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ALGAL OIL - THE NEXT DIESEL FUEL? A STRATEGIC NICHE MANAGEMENT APPROACH TO THE DEVELOPMENT OF NREL'S ALGAL OIL RESEARCH I Wayan G. Santika1), Jackie T. Lava2), Dieu Thanh Ho3) 1)Mechanical Engineering Department, State Polytechnic of Bali Kampus Bukit Jimbaran, Badung, BALI Phone:+62-361-701981, Fax:+62-361-701128, Email: wayangs@yahoo.com 2)STEDIN, Rotterdam, The Netherlands 3)Business Support Associates (Ltd.), Ho Chi Minh City, Vietnam Abstract: The present paper analyzes how the experiment conducted by the US Government's National Renewable Energy Research Laboratory (NREL) on algal oil as biodiesel influenced the development of the biodiesel technology. The research, known as the Aquatic Species Program (ASP), was funded by US Department of Energy with an objective of determining the technological, environmental and economical feasibility of using high-oil algae for biodiesel. The discussion is limited on the United States transportation sector during the year of 1978 to the present. Using a Strategic Niche Management (SNM) approach, we examine actors' expectations, their social networks, and methods of learning processes on algae technology. Keywords: Algal oil, strategic niche management, NREL, and aquatic species program Minyak Alga - Bahan Bakar Diesel Masa Depan? Sebuah Analisis Strategic Niche Management Mengenai Pengembangan Riset Minyak Alga oleh NREL Abstrak: Tulisan ini menganalisa pengaruh penelitian minyak alga sebagai biodiesel terhadap pengembangan teknologi biodiesel yang dilakukan oleh National Renewable Energy Research Laboratory (NREL) milik pemerintah Amerika Serikat (AS). Riset yang disebut Aquatic Species Program (ASP) ini dibiayai oleh Departemen Energi AS dan bertujuan untuk menentukan kelayakan penggunaan alga sebagai bahan biodiesel dikaji dari sudut teknologi, lingkungan, dan ekonomi. Pembahasan dibatasi hanya pada sektor transportasi AS dari tahun 1978 hingga kini. Menggunakan pendekatan Strategic Niche Management (SNM), kami menelaah ekspektasi para aktor, jaringan-jaringan sosial, dan metode-metode proses pembelajaran terhadap teknologi alga. Kata kunci: minyak alga, strategic niche management, NREL, dan aquatic species program I. INTRODUCTION The transportation sector consumes a significant amount of energy. In Asia alone, this consumption is expected to rise from 6.9 Quadrillion Btu in 2010 to 10.6 Quadrillion Btu in 2030 [1]. Unfortunately, this sector depends highly on petroleum based products, an energy source that is limited and polluting. The Energy Information Administration (EIA) projects that transportation will experience the fastest energy growth among sectors that use energy [2]. The 1973 global oil crisis also contributed to the instability of the transport fuel regime. The oil crisis started when the Arabian members of OPEC announced that they will not permit shipping or exporting of oil to nations that supported Israel in its ongoing war with Syria and Egypt. As a result, prices of oil rose sharply throughout the western part of the world from $0.25 to $1.0 in just a couple of months [3]. With this global oil crisis going on and the growth projections for the transportation sector, the US government was faced with the challenge of finding alternative sources of fuel to ensure a continuous supply to the country. One of the alternatives is to find suitable renewable sources that can, if not completely but gradually, replace our dependency on these remaining precious fossil fuel reserves. Biomass is seen as one of the major alternatives and definitely one of the biomass sources is algae. The present paper analyzes how the experiment conducted by the US Government's National Renewable Energy Research Laboratory (NREL) on using algae as biodiesel influenced the development of the biodiesel technology. The research, known as the Aquatic Species Program (ASP), was funded by US Department of Energy Copyright ©JURNAL MATRIX 2011 with an objective of determining the technological, environmental and economical feasibility of using high-oil algae for biodiesel [4]. The discussion is limited on the United States transportation sector during the year of 1978, when the research was started, to the present. In the present paper, we only discuss actors expectations, social networks, and learning processes on algae technology. II. METHODOLOGY The case study methodology is used to aproach the problem since we are going to answer the questions of how and why [5]. We use multiple source of information during data collection. All data are written materials and mostly collected from the ASP close out report, NREL website, research papers, newspapers, and some company websites. No interview was conducted. III. THE CASE STUDY The Aquatic Species Research Program (ASP), established in 1978, was funded by the United States Department of Energy (US DOE). The primary goal of the ASP was to investigate how waste CO_2 from coal fired power plants can be used to cultivate high lipid-content algae to produce biodiesel [4]. The project initially focused on cultivating macroalgae, microalgae and emergents and using it to sequester CO_2 from the coal-fired plants as well as hydrogen production from algae. However, after observing that some algae have high oil content, the project switched emphasis and focused on growing microalgae for producing biodiesel [6]. The shift in emphasis was not mentioned explicitely in [4] however, we can only infer that diesel production was not the main trigger for the research but it was CO_2 capture. The project started in 1978 and ended in 1996. From the research, it was concluded that biodiesel from algae can replace the US' yearly diesel demand with less resources needed [6]. According to [4], the research mainly focused on the feasibility of the technology and touches briefly on the social events that were ongoing during the course of the research. The program performed several experiments in California, Hawaii and New Mexico. At the beginning of the program, no previous experiments were performed in algae technology, researchers had to start from the beginning and build a collection of the different species of algae that can be used. Demonstrations on open pond systems were also conducted in an attempt to simulate mass production. A reduction in government budget caused the DOE to terminate ASP and focus its efforts and, consequently, its finances to the development of bioethanol. In the close out report [4], it was mentioned that the technology still requires R & D and that the cost of biodiesel from algae is double the cost of petroleum diesel. When the research started, they projected that the price of crude oil will continuously increase thus, research was justified. However, in the early 1990's the price of crude oil were not as high as expected. The situation brought about a change in expectation in the cost efficiency in the algae technology as well as the loss in motivation to develop the technology. The results of the ASP experiment have inspired private companies to start their own research work on algae technology. Sky high crude oil prices are bringing back interest of government and private entities in this field. Even oil giants such as Chevron and Shell have shown interest in investing in this technology [7,8]. 2.1. Algae Technology Algae (singular alga), the most primitive form of plants, is considered to be an efficient converter of energy because of its simple cellular structure [4]. Algal fuel is a third generation biofuel and compared to the second generation biofuel, algal fuel is high-yield feedstock (10/kg and 30 times more energy per acre than terrestrial crops) [9]. In addition, algae consumes a lot of carbon dioxide during cultivation therefore also provides a mearns for recycling waste carbon dioxide. The technology has been around since the 1950's where it focused more on using wastewater to grow algae [4]. The ASP extended algae fuel concept and developed the technology. The ASP program collected microalgae species, studied the physiology and biochemistry of the algae, process engineering and mass production of the algae cultivation, and conversion to the fuel process. Algae were cultivated in raceway ponds where water and nutrients are continuously fed. Waste CO_2 is continuously "bubbled" into the pond and captured by the algae. Figure 1 shows the algae pond schematic. Figure 1. Algae Pond Schematic [4] Test sites in California, Mexico, and Hawaii showed that for ponds greater than 1000 m2, 90% of the CO_2 injected into the pond was consumed by the algae [4]. Once the algae are harvested, oil is then extracted thru the process of transesterification. 2.2. The US Diesel Market In the year 1975, the energy demand for transportation was 18.2 quadrillion Btu, rising to 24.8 in 1996 and is projected to reach 36.5 quadrillion Btu by 2020 [2]. Petroleum products such as gasoline, jet fuel, and diesel dominate the energy use in the transportation sector while alternative fuels remain low. The demand for diesel fuel is still about 5 quadrillion Btu in 1996 [2]. During the time the ASP program was terminated (1996), the price of diesel fuel was $1.141/gallon and the projected 2020 price was $1.327/gallon [2]. The ASP study showed that the cost of biodiesel from algae would range from $1.40 to $4.40 per gallon based on long-term and current projections indicating that the technology could not compete with the current and projected costs of diesel [4]. Since the fossil fuel technologies are already well developed and optimized, they can be sold at a cheaper price. Meanwhile, new energy technologies like algal oil still need to overcome institutional and social barriers like unclear government policies and acceptability of the technology to the public [10]. Despite this relatively gloomy outlook on the future of biodiesel from algae and there were still some lessons to be learned on the development of the algal oil technology. The results of the Aquatic Species Program were instrumental in influencing other government departments, private research companies and oil companies in exploring the field of the biodiesel from algae technology. It leads us to the question: How did companies, government organizations and other concerned parties learn about the results of the Aquatic Species Program? What were the types of learning processes involved and which processes were dominant? IV. ANALYSIS OF THE NICHE PROCESS 4.1 Voicing and Shaping Expectations Expectations play a crucial role in the direction of an experiment. As can be seen from the ASP's fate, failure to meet expectations can also result in the termination of an experiment. Expectations statements can be classified in three (micro, meso and macro) depending on the level of detail [11]. Micro expectations are problem specific, they talk about artifacts and process to be developed. Micro expectations influence the local agenda. Meso expectations are less specific they are more about the functional requirements of a certain technology. Lastly, macro expectations are broad and general expectations. They are the least specific of the three and give the overall expectation from the technology. Micro Expectations. The micro expectations on the algae technology are that the oil extracted from the feedstock will have the same (or better) properties as the conventional diesel fuel. It must follow the same ASTM specifications for diesel fuel. The list of ASTM requirements for biodiesel can be seen in [12] with the importance of each parameter included. Micro expectations are mostly from the users of the algae technology. They are the car manufacturers and most importantly the vehicle owners and drivers. These expectations shape up the research agenda of the scientists/researchers involved in the algae technology. Meso Expectations. Meso expectations are formulated by actors who use the technology and actors who are involved in policy making. These are the government representatives, environmental organizations, health organizations and people involved in the algae fuel industry. We recognise three meso expectation in this case. First, carbon dioxide emissions should be within the allowed levels of the existing regulations. This expectation is already taken into account when the algae technology was considered. Algae consume a large amount of CO_2 during cultivation. Second, the alternative should use less resources so as not to compete or affect the food production. Today's biofuel production through traditional agricultural crops produces 100 gallons per acre each year. Through algae based production that number can increase from up to 10,000 gallons per acre each year depending on which species is used. The amount of water it takes for 1 acre traditional crops can be used to supply nearly 100 acres of algae bioreactors. In addition, this technology is expected to address the issue of using food for fuel [13]. Third, the technology should create employment opportunities. Algae can either be grown in the wild or in controlled environments. Either option will require people to run the plant. In addition, it may also stimulate growth in the area of R&D for the process equipment to be used. Macro Expectations. Macro expectations steer the technology in the direction where it is expected to grow by the actors. These types of expectations are general and try to take into account inputs from all actors. Three expectations are considered. First, the technology should contribute to Energy Security. This is arguably the most important driver for the Biofuels program of the United States. During the 1980's the US was importing more oil than it is generating. They have become dependent on foreign oil. Most of the imports come from the Persian Gulf, thus, the US is vulnerable to any event happening in the Persian Gulf which affects crude oil production. A decrease in supply can bring about an increase in fuel prices which may bring about an increase in the cost of basic commodities. Second, affordability of the technology. It is expected that once this technology reaches the mainstream, the cost of investments will decrease and once knowledge on the operation and maintenance of algae plants become widespread, operation costs will also decrease. Currently, the cost of biodiesel from algae is $ 1,40 - 4,40 per gallon [4] which is still more expensive than conventional diesel. Third, synergy of coal and microalgae. About 25% of the world's coal reserves are in the United States. It is projected that coal will continue to supply the US' energy demand. The production of electricity from coal emits a significant amount of carbon dioxide. Therefore, there is a need for technologies which solve the energy crisis and clean up the environment as well. 4.2 Ups and Downs in Expectations Expectations in algae technology fluctuated over time. Ups and downs in expectations will be divided in two periods, the first period is before and during the experiment, and the second is the current conditions. One concern is that the experiment was vulnerable to oil price fluctuation. Ups and downs in expectations were, and still are, greatly influenced by crude oil prices,as dictated by the Foreign Oil Exporter Countries. This condition is external and beyond the control of the experiment and even the regime. Expectations during the experiment period (1978 – 1996). Other than energy security, climate change and synergy of coal and microalgae, expectations were not clearly stated in the closeout report. At the beginning of the research (micro expectation), algae cultivation was dedicated in wastewater treatment and expected to absorb CO_2 emitted by power plants. The expectation shifted when it was noticed that the algae has high oil content. New technological opportunity (as expectation) emerged. When a new expectation emerged, generated externally or from previous work, its protagonists formulated promises about future performance and functionality to attract attention from sponsors. If the promises are accepted, they are translated into a share expectation, new goals, specifications, requirements and task divisions, for which projects are developed [14]. Funding increased from one year to the next. However, after the boom funding years of 1984 and 1985, funding fell rapidly to its lowest value in 1991 [4]. Due to external changes in the project (change in crude oil prices) the expectations became harder to meet and making the project less viable. In early 1990's, fossil fuel prices were lower than expected and the prices were predicted to be stable in the coming years. Higher costs in producing algae biofuel turned to negative expectation among actors. According to Geels & Raven as in [14], when learning processes produce outcomes that do not meet the expectations, this lead to a backlash in expectations that turn from positive to negative. When actors' beliefs turn sour, networks fall apart and resources are reduced, leading to decline in development [14]. Aquatic Species Program funding was eliminated in 1996 due to limited budget available in US Department of Energy. Negative expectations were used to legitimate the decision to stop the funding in algae researches. Recent Expectations. High oil prices recently (Northern California retail diesel oil price in May 2008, for example, reaches $4.908 per gallon [15]) has turned back the expectation positively on algae biodiesel research. New promises are formulated, new goals are set, new actors get involved and new networks and researches are established. Oil companies start to provide funding for the researches. Chevron in collaboration with NREL [8], for example, has agreed to fund further research development in algal strains that can economically be processed into transportation fuels. Most of the countries around the world have ratified Kyoto Protocol as a commitment to reduce CO_2 emission [16]. Sustainable energy productions such as algae technology regain its momentum in reducing CO_2 emission expectation. Expectation in algae as a promising oil source also spreads around the world. Japan announces a slogan to become an oil exporter country by 2025 based on algae derived oil [17]. In Australia, Queensland Premier announced $166,000 in government funding for a biodiesel plant and algae farm in Townsville, which would produce around 290 million tonnes of biodiesel by 2010 [18]. 4.3 Social Networks 3.3.1. During the experiment period (1978-1996) During the course of the experiment of biodiesel from algae, 4 actors can be observed: government, users, NREL, and universities. US Government expectations on algae biofuel are related to carbon dioxide emission reduction, employment creation opportunity, and contribution to energy security. US Government acted as resources of protective regulations and financial. US Government involved from the beginning of the experiment in 1978 until it ended in 1996 as the main financial sponsor of the experiment. In 1970 government through Environmental Protection Agency (EPA) came out with a passage called Clean Air Act that gives rights to EPA to more tightly regulate the emission standards of air pollutants such as nitrogen oxides, carbon monoxide, ozone, etc. Although it was not meant to directly regulate to protect the development of researches in biodiesel, this act has made the United States reconsidered to use biodiesel as a cleaner source of fuel. Another regulation passed in 1992 by EPA named Energy Policy Act aimed at increasing the usage of alternative fuels by the US government transportation fleets in order to reduce the dependencies on foreign fuels [18]. The regulation boosted researches on renewable energy sources. Users may be considered as actors who use the product of biodiesel. In this case they might be car manufacturers and power plant owners. The involvement of car manufacturers has not been mentioned explicitly in the experiment. This condition in turn might have weakened the importance of the experiment as a niche since users might give critical input in shaping the direction of the experiment. Car manufacturers' expectation is usually related to the affordability of the technology. Since the production costs of algae biofuel were higher than conventional fuel prices, this expectation could not be met. Fortunately, with the recent increase in fuel prices, the technology is becoming economically feasible. The power plant owners simply expect the synergy of coal and microalgae. As stated in the closeout report of Aquatic Species Program, algae technology can extend the useful energy we get from coal combustion and reduce carbon emission by recycling waste CO_2 from power plants into clean-burning biodiesel [4]. This kind of expectations motivated power plant owner to support the experiment. Power plants owner in New Mexico, to give an example, provided their power plants as the site of the researches conducted by The Roswell. The termination of the ASP project in 1996 might cause doubt to the feasibility of the technology. The fact that power plant owners recently pay more attention to Carbon Capture and Storage (CCS) technology may indicate that expectation in algae technology has diminished and shifted to CCS. NREL, the laboratory that carried out the experiment, is the main actor at which all the expectation, from micro, meso, and macro, are expected to be achieved. Promises (and promising researches) that led to expectations are all related to NREL. NREL should have set high promises to attract other actors' attention, resources, time and money. NREL is classified as the inside firm who possesses two important resources consisting of engineering expertise to develop biodiesel from algae and financial expertise to raise fund. NREL is the U.S. national primary laboratory for renewable energy and energy efficiency research and development. The laboratory's scientists and researchers support critical market objectives to accelerate research from scientific innovations to market- viable alternative energy solutions [20]. The total cost of the Aquatic Species Program is US$ 25.05 million over a twenty-year period [4]. NREL involved in the experiment throughout its period of about twenty years and played the major role in implementing and managing the research. There are also NREL's subcontractors who involved in the early phase of the research to conduct site collecting of different algae species and in different conditions in the west, the northwest and the southeastern regions of the continental U.S. as well as in Hawaii [4]. Their specific tasks were in growing algae to help the research in screening, isolating and collecting algae organisms. After diatoms and green algae species were selected the subcontractors dropped out the research. Then NREL researchers focused on how to improve oil production of these algae species. Universities, including their scientist and engineers, are actors that usually work in micro expectations. At the beginning, a small research was held at University of California Berkeley's Richmond Field Station to investigate the combination of algae based water treatment and fuel production. University of California and University of Hawaii that studied a variety of fundamental operational issues on small scale tests from 1980 to 1987 and Georgia Institute of Technology that combined experimental and computer modeling worked in late 1980s. After these actors dropped out from the experiment, scientists and researchers at NREL took control the researches and scaled up the algae mass productivity to large scale open pond operations and then came up to the conclusion of the research. There were shifts in actor expectation from water treatment goals to energy production and carbon dioxide capturing emphasis. 3.3.2. Recent social networks Three actors are recognised in recent social networks: governments, research centers and universities, and private company. Recent issues such as fossil fuels depletion, high oil prices, energy security, food production security, and global warming due to CO_2 emission have turned the attention back to algae technology. Algae technology is believed will contribute in solving the problems. Governments from different countries such as Japan and Australia, encourage further development of the technology and provide funding for research centers and universities. NREL is now continuing research on algae biofuel for jet fuel applications in collaboration with Chevron [8]. More universities are involved in algae technology researches around the world recently. Researchers at University of Tsukuba, Japan can produce 3.5 grams of dry-weight algae containing oil from a liter of culture fluid in the laboratory and they are now also preparing for outdoor tests [17]. James Cook University in Australia plans to build a 35,000 tonne algae pilot farm followed by a 400-hectare algae farm by 2010 which can ultimately consume in excess of two million tonnes of carbon dioxide and provide algae oil for a 250,000 tonne biodiesel plant [18]. Researchers at Oregon State University are working to find an efficient method of processing bio-diesel fuel and ethanol from one of the world's most plentiful organisms–algae–which could lead to breakthroughs in reducing the world's dependency on petroleum [21]. Privat actors are new actors that emerged recently providing funding, time and resources for new experiments and pilot projects in algae technology. When the expectation grows positively, new actors get involved. They replace governments in providing money for the experiments. For examples, Green Star Product Inc. announced that a major breakthrough has been achieved which substantially increases algae growth rate of certain strains of microalgae [22]. Another company named Green Shift has patented CO_2 Bioreactor to convert a concentrated CO_2 into oxygen and biomass, and the biomass can be converted into fuel through traditional means [23]. 3.3.3. The role of landscape actor Landscape, a wider context in which a regime is embedded, consists of material and immaterial societal factors such as demographics, political culture, lifestyle, and the economic system [24]. In this case, we consider Organization of Petroleum Exporter Countries (OPEC) as a landscape actor. Observation shows that OPEC also played an important role in biodiesel from algae experiment. As an outsider, its influence can be seen in the fluctuation of the crude oil prices in the world. Arab oil embargo in 1973-1974, and Iran Revolution in 1978-1979 followed by reduction in domestic oil production had increase oil prices in US. The situation, coupled with Clean Air Act regulated by EPA as described above, led researchers to consider other alternative sources of energy [19]. Research in algae was necessary and started in 1978 [4]. Cheap oil prices in 1996 that made the production costs of algal biodiesel could not compete with the cheap oil prices probably became one of the reasons why the experiment on biodiesel from algae was stopped. The role of foreign oil exporter countries was apparent. 4.4 Learning Processes Knowledge dissemination of ASP's study occurred in a variety of ways depending on the actors involved. Despite the termination of the program, NREL still made information on microalgae technology known. After NREL made its research findings public by putting together a closeout report and posting it in their website in 1998, it took sometime before activities in the biodiesel from algae field began. We can only presume that it is because the actors did not feel the need to explore more alternative sources of fuel due to the cheap diesel prices. It was only until early 2000 that companies such as Green Fuel Technologies (founded 2001) [21], Green Shift (founded 2005) [25], Solix (founded 2005) [26] to name a few, began to invest in this technology. Oil companies such as Chevron [8] and Shell [7] began to invest money in research and pilot plants for algal oil production. Through workshops, like the Workshop on Algal Oil for Jet Fuel Production, NREL was able to share the findings on algae technology to users of the fuel. This workshop, which was organized together with the United States Air Force discussed the feasibility of using microalgae oil as bio-based jet fuel. The two government organizations also invited experts on the microalgae technology to talk about research issues related to microalgal oil production as well as environmental laws and regulations that may impact the technology [27]. Through forums and seminars, like the NREL Industry Growth Forum, NREL was (and still is) able to demonstrate the environmental, economic and technical feasibility of the technology to entrepreneurs, venture capitalists and corporate investors [28]. Through publications of the Aquatic Species Program Closeout Report and Lessons Learned Report, universities and private research companies are able to use the ASP research report further on the issues identified in the report. This ensured the continuity of NREL's research on the technology. The University of New Hampshire even has a group that specifically addresses the issues raised by the ASP regarding the technology [6]. Research companies focusing on algae were also formed. Solix, a biofuel company, even claims to be a direct intellectual descendant of the ASP [26]. Through the establishment of knowledge networks, like The International Network on Biofixation of CO2 and Greenhouse Gas Abatement with Microalgae [29], information sharing and co-ordination of research projects regarding the technology were possible. NREL is able to provide technical assistance to the members who are conducting research on the technology. Through partnerships with oil companies further research can be done to make the cost of the technology compete with current diesel cost. Researchers from oil companies like Chevron can provide insights on the diesel market and provide pilot plants to serve as test facilities for the wide scale production of algal oil. Having illustrated the avenues with which the results of the Aquatic Species Program were disseminated, we can see that three of the four methods of learning: searching, doing, and interacting [5] are present but in varying degrees and in some cases overlapping with each other. The universities and private research companies learned about the ASP by searching. Since a closeout report and additional information on the ASP are posted in websites, universities can easily read about the findings and lesson learned during the course of the program. Universities can perform further R&D in the field to develop the technology further. Chevron learned (or will learn) by doing through using the technology developed by the ASP and using it in their test facilities. By testing the technology in their pilot plant, problems that were not seen during the experiments of the ASP can arise and hopefully get solved. The users of the technology such as research companies, investors, and also Chevron learned about the technology by interacting with NREL through forums, workshops and knowledge networks. This method, in our assessment, is the dominant method in disseminating the information on the algae technology. Through interaction, companies were able to communicate directly with NREL and raise their concerns. NREL was also able to demonstrate the technology and get feedback from the participants. This interaction between NREL and the participants of the forums, seminars and knowledge network contribute significantly to the growth of the microalgae technology. V. CONCLUSIONS In conclusion, we believe that the method of learning by interaction was the dominant method in disseminating the information on the algae technology. Through forums, workshops and knowledge networks the users of the algal oil technology such as research companies, investors, and also Chevron learned about the Aquatic Species Program. Through interaction, companies were able to communicate directly with NREL and raise their concerns. NREL was also able to demonstrate the technology and get feedback from the participants. This interaction between NREL and the participants of the forums, seminars and knowledge network contributed significantly to the growth of the microalgae technology. In addition, the process of learning by searching was also instrumental in the development of the technology since the universities and research companies also used this method to learn about the ASP. The learning by doing process will become dominant once more companies put up algal oil pilot plants. It is also interesting to notice the role of the landscape actor in the direction of the experiment. The landscape actor in the form of Foreign Oil Exporter Countries was influential in the expectation shift of the experiment and also in the stability of the regime. The landscape actor which influenced the termination of the project is also influencing the current revival in the interest in this technology. The landscape actor among other factors, we believe, is giving the algal oil niche the much needed boost for it to become a problem solver. ACKNOWLEDGEMENT The present paper is the first part of our project during the System Inovation & Strategic Niche Management course at Eindhoven University of Technology. We would like to thank Prof. Geert Verbong, dr. ir. Rob Raven, and dr. ir. Frank Veraart for their comments and great lecturing. REFERENCES [1] Energy Information Administration, "International Energy Outlook 2007", Washington DC: U.S. Department of Energy, 2007. [2] Energy Information Administration, "Annual Energy Outlook 1998", Washington DC: US Department of Energy, 1997. 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