

Sample Content of the Oilgae Report Academic Edition

*This e-book provides representative sample content to assist in evaluating the
Oilgae Report Academic Edition.*

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The Oilgae Report Academic Edition is a detailed report on all aspects of algae biofuels, targeted at the research and academic community. This preview provides inputs on focus areas of the report, the list of contents, and sample topics from each chapter of the report. The Oilgae Academic was last updated in the 1st week of January 2013, and has 605 pages.

An Invaluable Guide to the Algae Fuel Research Community

Don't Reinvent the Wheel

The Oilgae Report Academic Report, with its comprehensive coverage of critical algae fuel research developments worldwide will be an invaluable resource for researchers. It will enable them to save many years of their research efforts.

Algae fuels present an exciting opportunity. There is a strong view among industry professionals that algae represent the most optimal feedstock for biofuel production in the long run. It is also widely accepted that algae alone – and no other bio-feedstock - have the ability to replace the entire global fossil fuel requirements. Such a significant opportunity has resulted in companies both large and small investing in algal energy.

Algae present multiple possibilities for fuel end-products – biodiesel, ethanol, methane, jet fuel, biocrude and more – via a wide range of process routes. Each of these process routes presents its own set of opportunities, parameters, dynamics and challenges.

While academic research into algae fuels started over three decades ago, the intensity of research activities has accelerated tremendously in the past few years. This has been a consequence of the realization of algae's potential as a source of biofuel. As of January 2013, about two hundred universities worldwide have serious research programmes in algae biofuels.

All these efforts will benefit enormously if a comprehensive resource is available that brings them up-to-date on the various research activities, status of past and on-going efforts, and critical data for assessing the technical and economic feasibility of algae fuels. Such a comprehensive resource has the potential to save many months of research and analysis.

The Oilgae Report Academic Edition was developed to satisfy this clear need in the academic community.

The report is the most detailed report dealing with all aspects of the algae fuel industry. The report is divided into three main sections:

- Concepts and Cultivation
- Diverse Energy Products from Algae
- Processes & Challenges

Each section provides in-depth information, details and updates on the most critical aspects relevant to it, with an emphasis on research efforts.

The objective of the Oilgae Report Academic Edition is to facilitate ongoing and planned research efforts – specifically applied research efforts. The emphasis hence is on providing extensive review of research data, and related updates and insights.

In addition, the report has made special efforts in identifying the core challenges faced in each aspect of the algae fuels value chain. It also provides inputs on the current efforts and possible solutions to overcome these challenges.

The report has been developed with over two years of in-depth research, and has been developed with inputs from biotechnology researchers, biofuel industry experts, and professionals who have been constantly interacting with the algae fuels industry for over four years.

The Oilgae Report Academic Edition will be an invaluable guide to those in the academic and research domains keen on undertaking research in one of the most exciting renewable energy domains.

Why should you buy this report?

- *The report highlights research efforts having a focus on biofuels and bio-energy.*
- *It provides extensive details on research efforts done by hundreds of universities in this domain*
- *It presents numerous case studies and examples of what the pioneers are doing in the algae energy domain.*
- *It showcases case studies on algae research efforts in areas such as waste water treatment, CO2 sequestration at power plants.*
- *It lists algae culture centers, from where students and researchers can obtain algae strains.*
- *It provides current and future research areas in algae energy domain.*
- *It lists companies involved in algae energy commercial research, enabling students and researchers to get in touch with them for industrial collaborations*
- *It provides details, for researchers, on pathways and technologies for alternative energy products not just biodiesel - from algae.*
- *It has a specific emphasis on patents and research papers that have been published in this domain.*

The Oilgae Report Academic Edition was developed to provide research insights on new methodologies, perspectives and experiments on how best to derive energy from algae. This report is a customized edition for **academic** and **industry researchers**, and **students**.

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For a prospective buyer to obtain a better idea of the contents in the report, we provide samples and list of contents for the following topics from the report:

- ✓ Comprehensive List of Universities
- ✓ Emphasis on Current and Future Research Areas
- ✓ Focus on Algae Cultivation Processes and Technologies
- ✓ Highlights of Research in Algae-based Wastewater Treatment and Carbon Capture
- ✓ Detailed Inputs on Pathways to Multiple Energy Products from Algae
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Comprehensive List of Universities

The report provides extensive details on research efforts done by hundreds of universities in this domain.

Sample List of Universities & Research Institutes

1. Arizona State University
2. Auburn University
3. Brunswick Community College (BCC)
4. Clemson University
5. Cleveland State University, Fenn College of Engineering
6. Colorado State University
7. CSIRO, Australia
8. Eastern Kentucky University, Richmond, USA
9. Florida Tech University
10. Iowa Power Fund, USA
11. James Cook University, Queensland, Australia
12. Massachusetts Institute of Technology MIT
13. Massey School of Engineering, Wellington, New Zealand
14. Montana State University
15. NASA
16. National Renewable Energy Laboratory
17. Natural Energy Laboratory of Hawaii Authority (NELHA), USA
18. Natural Resources Defense Council
19. New Mexico State University
20. Oregon State University
21. Sandia National Laboratory
22. Southern Illinois University Carbondale (SIUC), USA
23. Texas A&M University
24. The Carbon Trust (UK)
25. The National Institute of Oceanography (NIO)
26. University of Adelaide Chemical Engineering

27. University of Arizona
28. University of Arkansas
29. University of California at Berkeley
30. University of California at Davis
31. University of California at San Diego
32. University of Florence, Italy
33. University of Georgia
34. University of Nevada
35. University of New Hampshire
36. University of Texas at Austin
37. University of Virginia
38. University of Washington (UW), USA
39. Utah State University, USA
40. Western Michigan University

Emphasis on Current and Future Research Areas

Sample Topics of Energy “Products” from Algae

- Upstream and Downstream Processes
- The Biochemical Dimension
- Processes in the Fossil Fuel and Alternative Energy Industries
- The Energy Product Basket from Algae

Examples of Research & Case Studies to Enhance Oil Yields from Algae

- Enhancing lipid production rates by increasing the activity of enzymes via genetic engineering
- Through nitrogen & phosphorus deprivation
- Si Depletion - research into diatom lipid accumulation by silicon depletion
- “Spigot” Analogy
- Increasing Oil Yields of Algae By a Shift in pH

Sample Topics from Algae Oil Extraction – Trends & Developments

- Technologies for *in vivo* lipid profiling of oil producing microalgae
- Algae Oil Extraction Using Ultrasonication
- Oil Extraction – Efforts & Solutions
- Ultrasonic Solvent Extraction
- Ultrasonic Enzymatic Extraction
- Advances in Oil Expellers
- Ultrasonic Extraction
- Production of algae-based biodiesel using the continuous catalytic Mcgyan process

Focus on Algae Cultivation Processes and Technologies

The report provides extensive details on current and emerging technologies and processes that can facilitate large-scale algae cultivation at optimal costs.

Sample Topics of Factors that Determine Algal Growth Rate

Detailed inputs are provided for the following factors, which are important for the algal growth.

- **Light** - Light is needed for the photosynthesis process
- **Temperature**: There is an ideal temperature range that is required for algae to grow
- **Medium/Nutrients** - Composition of the water is an important consideration (including salinity)
- **pH** - Algae typically need a pH between 7 and 9 to have an optimum growth rate
- **Algae Type** - Different types of algae have different growth rates
- **Aeration** - The algae need to have contact with air, for its CO₂ requirements
- **Mixing** - Mixing prevents sedimentation of algae and makes sure all cells are equally exposed to light
- **Photoperiod** - Light & dark cycles

Sample Topics from Design Principles of Photobioreactors

- Lighting
- Light Guides/Transmitters
- Mixing
- Airflow
- Cultivation under Sterile Conditions
- One Reactor for Different Processes
- Large-scale Processes

Sample Topics from Culture Methods Followed for Different Algal Species

Dunaliella sp.

Isolation and screening:

Purification by single cell isolation technique in ESM enrichment medium (NaNO_3 -120 mgL^{-1} , KH_2PO_4 - 5 mgL^{-1} , EDTA-Fe 0.26 mgL^{-1} , EDTA-Mn 0.33 mgL^{-1} , vitamin B1-HCl 0.1 mgL^{-1} , vitamin B12 - 10 μgL^{-1} , biotin - 1 μgL^{-1} , tris-buffer 1 g.L^{-1}).

Macro elements	Amount per 100ml
KNO_3	1.0 g
K_2HPO_4	0.1 g
$\text{MgSO}_4 \times 7\text{H}_2\text{O}$	0.1 g
Artificial sea water	
NaCl	60 g
$\text{MgSO}_4 \times 7\text{H}_2\text{O}$	10 g
KCl	1.5 g
CaSO_4	2.0 g

Screening is done with Herbicide phosphinothricin

*Medium*¹: General medium: 20 ml of the stock macro elements solution is mixed with 910 ml of artificial seawater and 30 ml of seawater soil extract. Some other common mediums used for culturing this species are: Provasoli-enriched Sea water medium (PES), Artificial J/1 medium, Johnson's medium, NORO medium.

Procedure: All strains are cultivated in the medium containing 1M NaCl. Cultures are bubbled with 3% CO₂ in air (v/v), at continuous light (200 μmol photon m⁻²s⁻¹) and grown in 500 mL borosilicate flasks containing 500 mL of media at 25 ± 2°C.

Culture environment: Optimal growth temperature for *D. salina* was 22°C (3.06 × 10⁶ cells mL⁻¹) and 26 °C for *D. viridis* (4.04 × 10⁶ cells mL⁻¹).

Sample Research & Publications on Algae CO₂ Capture

- Light Penetration Depth as a Function of Algal Density
- Stimulatory effect of aerosil on algal growth
- *Chondrus crispus* (Gigartinaceae, Rhodophyta) tank cultivation: optimizing carbon input by a fixed pH and use of salt water well
- Photosynthesis driven conversion of carbon dioxide to fatty alcohols and hydrocarbons in cyanobacteria
- Development of suitable photobioreactors for CO₂ sequestration addressing global warming using green algae and cyanobacteria

¹ http://www.dunaliella.org/dunabase/media/ccala_dunaliella.php
<http://www.scielo.cl/pdf/bres/v36n2/art08.pdf>

Highlights of Research in Algae-based Wastewater Treatment and Carbon Capture

Sample Research Efforts on Algae CO₂ Capture

- Production of marine unicellular algae from power plant flue gas
- The effect of trace acid gases on CO₂ sequestration by microalgae, such as NO_x and SO₂.
- CO₂ mitigation from photosynthetic microbes
- One calculation showed that 1600 giga-watt power plants converted to algae
- A different perspective for algae-based CO₂ sequestration
- A report from the testing firm CK Environmental
- A coal-fired steel facility to implement its carbon dioxide reduction/algae growth solution
- Carbon dioxide reduction and algae growth solution for biodiesel production

Sample List of Case Studies on Algae CO₂ Capture

- NRG Energy testing GreenFuel's algae system in Louisiana
- CEP, PGE Want to Turn Pollution into Algae
- Linc Energy, BioCleanCoal Work on Algae CO₂ Sequestration from Power Plants
- Seambiotic, Israel
- EniTecnologie
- Trident Exploration

Sample Research & Experiments of Algae-based wastewater treatment

- Algal treatment of pulp and paper industry wastewaters in SBR systems
- Cleansing Waste Water with Algae – Sintef Fisheries / Irish Seaweed Centre Project
- Biosorption of reactive dye from textile wastewater by non-viable biomass of *Aspergillus niger* and *Spirogyra* sp.
- Algal Treatment of Textile Dyehouse Wastewater
- Ability of Algae to Biotreat Pesticides, Herbicides and Related Compounds
- Single-cell oil production by cyanobacterium *Aphanothece microscopica* Nägeli cultivated heterotrophically in fish processing wastewater
- Characterization of a microalga *Chlorella* sp. well adapted to highly concentrated municipal wastewater for nutrient removal and biodiesel production
- Renewable biomass production by mixotrophic algae in the presence of various carbon sources and wastewaters
- Cultivation of filamentous cyanobacteria (blue-green algae) in agro-industrial wastes and wastewaters
- Reuse of effluent water from a municipal wastewater treatment plant in microalgae cultivation for biofuel production

Detailed Inputs on Pathways to Multiple Energy Products from Algae

Sample Topics from Methodologies for Producing Hydrogen from Algae

Detailed inputs on the following methods of hydrogen production from algae are given in the report.

- Biochemical Processes
 - Hydrogenase-dependent Hydrogen Production
 - Producing Hydrogen from Green Algae by Restricting Sulfur from their Diet
 - Using Copper to Block Oxygen Generation in the Cells of *Chlamydomonas reinhardtii*
 - Hydrogen from Algae by Reducing Chlorophyll Molecule
 - Nitrogenase-Dependent Hydrogen Production
 - Hydrogenases in Green Algae
 - DIY Algae/Hydrogen Kit
- Hydrogen Production through Gasification of Algae Biomass
- Through Steam Reformation of Methane from Algae Fermentation

Sample Topics of Ethanol Production from Algal Biomass

A typical process for the production of ethanol from algae is to harvest starch-accumulating algae to form a biomass, initiate cellular decay of the biomass in a dark and anaerobic environment and ferment the biomass in the presence of yeast to produce ethanol.

- Details of the Algal Fermentation Process to Produce Ethanol
- Optimal Species/Strains for Producing Ethanol
- Cultivation
- Harvesting
- Initiating Decay of the Biomass
- Fermentation
- Ethanol Extraction

Comprehensive Profiles of Companies Involved in Algae to Fuel Research and Commercialization

The report lists companies involved in algae energy commercial research, enabling students and researchers to get in touch with them for industrial collaborations... Here is a sample of the list

1. A2BE Carbon Capture	37. Greenbelt Resources Corporation
2. Algae.Tec	38. GreenFuel Technologies Corporation
3. Algae Biosciences Corp.	39. Greenshift
4. Algaewheel	40. Hawaiian Electric Company
5. Algatechnologies, Ltd.	41. Imperium Renewables
6. Algenol	42. Infinifuel Biodiesel
7. AlgoDyne Ethanol Energy Corp	43. International Energy
8. Aquaflow Bionomic	44. Inventure Chemical Technology
9. Aquatic Energy	45. Kai Bioenergy
10. Aurora Algae	46. Kent Seatech
11. AXI	47. Kuehnle Agrosystems
12. Biofuelbox	48. LiveFuels
13. Bionavitas	49. MBD Biodiesel
14. Bioverda (Has a Joint Venture with the Virgin Group)	50. Neste Oil
15. Blue Marble Biomaterials	51. Ocean Technology & Environmental Consulting
16. Blue Sun Biodiesel	52. Oilfox Argentina
17. Bodega Algae	53. Organic Fuels
18. BTR Labs	54. OriginOil
19. Carbon Capture Corporation	55. Patriot Biofuels
20. Cedar Grove Investments	56. Parabel
21. CEHMM	57. PetroSun Biofuels
22. Cellana	58. Phyco2
23. Center of Excellence for Hazardous Materials Management	59. Primafuel
24. Cequesta Algae	60. Renewable Energy Group
25. Chevron	61. Revolution Biofuels
26. Circle Biodiesel & Ethanol Corporation	62. Sapphire Energy
27. Cobalt Technologies	63. Seambiotic
28. Community Fuels	64. Solazyme
29. Culturing Solutions, Inc	65. Solena Group
30. DFI Group	66. Solix Biosystems
31. Earth2tech	67. Synthetic Genomics
32. Enhanced Biofuels & Technologies	68. Texas Clean Fuels
33. Euglena	69. Alterrus
34. Fluid Imaging Technologies	70. W2 Energy
35. General Atomics	71. PhycoBiosciences
36. Green Gold Algae and Seaweed Sciences Inc.	

Culture Collection Center Listing

The report lists algae culture centers from where students and researchers can obtain algae strains.

How many culture collection centers are listed in the report?

The report provides the details of more than one hundred culture collection centers all over the world.

Which are the countries represented in the context of culture collection centers?

The report provides the list of culture collection centers for the following countries:

- | | |
|---------------------|------------------------|
| 1. Australia | 17. Malaysia |
| 2. Austria | 18. Mexico |
| 3. Brazil | 19. Pakistan |
| 4. Canada | 20. Philippines |
| 5. China | 21. Poland |
| 6. Czech Republic | 22. Portugal |
| 7. Denmark | 23. Russian Federation |
| 8. France | 24. Senegal |
| 9. Germany | 25. Slovak |
| 10. India | 26. Spain |
| 11. Indonesia | 27. Sri Lanka |
| 12. Iran | 28. Thailand |
| 13. Italy | 29. Turkey |
| 14. Japan | 30. UK |
| 15. Kazakhstan | 31. USA |
| 16. Korea (Rep. of) | 32. Ukraine |

In addition, the report provides the details about various companies that commercially sell algae cultures

Sample List of Organizations from Which Data have been Sourced

1. NREL - www.nrel.gov
2. Algal Biomass Association - www.algalbiomass.org
3. FAO - www.fao.org
4. Parliamentary Monitoring Group, South Africa - www.pmg.org.za
5. Energy Information Administration, Government of USA - www.eia.doe.gov
6. Department of Chemical Engineering, Indian Institute of Technology, Guwahati, India - www.iitg.ernet.in
7. The First Institute of Oceanography, State Oceanic Administration - www.fio.org.cn
8. Institute of Oceanology, Chinese Academy of Sciences - www.qdio.ac.cn
9. The Center of Excellence for Hazardous Material Management in Carlsbad - www.cehmm.org
10. University of Nevada - www.unr.edu
11. California Water Board
12. Old Dominion University - www.odu.edu
13. Auburn University in Alabama - www.auburn.edu
14. Middle East Technical University - www.metu.edu.tr
15. Sintef Fisheries and Aquaculture - www.sintef.no
16. National Center for Radiation Research and Technology - www.eaea.org.eg
17. Water Environment Federation - www.wef.org
18. Royal Netherlands Institute for Sea Research - www.nioz.nl
19. Australian National University – www.solar-thermal.anu.edu.au
20. Wuhan University - w3.whu.edu.cn/en/

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2. Macroalgae Strains with High Carbohydrate Content (By Dry Weight)

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2. Continuous Culture Methods for Various Types of Algae in 40L Internally-Illuminated Vessels (Suitable for Flagellates Only) (Modified from Laing, 1991)
3. Dunaliella Sp. Culture Medium
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6. Comparison of Large Scale Systems for Growing Algae
7. Prominent Spirulina Farms Around the World
8. Fertilizers for Marine Algae
9. A Generalized Set of Conditions for Culturing Micro-Algae
10. Chu 13
11. Johnson's Medium
12. Bold Basal Medium
13. F/2 Medium
14. Benecke's Medium
15. Medium for Spirulina
16. PES Medium
17. Fogg's Nitrogen Free Medium (Fogg, 1949)
18. Modified NORO Medium
19. BG 11 Medium
20. C Medium
21. Artificial Sea Water Medium (ASW)

4. Photobioreactor

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2. Photobioreactor Cost for a 1 Ton/Day Dry Algae System
3. Algaelink Photobioreactor Specifications & Costs
4. Data for Photobioreactor Systems from Various Companies

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6. Manufacturers & Suppliers
7. Parts of a Photobioreactor

6. Algae Grown in Open Ponds, Closed Ponds & Photobioreactor

1. Differences between Open Pond and Closed Pond Cultivation

7. Algae Grown in Sewage & Wastewater

1. Examples of Industries Employing Algae-Based Wastewater Treatment Technology
2. Description of Algae Production from Poultry Waste
3. Composition of Poultry Industry Wastewater
4. Content of Selected Heavy Metals in a Sample Waste Water Treatment Plant
5. Algal-Bacterial/Microalgal Consortia for Organic Pollutant Removal
6. Theoretical Sewage & Wastewater Resource Potentials by 2020

8. Algae Grown in Desert

1. Characteristics of Photobioreactor Materials and the Energy Content of Tubular Photo Bioreactors

9. Algae Grown in Marine & Saltwater Environment

1. Composition of Seawater
2. Detailed Composition of Seawater at 3.5% Salinity

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1. Percentage of Lipid Content in Various Macroalgae Species

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5. Energy and GHG (CO₂) Balance Per Liter of Oil Produced Using Three Different Technologies.
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10. Solubilities of Flue Gas Components
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12. Countries Heavily Dependent on Coal for Electricity (2006e)
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3. Strains of Microalgae Having High Carbohydrate Content
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17. Other Energy Products – Syngas, Other Hydrocarbon Fuels, Energy from Combustion of Algae Biomass

1. Gasification Reactions and Their Reaction Enthalpy
2. Various Fuel Routes Compare with Regard to Cost and Scalability.
3. Survey Results: Gasification Operating Plant Statistics 2004 Vs. 2007
4. Petroleum Products Produced from One Barrel of Oil Input to U.S. Refineries, 2007
5. U.S. Refiner and Blender Net Production of Refined Petroleum Products in 2007 (Total = 6.57 Billion Barrels)

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3. Worldwide Growth in Gasification Technologies

Select List of Questions Answered

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1. What is the comparative production capacity of PBR & pond alternative, for similar area used?
2. How often should the PBR be cleaned?
3. What are the major parts of a PBR, and what are the parts that make it costly?
4. What are closed loop photobioreactors?
5. Is it possible to eliminate some photobioreactor components without affecting the algae growth process?

Chapter 6 - Algae Cultivation in Open Ponds

1. Can we have a hybrid of open pond and closed systems?
2. Can open ponds for algae cultivation use CO₂ from industrial emissions?
3. Is a closed pond similar to green house?
4. What are the materials used in closing the pond?

Chapter 7- Algae Cultivation in Sewage

1. At which stage of wastewater treatment are algae is introduced?
2. As sewage already contains nutrient, is there any need for additional nutrients for algae cultivation in sewage?
3. Are there algae predators in sewage?
4. Will toxins affect algae growth in sewage?
5. Which is the best algae harvesting method for sewage cultivation?
6. What are the natural microfloras in sewage?
7. What are the monitoring techniques used in algae wastewater treatment?
8. What is the potential of algae wastewater treatment for anaerobic digestion effluents?
9. What are the constraints in using wastewater grown algae for animal feed?
10. Is it possible to use algae to treat organic pollutants like phenolic wastes?

Chapter 8 - Desert Based Algae Cultivation

1. What will be the source of water in desert region?
2. How can the problem of evaporation be overcome?
3. Is it possible to cultivate algae in closed loop?
4. In desert environments, which is best - open pond, closed pond or PBR?
5. Can PBR withstand high temperature?

Chapter 9 - Marine Algae Cultivation

1. What are the challenges for marine algae cultivation?
2. Are algae cultivated in marine for other purpose?
3. How & why does iron fertilization help algae growth?
4. How can we control algae growth boundaries in marine environments?
5. Do the nutrients in seawater serve as natural nutrients for algae growth?

Chapter 11- Algae Cultivation Coupled with CO₂ from Power Plants – Q&A

1. Is there a possibility of heavy metal contamination in algae due to their presence in the flue gases?
2. How do the constituents other than CO₂ in flue gas from power plants affect algal growth?
3. Will NO_x present in the flue gas serve as a nutrient, in addition to the CO₂?
4. Can algae withstand the high temperatures in the flue gases?
5. What is amount of CO₂ required for algae growth?
6. What is the approximate cost of cultivating algae next to power plants for CO₂ capture and biofuel production?
7. Can we grow macroalgae for power plant CO₂ sequestration?
8. What are the major problems faced by companies implementing algae based CO₂ sequestration techniques near power plants?
9. Can power plants use waste water from their facilities for growing algae?
10. What are the methods by which flue gas can be cooled before passing it into algae systems?
11. Is it necessary that algae ponds need to be constructed right next to power plants?
12. What is the average area required for the construction of algae ponds for each power plant?

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