both species were cultivated with sufficient access to nutrients. Therefore, the percentages of oil can increase when the algae are cultivated with a shortage of nitrogen. The Scenedesmus seems the best algae to produce oil. However, other species can be used as well, since the best circumstances under which different algae grow are dissimilar. Therefore, algae should be selected on the adaption and preference for certain circumstances.
On industrial scale, the extraction of oil is different and takes a lot longer.

INDUSTRIAL SCALE

There are lots of different ways to extract oil from algae.[10] Each way has advantages and disadvantages. The challenge with extracting oil from algae is to destroy the cell walls. When algae are in a suspension with water, the walls are almost indestructible. To extract the oil most efficiently, which means cheap and an extraction of 100%, different methods should be used together.
The single-step oil extraction designed by OriginOil is a relatively cheap method to extract oil from algae. Firstly, the algae are harvested. The algae do not have to be dried or taken out of the suspension of water. This is a great advantage compared to many other methods. After this first step, the algae are led to the extraction tank. Just before the algae arrive in the extraction tank, electric pulses and a change in pH cause the cell walls to open up. When the algae enter the extraction tank, the processed culture continues into the gravity clarifier and the part of the algae of which the cell wands did not open are led back to the place where the electric pulses and the change in pH take place. In the gravity clarifier the lipid, water and biomass separate automatically.



The water can then be recycled and the oil can be extracted. The biomass which is left over can be used as animal food or chemicals, which ensures an extra profit that makes the process feasible.[11] Besides the advantage that the algae can stay in suspension, there are more positive aspects of this extraction. No chemicals are needed and no heavy machinery is required. These aspects ensure the extraction to be relatively cheap. Moreover, little energy is required. This single-step extraction needs less than a tenth of the energy used in conventional methods. Altogether, this extraction contains a good method to extract oil from algae.

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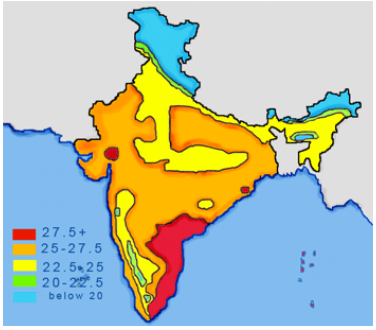
[9] Appendix F: Experiment
[10] Appendix G: Extraction of oil
[11] http://www.celsias.com/article/oil-algae-new-one-step-process/

GLOBAL OVERVIEW OF INDIA

CLIMATE

Since India is a rather big country, the climate conditions can differ. Therefore, India has several major subtypes of its climate, which divide the country in different regions.[12] An arid desert is situated in the west, there are glaciers and an alpine tundra in the north and in the southwest and islands, the climate is (sub)tropical.

In India, the year is divided in four seasons: winter (January and February), summer (from March to May), a monsoon season from June to September and a post-monsoon season from October to December. In South India, the maximum temperatures during the winter are 17 to 20 °C. The west of India has warm winters as well. The temperatures in the north can decrease during winter, due to the closeness of the Himalayas. Moreover, heavy snowfall occurs in this region. The east of India is comparable to the north, since its temperatures can be low as well. The monsoon period also varies in the different areas. In the desert region, very little rainfall occurs, while the rainfall in most other parts is heavy. The temperatures in summer are high; they can increase to 45 °C in July in the warmest parts of India.



Temperature averages India [13]

DEMOGRAPHY

India is considered as the second most populous country in the entire world[14]. India has more than 1.21 billion inhabitants (2011 Census), and these people together are more than a sixth part of the world population.

INFRASTRUCTURE

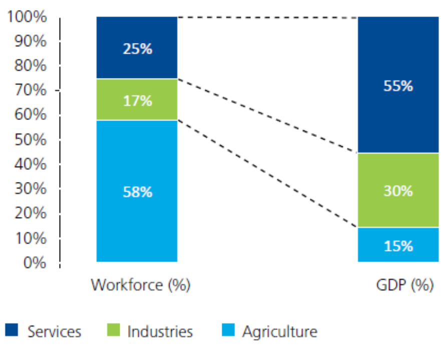
The infrastructure together with the transport sector account for approximately 5% of the GDP. The road network in India is the second largest in the world.[15] It has a length of more than 4.3 million kilometres. This network consists of modern highways but also of unpaved roads. Although the network of roads is enormous, the lane road density in India per 10000 people is the lowest compared to other G-27 countries, which results in traffic congestion.

India has one of the largest rail networks, there are 13 major ports, 60 non-major ports and 125 airports. Nhava Sheva in Mumbai is the largest public port.

ECONOMY

India is one of the lands which are part of the G-20 major economies. Furthermore, it is one of the BRICS lands and belongs to the top 20 of global traders.[16] In 2011, the agricultural sector contributed for 15% to the GDP, while it preserved 58% of the employment. The industrial sector constituted 30% of the GDP and delivered work to 17% of the labour force. The services sector accounted for the biggest part of the GDP, namely 55%. The sector employed 25% of the total working population.

Until 1991, India was isolated from world trade. Since the liberalisation, the contribution to the GDP of trade in services and goods raised from 16% to 47% in 2010.[17]



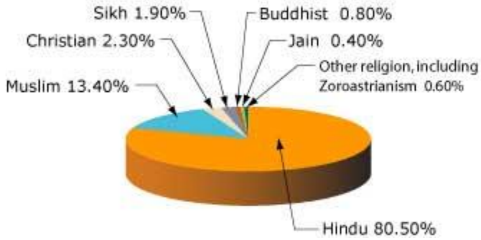
Sector contribution to GDP, Census 2011, VMW Analytics Service data

[12] Appendix H: Climatic regions of India
[13] http://www.cs.mcgill.ca/~rwest/link-suggestion/wpcd_2008-09_augmented/images/837/83797.png.htm
[14] "CIA World Factbook". Central Intelligence Agency, USA. Retrieved January 2012.
[15] "Infrastructure Rankings". CIA. Retrieved 2011-01-17
[16] World Trade Organization, World Trade Report 2013, Geneva,
[17] "Trade profiles-India". World Trade Organisation. Retrieved 2012-02-07.

POLITICS

India is a federal parliamentary democratic republic and it has a dual polity. The head of the state is the President and the head of the government is the Prime Minister.. Every five years, an election takes place to choose the new government.

CULTURE AND RELIGION



Several religions find their origin in India. The Hinduism, Buddhism, Jainism and Sikhism are all known as Indian religions. India is one of the nations with the most different religions and India has many deeply religious cultures and societies. According to the 2001 census, the diagram which stands on the left was made.
The major languages in India are part of the Indo-Aryan languages; these languages are spoken by 73% of the Indians and part of the Dravidian languages, which are spoken by 24% of the Indian population. There is no national language in India[18], but the official languages are Hindi and English.
India formerly had a caste system and nowadays the castes still matter. Historically, the system divided communities into hereditary groups which were called 'jātis'. The jātis were clustered in four varnas: the Brahmins, Kshatriyas, Vaishyas and Shudras. There were groups, which are known today as the 'Untouchables', ruled out from the varna system.[19]
Since 1950, the Indian government has made several laws and set up social initiatives to improve and protect the situation and conditions of the lower caste population.

PROBLEMS

Poverty is a common occurrence in India and it is widespread. Different methods are used to measure this poverty. Since 2005, the Tendulkar methodology is used by the Indian government. [20] The Indian government made clear in 2013 that 21.9% of the inhabitants of the country lived below the official poverty limit.[21] In 2010, the World Bank made an estimation that 32.7% of the people in India must live from $1.25 a day. In May 2014, the World Bank used a new calculation method and concluded that 872.3 million people in the world lived below the new poverty line. 179.6 million of those people lived in India. The poverty line per day in India is 32 rupees, which is comparable to $0.53.[22] India contributes 17.5% to the world's population and 20.6% to the world's poorest people.
Another major problem in India is the supply of drinking water and sanitation. Despite efforts by the Indian government and several organisations, this problem remains alive in India. Since 2000, more money is invested to diminish this problem. The rate of Indians with access to water increased from 72% in 1990 to 88% in the year 2008.[23] In 2011, 92% of the total population had access to improved sources of water.[24] However, the problem is not solved yet. There are only two cities with a continuous water supply and in 2001 still 65% of the total population did not have access to better sanitation facilities. The lack of good sanitation and safe drinking water results in health impacts such as diarrhoea.
Because of this lack in sanitation, India is one of the lands that are known for their open defecation. This open defecation does not only cause health problems, but it results also in a risk full situation for women. These women have to leave their homes in search for a place which they can use as a toilet when it is dark, which provides a risk of being raped.

[18] Khan, Saeed (25 January 2010). "There's no national language in India: Gujarat High Court". *The Times of India*. Retrieved 5 May 2014.
[19] Appendix I: Caste system pyramid
[20] http://planningcommission.gov.in/reports/genrep/rep_hasim1701.pdf
[21] Number and Percentage of Population Below Poverty Line". Reserve Bank of India. 2012. Retrieved 4 April 2014.
[22] Not poor if you earn Rs.32 a day: Planning Commission India Today (September 21 2011)
[23] UNICEF/WHO Joint Monitoring Programme for Water Supply and Sanitation estimate for 2008 based on the 2006 Demographic and Health Survey, the 2001 census, other data and the extrapolation of previous trends to 2010.
[24] WHO & UNICEF Joint Monitoring Programme - table

CURRENT SITUATION IN MUMBAI

Mumbai is the capital city of Maharashtra, an Indian state. Mumbai is also known as Bombay. It is the Indian city with the biggest population and is the eighth most populous city in the world. The city population is estimated on 18.4 million people. Mumbai is seen as the financial, entertainment and commercial capital of India. It makes 6.16% of the GDP.[25]

Mumbai, however, is a city of contrasts. Although Mumbai is a relatively wealthy city, the problems which occur in the whole country are not absent here. Many people live in slums under bad circumstances. According to the Mumbai Sewerage Development Project-II, approximately 50% of the population living in slums does not have acceptable admission to safe sanitation. 73% of the people in slums use community toilets, 28% defecates and urinates in the open air and 0.7% pays to use a toilet. When preserving a norm of 1 toilet for 50 people, there is a shortage of 65000 toilets in Mumbai. Therefore, the waiting times for the present toilets are high. The most toilets are unhygienic because of overuse and there is no adequate water supply.

A map showing the slums in Mumbai (green areas), Mumbai City Development Plan 2005-2025

Dharavi is the largest slum in Mumbai. This slum houses around 800 thousand people and is not even one square mile. Therefore, Dharavi is one of the places on earth with the highest population density. Dharavi is a slum with many small-scale businesses. These small industries produce pottery, leather goods, embroidered garments and plastic. These products are mostly made in units that are spread across the slum. The small units in the slum employ many Indians who come to Mumbai in search for a job.

Just like the other parts of India, also in Dharavi there are serious problems with public health. These problems are mostly caused by the shortage of sanitation facilities. In 2006, 1440 people had to share one toilet.[26] The people in the slum use the Mahim Creek, which is a local river, for defecation and urination. This leads to the spread of infectious diseases. In the history of Dharavi, many epidemics have taken place. Some of these epidemics resulted in the loss of many lives.

In Dharavi, there are three types of public sanitation facilities: free toilets, paid ones and toilets which are preserved by housing societies. The free toilets mostly do not have water provision, so people need to get their own water. There are not many toilets which are attached to houses. Some housing settlements use one facility together and often take care of the hygiene and cleaning.

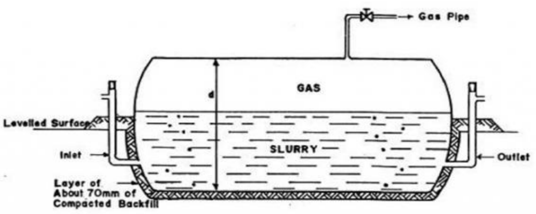
Public toilet in Dharavi, (photo by Benita Fernando)

[25] "Mumbai Urban Infrastructure Project". Mumbai Metropolitan Region Development Authority (MMRDA). Retrieved 18 July 2008.

[26] Toilets Underused to Fight Disease, U.N. Study Finds, *New York Times*, 10 November 2006

LINK BETWEEN TECHNOLOGY AND COUNTRY

Since algae grow the best with much sunlight, a country is needed with a high amount of sun hours. India fits these criteria, since Mumbai has 2584 sunny hours a year.[27] [28] This amount is for example almost twice as much as in the Netherlands.
Algae can be part of a technology which can be used as a solution to a great problem in India: the lack of sanitation. To grow microalgae, nitrate and phosphate are required, because algae must be cultivated under optimal conditions before they are put on a nutrient-restricted diet. During the diet, the oil percentage will increase. The required nutrients are present in human faeces and urine, which are together called blackwater. Therefore, the faeces and urine of humans can be used as a source of nurture for the algae. A way is developed to use the blackwater as a food source for algae. This blackwater can be converted to digestate and then this product can provide nutrients, since these nutrients are still present. When the blackwater is collected, it is lead to a biogas reactor. This reactor is an airtight container where the anaerobic degradation of the blackwater by bacteria takes place. The anaerobic digestion is a process that requires a specific mix of bacteria. Biogas is then formed, which is a mixture of CO_2 and methane, CH_4. The biogas is comprised for 50-75% of methane and 25-50% of carbon dioxide. It also contains varying quantities of hydrogen sulphide, water vapour, nitrogen and other components.[29] The biogas is formed in the blackwater and ends up at the top of the reactor. By going from the bottom to the top of the reactor, the biogas mixes the blackwater. After the digestion, the blackwater is transformed to digestate. This digestate contents many nutrients and organics. Furthermore, it has almost no smell and a part of the pathogens are inactivated. The suitable temperature for the digestion lies between 20 to 35°C. In hot climates, the average amount of time that the blackwater should stay in the reactor is 15 days. The energy of the biogas is equal to 6 kWh/m^3. This is comparable to 0.61 L diesel fuel. Per cubic meter digester, 0.3-0.5 m^3 biogas is formed.[30]
There are different types of biogas reactors. Reactors can be made out of bricks or plastic containers. The rubber balloon biogas plants are the cheapest and the most simple biogas reactors. The biogas plant consists of a plastic bag where the blackwater lays on the bottom.
The biogas collects in the top part of the balloon. To transport the gas out of the balloon, weights can be placed on top of the balloon and due to the elasticity, the gas will flow out. There are several advantages of this design. The digester can reach high temperatures when the sun shines at its top and it can easily be cleaned and emptied. Furthermore, the design is simple and very cheap.



A rubber balloon biogas plant (Spuhler 2010)

By using a biogas reactor to create a source of nurture for the algae, the microalgae technology can be combined with the current problems in India. Toilets can be placed in the slum Dharavi and the blackwater of those toilets will supply nutrients for the algae. By placing the toilets, there will be a contribution to improve the sanitary circumstances of people living in the slum. The toilet-users will urinate or defecate less or not at all at public spaces. This will diminish the number of bacteria and viruses, so fewer diseases will be spread. Therefore, a small change is made in the lack of sanitation. Moreover, the blackwater is not thrown away, but used as a valuable source. On this blackwater the microalgae can grow and therefore the supply of other nutrients is not necessary. The reuse of this blackwater has many advantages and provides a link between the slum Dharavi and the microalgae technology.

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[27] http://www.currentresults.com/Weather/India/annual-sunshine.php
[28] Appendix J: Hours of bright sunshine world map
[29] Appendix K: Production of biogas
[30] *Biogas* guideline data. Adapted from WERNER et al. (1989); ISAT/*GTZ* (1999), Vol. I; MANG (2005)

ECONOMIC ASPECTS

To describe the economic aspects of the microalgae technology, a business model is used. The Business Model Generation has developed a practical handbook to create a business plan. This handbook describes nine aspects which apply to every business model. Because this business model is about producing oil and building toilets, there are actually two different products. Because of the difference, the products will be treated separately. However, the costs and profits will be united to get a total overview of the business plan. The plan described below is the plan for the implementation of the product in the first year.

MICROALGAE TECHNOLOGY

By using the microalgae technology, rough oil and biomass are produced. Because of the ecological origin of the rough oil, people and industries are expected to be interested in this sustainable solution. Bio fuel is a relatively new field. Therefore, the expectation is that the demand for the products will be high and that there will be no constraining competition. Furthermore, the project has a non-profit basis, which means the price of the products will be as low as possible. The revenue of the products is calculated in the profit structure[31].
If this is not enough to keep the project going, negotiations with other parties may lead to a higher price. Because the algaeparc, the place of the laboratory and cultivation systems, is nearby the city, the products could directly be sent to industries nearby. This opportunity requires little transport and therefore less costs and less damage to the environment.

To realize the project, different resources are required. The resources for microalgae technology are: microalgae (such as Scenedesmus Obliquus and Chlorella Vulgaris), cultivation systems, material to extract the oil, vehicles to transport the oil from the algaeparc to the industry and people with the knowledge to create oil from microalgae. To grow microalgae, nutrients are necessary. The faeces and urine will offer the required nutrients. Besides, technology for administration is needed, such as telephones.

To produce rough oil out of microalgae, several experts and scientists are necessary. Those scientists can come from places all over the world. Students and scientists should be able to do internships at the algaeparc as well. Furthermore, local people will be deployed to help with the extraction and digestion. The transport of the products demands drivers, the drivers could be inhabitants of the slum or the city who own a driving license. The industries and employees of the algae park will be contacted personal: by e-mail, phone calls, online conversations and meetings. Furthermore, different enterprises are required to build the algaeparc such as an enterprise which produces cultivation systems, a supplier of materials to build a laboratory, an enterprise to supply microalgae and of course, people who are able to build the algaeparc.

TOILETS

The microalgae will grow on the nutrients of human urine and faeces. By using the toilets for the microalgae technology, there are few costs for the nutrients and materials will be recycled.
The urine and faeces will be collected in containers at the bottom of the toilets. The containers will be replaced and transported to the algaeparc, where they will be emptied. Before the blackwater will serve as nutrient supplier, it is lead to a biogas reactor, and biogas is produced [31] .
Furthermore, the toilets improve the health and safety of the local people and should be available for everyone. Therefore, ten toilets (two toilet blocks with five toilets) are placed on the outskirts of the slum. People should pay 1 rupee (~€0.01) to visit the toilet. This fee gives the toilets importance and value and provides a profit which makes the whole project more feasible. Moreover, local people are needed to collect the money to visit the toilet and to maintain the toilets.
If the toilets will be successful, the number of toilets will increase. Furthermore, the toilets will be cleaned with ecological cleaning products to ensure that the environment will not be damaged.
The resources for building toilets and maintaining them are: material to build the toilets, cleaning products, toilet paper and vehicles to transport the containers from the slum to the algae park.

[31] Appendix O: Profit structure

An important part is to cooperate with the local people, who take care of the maintenance of the toilets and should collect the money. With the cooperation a social aspect is developed. The local people are reached in person, through oral conversation.
Furthermore, enterprises for the building and the maintenance of the toilets are required, such as suppliers of materials to build the toilets, people to build the toilets and a supplier of ecological cleaning products.

COST STRUCTURE

	Investment	Repetitive costs (yearly)
Toilets [32]		
Building materials	€200.00	
People to build	€75.00	
Toilet paper		€345.00
Cleaning Products		€ 900.00
Caretakers		€3,832.50
Safe	€ 26.64	
Laboratory[33]		
Accommodation	€1,050.00	
Cultivation systems	€515.00	€945.00
Bioreactors	€210.00	
Materials to extract oil	€700.00	€250.00
Employees		€3,494.40
People to build	€245.00	
Microalgae	€130.00	
Phone		€240.00
Transport[34]		
Vehicles	€1,000.00	€300.00
Fuel		€208.00
Unexpected costs	€2,000.00	€1,000.00
Total	**€6,151.64**	**€11,269.90**

Apart from financial cost, there are environmental and human costs as well. The algaeparc will take around 500 square meters of local nature. Furthermore, the vehicles will emit exhaust fumes and will drive through local nature. For people who live close to the toilets the stench and the human activity could be a cost.

PROFIT STRUCTURE[35]

	Investment	Repetitive profit (yearly)
Rough oil		€36.96
Biogas		€125.81
Biomass algae		€7,475.20
Toilets		€7,503.80
Sponsors	unknown	unknown
Total		**€15,141.77**

Furthermore, the project will have non-financial profits. For local people, an improvement of hygiene will take place and the young women will not be raped at night.
Besides, bio fuel is a sustainable source of energy which is a profit with regard to the environment.

[32] Appendix L: Costs toilets
[33] Appendix M: Costs laboratory
[34] Appendix N: Costs transport
[35] Appendix O: Profit structure

CONCLUSION AND DISCUSSION

To answer the main question: *How can the microalgae technology contribute to a sanitary improvement in India?*, the various sub questions firstly need to be answered concisely.

What is the microalgae technology and what are the possibilities? Microalgae, especially green algae, contain many products, including lipids. Those lipids can be extracted from the cells and can be converted into for example bio fuel. Currently, the extraction of the oil is not commercially feasible. Therefore, other ways need to be discovered which make the extraction of oil possible. The single-step extraction of OriginOil might be a solution, as the biomass of the algae can be resold after the oil is extracted. When the extraction of oil from microalgae is feasible, microalgae can be a replacement for fossil fuels.

What is the current situation like in India? India is a diverse country with an incomparable range of landscapes, cultures, religions and people. However, the land has several problems, for instance the lack of sanitation and the amount of people who live beneath the poverty line. These problems occur in the whole country. In Mumbai, moreover, a great difference between rich and poor is noticeable. Mumbai is a wealthy city, but its outskirts comprise many slums. Dharavi is the biggest slum in Mumbai and has a major lack of sanitation. This shortage provokes other problems such as the spread of diseases. The government has taken several measures, but the problems cannot be solved easily.

Why could India benefit the most from the microalgae technology? Microalgae need several circumstances to grow, such as light, CO_2 and water. The cultivation of microalgae prefers a warm milieu. This milieu can be realized in Mumbai, since the temperatures stay high even during winters. Besides, Mumbai is a sunny city and is situated close to the sea, which ensures the availability of water and sunlight. Furthermore, algae need nutrients to grow. These nutrients include nitrogen and phosphate. Human faeces and urine, together called black water, contain these nutrients in great amounts. Algae can grow on this black water once it is converted by bacteria in a biogas reactor. When toilets are placed in the slum Dharavi, the black water can function as the source of nutrients for the algae. Therefore, microalgae can contribute to a solution for the sanitation problem in India.

What are the economic aspects of introducing the microalgae technology in India?
To realize the project, toilets must be placed in the slum Dharavi and an algaeparc must be built. The toilets will be placed in two blocks of five at the outer parts of the slum. Two caretakers will collect the fee, which will be ₹1 ≈ €0.01. This fee gives the toilets importance and value and provides a profit which makes the whole project more feasible. Every day, the toilets will be emptied and the black water will be brought to the algaeparc. At the algaeparc, the cultivation systems, biogas reactors and machinery for the extraction of oil will be placed. Several locals and a few scientists will work here to manage the harvest and extraction. The biogas, oil of the algae and the remaining biomass will secure profits which can hopefully keep the project going. When the profits are not high enough, sponsors will need to be sought.

In this project, the growth of microalgae involves and needs toilets. This connection between algae and toilets results in the start of a sanitary improvement by using microalgae.

However, the implementation of the project is not perfect. Estimations had to be made with little concrete information and this made it difficult to end with a likely cost and profit structure. Moreover, the real implementation will always be different than initially expected. It is most likely that there will be situations that were not taken into account. Furthermore, the oil extraction of algae is currently subject to many research projects. The techniques are developing and consequently, the technique described in this project might soon not be considered as one of the best anymore. In some years, it is expected that a technique will be found for oil extraction that can be commercially feasible. When this technique is discovered, this project will have higher profits and will probably be better achievable.

POSTFACE

While carrying out our project, we have improved many of our competences, such as cooperation, accuracy and creativity. We have learned to think out of the box and to project ourselves into the life of the people in India. When we started the project, we never thought we would develop so many new skills.

We would like to thank several people who contributed to the succeeding of our project.

- First of all our biology teacher Ms Havik; thank you for answering all our questions and for being there when we needed you, and of course for all the correction work.
- Then, we would like to thank the scientists: Ben van den Broek and Dorinde Kleinegris from the WUR. Thank you for introducing us to the concept of microalgae. You inspired us and provided us with the scientific knowledge we needed. And thank you for answering all our e-mails so quickly and of course for helping us with the experiment. Because of you it was possible to write this paper.
- Moreover, we must thank Tania Fernandes, researcher at the NIOO-KNAW in Wageningen. We had the opportunity to interview her about the growth of microalgae on blackwater. Thanks to this interview, we could complete or ideas of combining the microalgae and the sanitation problems in India.
- Last but not least, the staff of Imagine, thank you for creating the opportunity to let us contribute to a better world. We have learned a lot from the workshops and the scientists you assigned to us.

Thank you all, you gave us the chance to make the world a better place.

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- http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/processes/ anaerobic-digestion-general
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- www.groenegrondstoffen.nl
- www.marktplaats.nl
- www.oilgae.com
- www.originoil.nl
- www.seaweed.ie

People
Ben van den Broek
Dorinde Kleinegris
Tamara Havik
Tania Fernandes

APPENDICES

APPENDIX A: DESCRIPTION OF SPECIES

Red algae
Red algae are mostly metazoans and live in the littoral zone of the sea. Around 5000 species of the red algae have been discovered. Red algae thank their name to the use of the pigment r-fycoërythrine when carrying out photosynthesis. Red algae differ from the plants in 2 ways. The red algae produce no starch and they contain different pigments. Red algae are used in daily life as for example Nori (seaweed that the sushi is wrapped in). They contain a lot of vitamins and proteins. [36]

Diatoms
Diatoms have more than a 100.000 species, and together all these species form half of the primary food production in the sea. Diatoms are mainly eaten by zooplankton in both salt and fresh water. They are very attractive because of their skeleton made of silica (hydrated silicon dioxide), consisting of two parts called `valves`. Diatoms produce mostly oil to store the energy from photosynthesis and to make sure they will float in the water. [37]

Brown algae
This is the type of algae that most people hate. Brown algae cause the slimy layer on stones and on wood. Around 1500 to 2000 species have been discovered of the multicellular brown algae. They live in the sea and most people would regard this as the original seaweed. Due to the pigment fucoxanthin the brown algae are brown. The brown algae is used for the seaweed, and in some species of the brown algae, the aglicid acid is extracted and used for different kinds of products. [38]

Gold algae
1000 species of the gold algae are known, they mostly live in fresh water and are protozoa. Gold algae are famous for their beautiful colours. They contain the pigments chlorophyll a, c, and β-carotene. The gold algae move by using their two flagella. Those golden algae release toxins which are a serious threat to fish and clams. [39]

Yellow-green algae
Although the yellow-green algae contain the pigment chlorophyll c and thus are yellow/green, they are similar to the brown algae. 600 species are now known and most are protozoa and live in freshwater. [40] There is an exception, namely the specie Nannochloropsis. This specie lives in the sea and can produce a lot of oil as stock food. Research has shown that with a lower level of nitrogen (no favourable conditions) than sufficient, the oil production is twice as much. Therefore, the yellow-green algae can be used for oil production. [41]

Blue algae or cyan bacteria
Blue algae live in almost all the water; oceans, fresh water, salt water and damp soil. When there are lots of blue algae together, they can form blooms. Blooms seriously decrease the quality of the water. Furthermore, blue algae can produce toxins. Those toxins can kill animals and leave a rash after skin contact with humans. People can get seriously ill when a toxin is swallowed. [42]
The cell of blue algae is made up for 50% of proteins and the cell produces starch as stock food. Some of the species are used in daily life, such as Sprirulina. These algae are eaten by people who want to lose weight. [43]

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[36] http://www.seaweed.ie/algae/rhodophyta.php
[37] http://www.ucl.ac.uk/GeolSci/micropal/diatom.html
[38] http://www.seaweed.ie/algae/phaeophyta.php
[39] http://nl.swewe.net/word_show.htm/?130295_1&Gouden_algen
[40] http://www.ucmp.berkeley.edu/chromista/xanthophyta.html
[41] http://www.groenegrondstoffen.nl/downloads/Boekjes/12Microalgae_UK.pdf
[42] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298167/geho0809brgn-e-e.pdf
[43] http://www.groenegrondstoffen.nl/downloads/Boekjes/12Microalgae_UK.pdf

APPENDIX B: DIFFERENT CULTIVATION SYSTEMS [44]

Open ponds or raceways

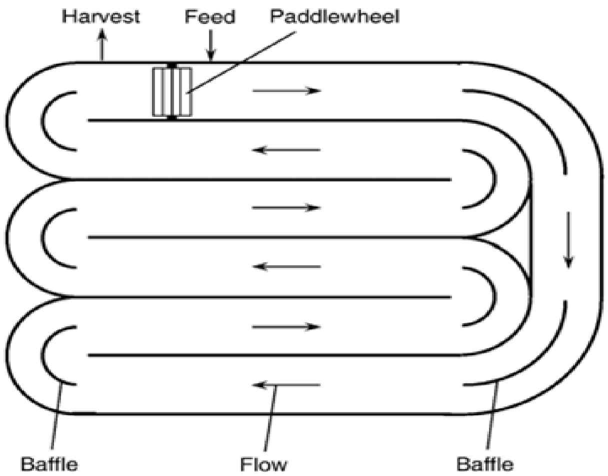
The most common cultivation system worldwide is the raceway system. The raceway system is composed of annular channels. The channels are shallow and the paddle wheels provide the system's flow and mixing. The raceway system has relatively low costs because of the simple construction. However, there are multiple disadvantages of this cultivation system. A raceway system is difficult to monitor, since the environment influences the circumstances. For example, water in the system evaporates and the system is sensitive to infections. These disadvantages limited the amount of usable and efficient algae.

Since the sunlight mainly reaches the surface of the open pounds, the raceway system is not the most effective cultivation system. Theoretically 10% of the solar energy can be converted to chemical energy, but in reality this is only 1.5%. This problem is caused by the limited penetration.

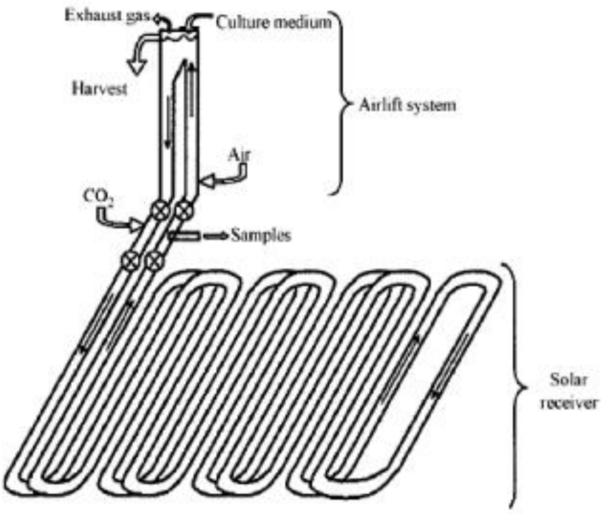
Single-layer or horizontal tube reactors

An example of a closed culture system is the single-layer system. The system is composed of a single layer of horizontal tubes. Because of the closed system, the controlling of the circumstances is much easier than in an open system. Therefore, the productivity per square meter is higher. Furthermore, the single-layer system can easily be enlarged by extending the tube length.

Of course, there are disadvantages of this system as well. A drawback is the high light intensity on the tube surface. This provokes a reduced growth of the algae, thus a lower productivity. Other disadvantages of the single-layer system are the costs of the total construction and the costs of circulating the algae in the water. Furthermore, the natural gas exchange cannot take place because of the closed system. This causes accumulation of the toxic O_2.



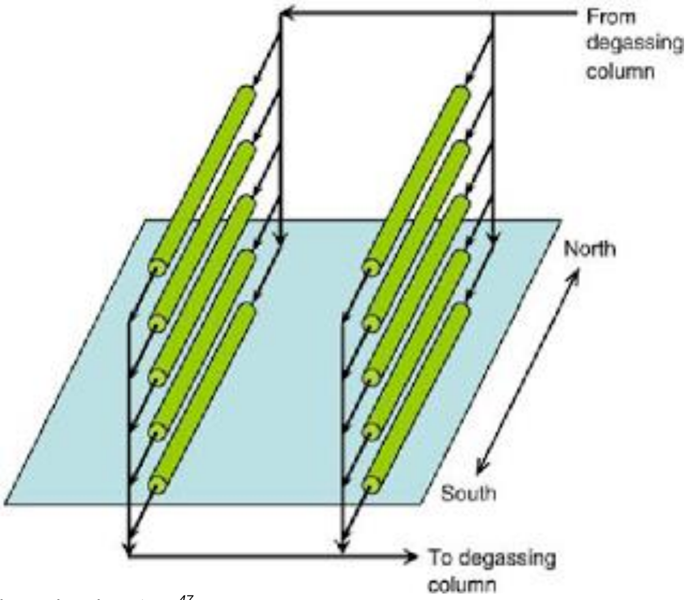
Raceway system [45]



Single-layer system [46]

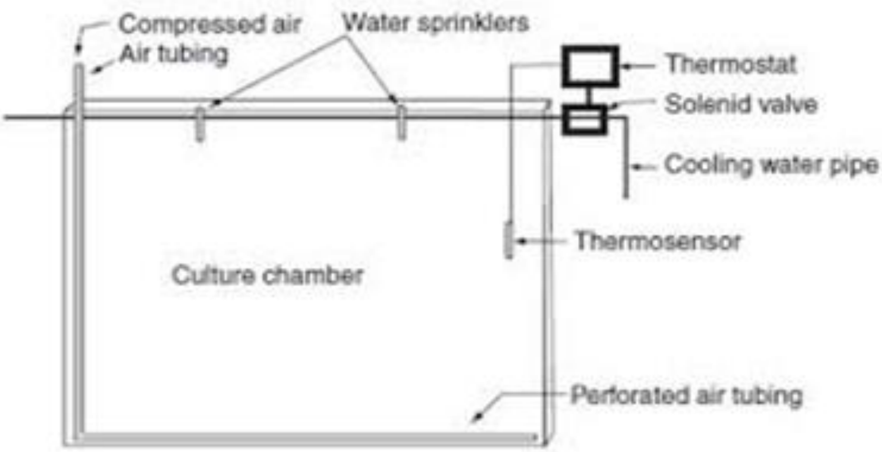
[44] http://www.groenegrondstoffen.nl/downloads/Boekjes/12Microalgae_NL.pdf
[45] https://wiki.uiowa.edu/download/attachments/38347194/raceway_pond.png?version=1&modificationDate=1272558953593&api=v2
[46] http://esciencecentral.org/ebooks/recent-advances-in-microalgal-biotechnology/images/RAMB_CO2-g002.gif

Three-dimensional tube reactors
The three-dimensional tube reactor system is quite similar to the single-layer system. The difference is that the tubes are placed vertically on top of each other. Therefore, the tubes are placed in each other shades. This concept provides the reactor does not suffer from a high intensity of light. Furthermore, the production per square meter has increased, compared to the single-layer system. The other advantages and disadvantages are the same as the single-layer system.



Three-dimensional system [47]

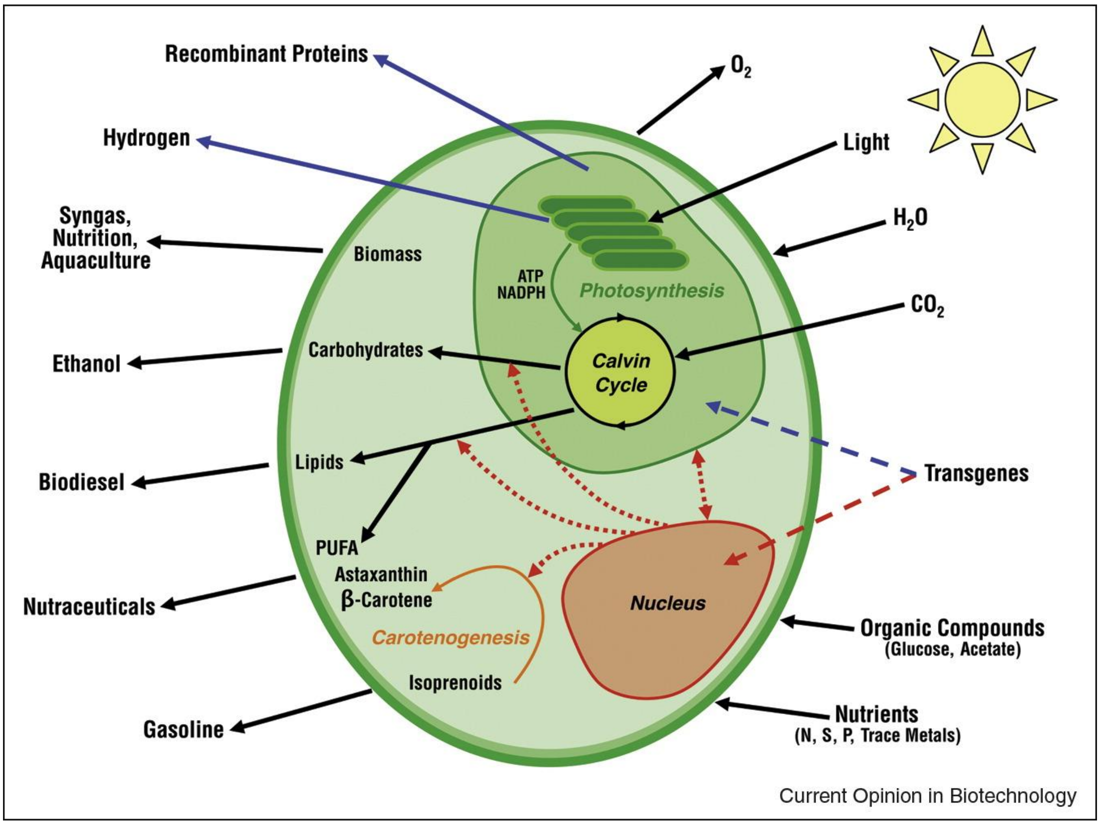
APPENDIX C: FLAT PLATE REACTOR[48]



[47] http://3.bp.blogspot.com/_RiZ7emAk6FM/TOvAnplnbnI/AAAAAAAAAAg/z7ZzSyj92Bg/s320/4.png
[48] http://www.oilgae.com/includes/site_img/fp_photobio.jpg

APPENDIX D: WATERBAG[49]

APPENDIX E: PHOTOSYNTHESIS MICROALGAE[50]



[49] http://www.biosolarcells.nl/over-biosolar-cells/proviron.html
[50] http://betenbaugh.org/microalgae-engineering.html date: 15-10-2014

APPENDIX F: EXPERIMENT

Aim:
The aim of the experiment is to find out which algae produce the most oil and to find out how oil is extracted. For this experiment, the Scenedesmus Obliquus and the Chlorella Vulgaris are used as algae.

Hypothesis:
As Chlorella Vulgaris and Scenedesmus Obliquus are both green algae, it is hard to say which algae produce the most oil. Based on research earlier done, the expectation is that the Scenedesmus will produce the most oil.

Equipment:
- 2 types of dried green microalgae
- Scale
- 6 Greiner tubes
- chloroform/methanol
- Sodium chloride
- vortexes (shaker)
- centrifuge
- Pasteur pipette
- counting vials of glass
- Nitrogen blower

Procedure:
These were the steps which are taken in order to conduct the experiment.
1. Way 25 mg of freeze dried algae and put it in a 15 ml Greiner tube. Do this for both the Chlorella and the Scenedesmus, fill 3 bottles of each.
2. Add 8 ml of chloroform/methanol.
3. Put both the bottles in a vortex.
4. Add 2 ml of 0.73% Sodium chloride.
5. Put the bottles in a vortex.
6. Put the bottles in a centrifuge, for 5 minutes at 25ºC.
7. Get the lower layer out, using a Pasteur pipette.
8. Put the lower layer in a counting vial of glass. Do this for all the 6 tubes.
9. Bring the 6 tubes to a nitrogen blower at 25°C to evaporate the solvent.
10. Way the bottles again and write down the results.

Results:

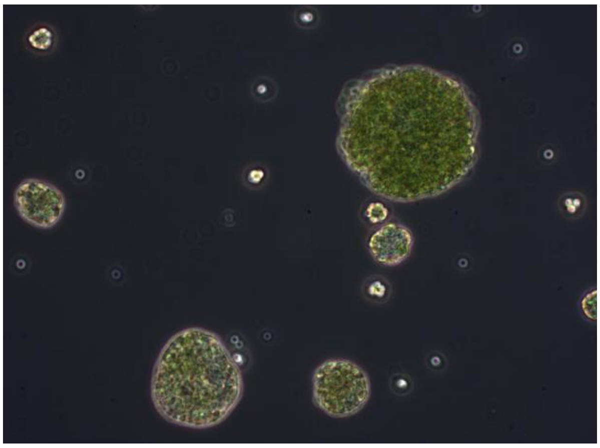
	Beginning (mg) Weight algae	Weight Greiner Tube (g)	End (g) Weight after nitrogen blower	Oil percentage (%)
S1	28.27	15.48580	15.48842	9.27
S2	25.92	15.25616	15.25931	12.15
S3	24.97	15.11449	15.11748	12.21
C1	27.75 - 27.65	15.40621	15.40774	5.53
C2	28.88	15.46399	15.47080	23.58
C3	26.23	15.31248	15.31402	5.87

The average oil percentage of the Scenedesmus Obliquus is: 11.21%.
The average oil percentage of the Chlorella is: 11.66%.

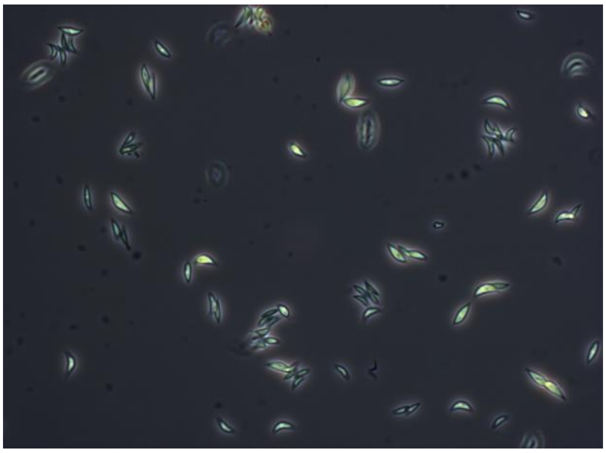
Discussion:
First of all, the experiment is done for both species 3 times, using 3 different bottles. The oil percentages for the different algae were almost the same, except for C2. This is probably due to the

fact that not all the solvent had evaporated yet.

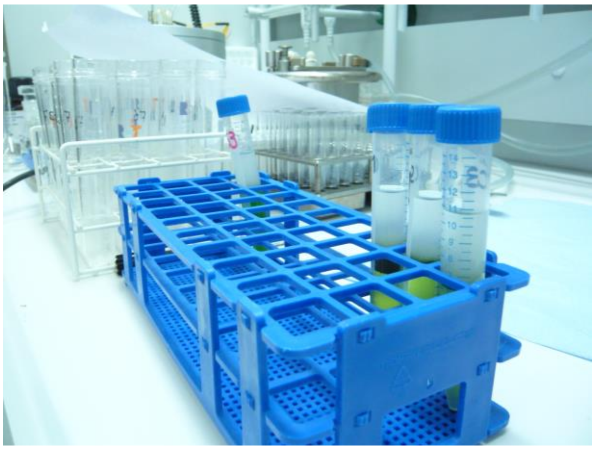
Conclusion:
After looking at the average percentages of oil, it is unclear which algae can produce the most oil. To come to a conclusion, all the oil percentages have to be taken into consideration. It is most logical that C2 is not accurate. Leaving the oil percentage of C2 out causes the average oil percentage of the chlorella to be 5.7 %. This shows that the best specie to produce oil is the Scenedesmus Obliquus.



Microscopic photo Chlorella (400x)



Microscopic photo Scenedesmus Obliquus (400x)



The algae before the centrifuge, different layers have appeared

The algae after the nitrogen blower, the oil

APPENDIX G: EXTRACTION OF OIL[51]

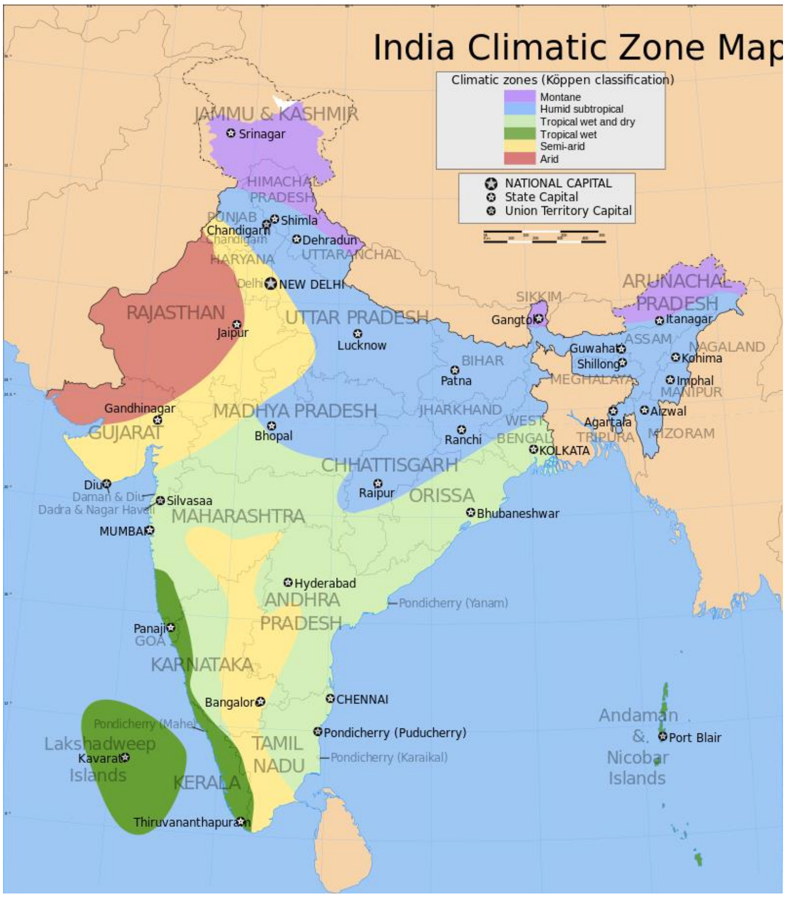
Mechanical methods
Expression/expeller press: The press works just like an olive press.
Advantage: Easy and cheap to use
Disadvantage: The algae need be dried before the press can be used; this takes a lot of energy.
Ultrasonic-assisted extraction: The ultrasonic reactor creates waves which cause bubbles. When these bubbles collapse near the cell wall of the algae, the cell wall breaks and the algae loses the oil in the solvent.
Disadvantage: the oil still needs to be extracted from the solvent and the ultrasonic reactor is quite expensive.

Chemical methods
Hexane Solvent Method: This method is mostly used in combination with the expression/expeller press. After the oil has been extracted, it still contains biomass. The oil will solve in the hexane and the biomass can be filtered out.
Advantage: It is very cheap.
Disadvantage: Hexane and other chemical solvents are dangerous to use (health and safety issues).
Soxhlet extraction: Soxhlet extraction is a way in which the algae go through different solvents different amount of times. The oil is extracted this way.
Advantage: Cheap
Disadvantage: Takes some time and the solvents are dangerous.
Supercritical fluid Extraction: For this extraction, CO2 is used. The CO2 acts as a solvent but first the CO2 needs to be a gas and a liquid at the same time.
Advantage: By using this method, almost 100 % of the oil is extracted and less solvent is needed.
Disadvantage: The equipment that is needed is very expensive and the method takes a lot of energy.

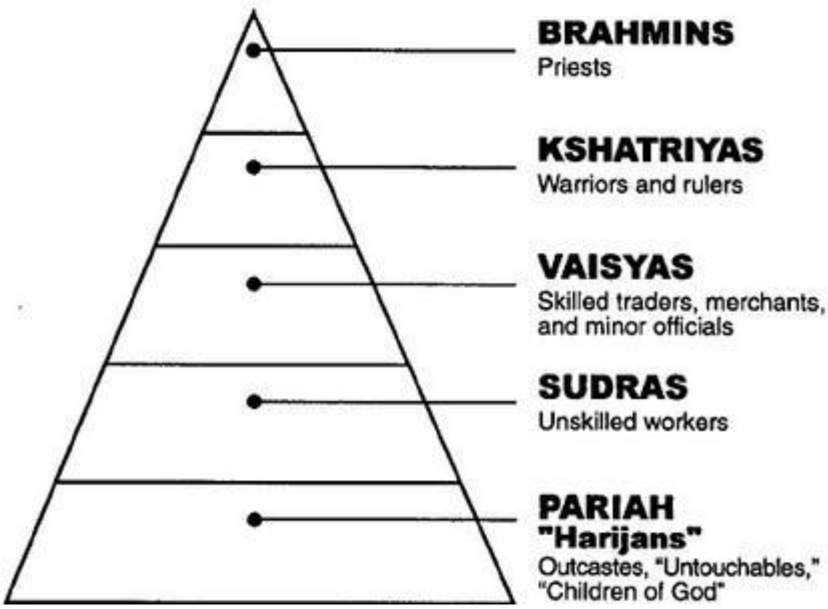
There are furthermore to other methods besides the mechanical and chemical methods.
Enzymatic extraction: Enzymes are used to destroy the cell walls and water is used as the solvent.
Disadvantage: Very expensive.
Osmotic shock: The osmotic pressure is suddenly changed, this causes the cell walls to break and oil is released.

[51] http://www.oilgae.com/algae/oil/extract/extract.html
http://science.howstuffworks.com/environmental/green-science/algae-biodiesel2.htm

APPENDIX H: CLIMATIC ZONES OF INDIA[52]



APPENDIX I: CASTE SYSTEM PYRAMID[53]



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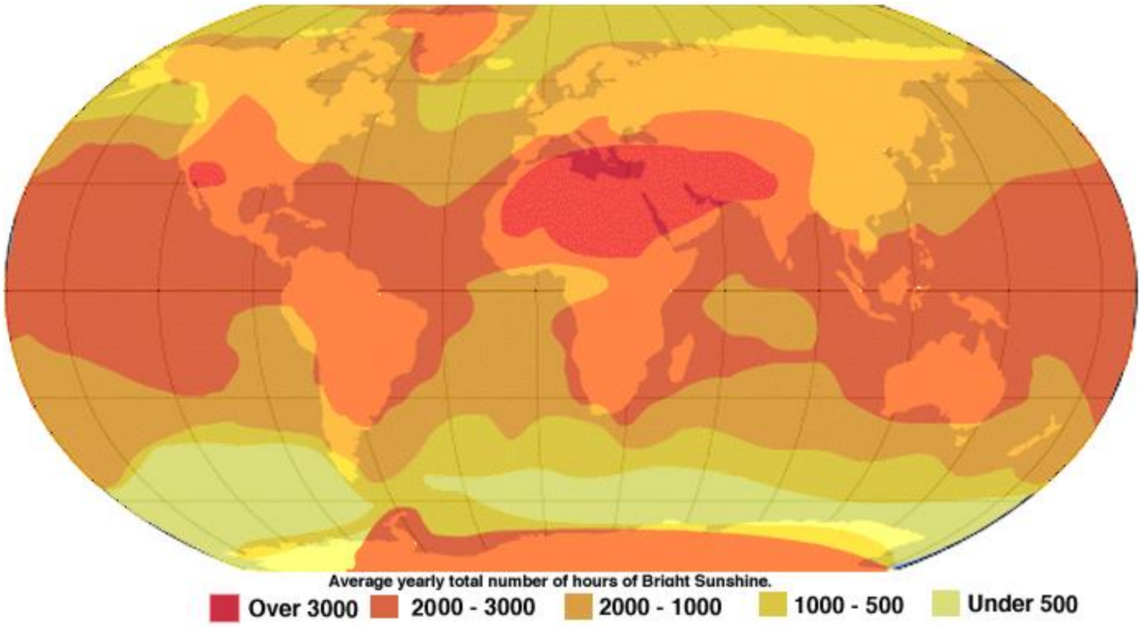
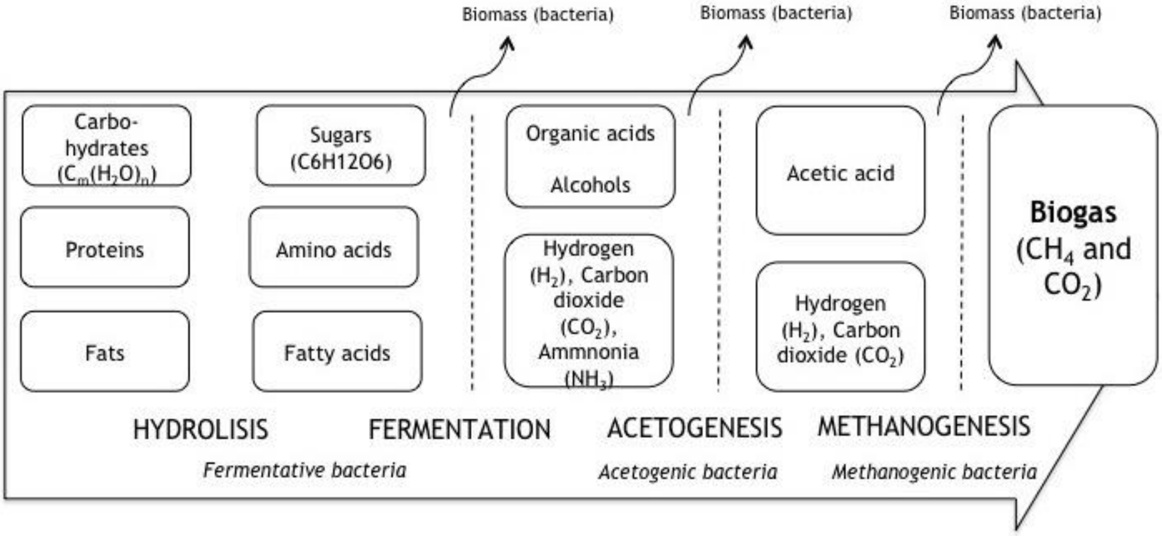
[52] http://en.wikipedia.org/wiki/Climatic_regions_of_India (25-11-2014) based on the Köppen classification system
[53] http://imgarcade.com/1/caste-system-in-hinduism/ (23-01-2014)

APPENDIX J: HOURES OF BRIGHT SUNSHINE WORLDMAP [54]



APPENDIX K: PRODUCTION OF BIOGAS

This biogas is produced during the fermentation process. This fermentation process is the second step of the anaerobic digestion. The anaerobic digestion is divided in four stages. In the first stage, the hydrolysis, complex molecules are broken down to fatty acids, amino acids and short sugars. During the fermentation, bacteria convert sugars and other products which are formed during the hydrolysis to alcohols, CO_2, organic acids, NH_3 and hydrogen. In the third step, the acotegenesis, products formed during the fermentation are transformed into hydrogen, CO_2 and CH_3COOH, acetic acid. To produce this acetic acid, the acetogenic bacteria need carbon and oxygen. Therefore, an anaerobic condition is created, which is essential for the last step: the methanogenesis. In this final step, the acetic acid, hydrogen and CO_2 are transformed to biogas.



Anaerobic digestion[55]

[54] Earth Forum, Houston Museum of Natural Science; Data from the World Resources Institute http://earth.rice.edu/MTPE/geo/geosphere/hot/energyfuture/Sunlight.html (25-11-2014)
[55] http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments/b

APPENDIX L: COSTS TOILETS

Building materials (€200.00)
± € 20 for one toilet [56]
10 toilets → €200.-

People to build (€75.00)
Minimum wage India = $0.28/hour ≈ ₹17.35/hour ≈ €0.24/hour [57]
Time to build the toilets: ±150 hours = ± 2 days with 10 people
€0.50/hour → € 75.00

Toilet paper (€345.00/year)
The Netherlands: ±1 roll (20 meter) for each person every week.
Because the local people normally never use toilet paper, the expectations of usage are low.
To start with 1 roll (170 meter) for each toilet every month
→120 rolls of toilet paper/year
12 rolls = €34.50 [58]
→ € 345.00/year

Cleaning products (€900.00/year)
± 5L chlorine for one toilet in 2 months
→ 60 cans (5L) for 10 toilets every year
Chlorine (5L) = € 14.99 [59]
→ €900.00/year

People to take care (€3,832.50/year)
Minimum wage India: €0.24/hour
Day job: ± 7 a.m. – 9 p.m.
Payment (14 hours): € 3.50
During the day, two people take care of the toilets → € 7.-
Night job: ± 9 p.m. – 7 a.m.
Payment (10 hours): € 3.50 (harder job)
During the night, one toilet block is opened and therefore, one person takes care → €3.50
→€ 10.50/day
→€ 3,832.50/year

Safe (€26.64)
Safe= €13.32 [60]
One safe for one toilet block and therefore, two safes are needed → € 26.64

[56] http://www.connectinternational.nl/overconnect/nieuws/emailci?page=0%2C0%2C0%2C17
[57] http://en.wikipedia.org/wiki/List_of_minimum_wages_by_country
[58] http://www.cleandirect.nl/64-toiletpapier
[59] http://www.vikingdirect.nl/catalog/catalogSku.do?id=7511038&pr=QH1&cm_mmc=Google-_-PLA_GEN_GOOGLE-SHOPPING_google-shopping_-_-google%20shopping-_-glorix&s2m_channel=544&s2m_campaign=PLA_GEN_GOOGLE-SHOPPING_google-shopping_&s2m_exaffid=google+shopping
[60] http://www.officesupplies-shop.nl/wedo-geldkoffer.html?gclid=CP7Q8bvRkcMCFauWtAod_XcAUA

APPENDIX M: COSTS LABORATORY

Accommodation (€1,050.00)
Several businesses will be hired to build the accommodation. It does not need to be a sophisticated building, but there must be a place where the administration can be done and where the oil extraction can take place.
Construction costs India[61]: 2300 rupees/m^2
₹2300 ≈ €30.00/m^2
The accommodation will have a surface of approximately 35 square meters.
35 * €30.00 = €1,050.00

Biogas reactor (€210.00)
More expensive ones are around €130.00, building included.
Estimated costs simple biogas balloon: €70.00 pp.
3 pieces to start with: 3 x 70 = €210.00

Cultivation Systems (€360.00)
Water bag = €10.- per m^2
6x2 meters = 12 m^2 /water bag
3 pieces → €360.-
Production/operating costs of water bag: €10.49 / kg DW[62] → contains also installation, maintenance etc.
0.477 kg/day (calculation at appendix 15: profit structure) * €10.49 * 365 = €1,826.36
This is calculated with Dutch prices, therefore, the costs in India will be less high. The salaries and price of materials are lower and the water bag does not have to be heated, since the temperatures in India are far higher than in the Netherlands. Therefore, the estimation of the costs in India is 60% of the total price: 0.6 * €1,826.36 = €1,095.81
When this price is round off, it will be €1,100.00 for the whole maintenance, installation and materials for the water bag.
14% of this price is an investment (installation) and the other 86% is a repetitive cost.
0.14 * €1,100.00 = €154.46 → €155.00
0.86 * €1,100.00 = €945.53 → €945.00

Materials to extract oil (€700.00)
Pulser: approximately €200.00[63]
Pumps and pipes: €200.00
Tanks: €200.00
Installation coasts: €100.00
Total costs approximately: €700.00

Energy costs extraction: $0,20/kg[64]
410625 g algae/year
$0,20 ≈ €0,18
0,18 * 410,625 ≈ €73,91

costs of CO_2 : $235/1000 pounds[65] ≈ €0,50/kg
For one year: roughly 300 kg → 0,50 * 300 = €150,00

Total maintenance: energy costs, CO_2 and extra: €250,00

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[61] http://www.indianrealestatefordummies.in/2013/04/what-will-your-construction-cost-per.html
[62] Taelman, S.E., et al. The environmental sustainability of microalgae as feed for aquaculture: A life cycle perspective.Bioresour. Technol. (2013), http://dx.doi.org/10.1016/j.biortech.2013.08.044
[63] http://www.amazing1.com/emp.html
[64] http://www.originoil.com/pdf/OOIL_World_Biofuels_Markets_100316.pdf
[65] http://www.kaycircle.com/What-Is-The-Average-Cost-Of-Liquid-CO2-Average-Liquid-CO2-Price

Employees (€3,494.40/year)
In the laboratory: one scientist and one local inhabitant
Scientist: €1/hour
Local: €0.60/hour → total: €1.60/hour
Work in the laboratory: 7 days/week and 6 hours each day → 42 hours/week
→ €67.20/week
➔ €3,494.40/year

People to build (€245.00)
10 people working 1 week of 7 hours a day: 490 hours.
€0.50/hour: € 245.-

Microalgae (€130.00)
One living culture chlorella: €130.00 [66]

Water
6 m^3 water in one water bag as buffer, this can be salt water
Therefore, the water will be supplied from the sea.
The further use of water will be very small, thus it is not added in the cost structure.

Phone (€240.00/year)
Phones for the employees
± €20.00/month → ±€240.00/year

APPENDIX N: COSTS TRANSPORT

Vehicles (€1,000.00 + €300.00/year)
To transport the urine and faeces and the oil, a Pick-up is needed.
In the Netherlands a pick-up costs ±€1,600.- [67] and the price in India is expected to be lower.
Expectation: €1,000.00
Furthermore, maintenance costs are involved, which will be around €300.00/year.

Fuel (€208.00/year)
Normal fuel: € 0.94/L
Super fuel: € 0.93/L
Super plus: € 1.08/L
Diesel: € 0.81/L [68]
Expectation to drive 60 km/week. Use of normal, cheapest fuel.
15 km/L → 4L/week
→± €4.00/week → €208.-/year

[66] http://utdirect.utexas.edu/txshop/item_details.WBX?application_name=BSALGAES&component=0&dept_prefix=BS&item_id=102&cat_seq_chosen=01&subcategory_seq_chosen=000
[67] http://www.marktplaats.nl/a/auto-s/volkswagen/m881106597-volkswagen-transporter-2-4-d-292-pickup.html?c=a2384ef0ece270f44503df9f8598c624&previousPage=lr
[68] http://nl.gas-globe.com/international.phtml?kontinent=EU&land=75&einheit=Liter&waehrung=USD)

APPENDIX O: PROFIT STRUCTURE

Rough oil (€36.96/year)
The daily harvest of one water bag is in the Netherlands: 0.53g/L
This means per litre algae in the bag, 0.53 gram algae adds to the total mass of algae. In Spain, the daily harvest is 1.25 g/L. Since India is more comparable to Spain than to the Netherlands, the daily harvest in India is estimated at 1.25 g/L.
The amount of litres of algae in one water bag is: 300 L
1.25 * 300 * 3 * 365 = 410625 g algae/year
The oil content of microalgae can easily reach approximately 20% of the dry weight.
0.20 * 410625 = 82125 g oil/year
Density: 0.90 g/cm^3
82125 * 0.9 = 73912.5 cm^3 ≈73.91 L oil/year
estimation of €0.50/L: 73.91 * 0.50 ≈ €36.96

Biogas (€125.81/year)
3 biogas reactors with a content of: length 4 m * wide 1.5 m * depth 1.5 m = 9 m^3
Per cubic meter digester: 0.3-0.5 m^3 biogas. Average: 0.4 m^3 biogas.
9 * 0.4 = 3.6 m^3
The blackwater stays around 15 days in the reactor:
365 / 15 ≈ 24 times of refilling.
24 * 3.6 m^3 biogas * 3 reactors = 259.2 m^3 biogas/year
1 m^3 biogas delivers 6 kWh → 259.2 * 6 = 1576.8 kWh/year
The required price for kWh in India is to be found between 5.41 and 5.73 rupees.[69]
Average: 5.57 rupee/kWh
5.57 * 1576.8 = ₹8782.78 ≈ €125.81

Biomass algae (€7,475.20)
80% of 410625 g = 328500 g biomass
Chlorella: $23.00 / lb.[70]
1 pound is 0.45 kg
328.5 kg/0.45 = 730 pound biomass/year.
$23.00 = €20.48
730 * 20.48 = €14950.40
Since the algae grew on human faeces, the biomass can't be used for all commercial purposes. It still can be used for chemicals.
Since the biomass which is created during the single step extraction is not ready for sale yet, the profit of it will not be as high as €14,950.40. Since this biomass has to endure several processes before it can be sold as the algae powder on which the calculation is based, the estimation is that it will be 0.50 of this price: €7,475.20.

Toilets (€7,503.80/year)
Visiting the toilet = ₹1 ≈ €0.01
One toilet will be visited ±150 times/day
Total: 1500 visitors/day → ₹1500/day
→₹547500/year ≈ €7,503.80/year

Sponsors
There will be searched for sponsors when the profits alone are not enough to keep the business going.

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[69] http://www.ieefa.org/wp-content/uploads/2014/05/IEEFA-Briefing-Note_IndianElectricityCoalPricing_4-May-2014.pdf
[70] https://www.buyalgae.com/product/chlorella/


शौचालय
TOILETS