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High Density Vertical Growth (HDVG) systems such as this one grow algae with only light, water, and air in a closed-loop, vertical system of polyethylene sleeves in greenhouses.

Cultivating Clean Energy: The Promise of Algae Biofuels

Innovative approaches to clean energy development are vital as America looks for ways to reduce global warming pollution and fuel the clean energy future. Recent research published by NRDC analyzes one potential new energy source: algae biofuels.

The algae biofuels industry is dynamic but sprawling, exploring innumerable pathways to produce fuels from algae. To quickly move algae biofuels from concept to reality and bring this fuel source to market, the biofuels industry must now build on the data currently available and fill remaining information gaps regarding environmental performance.

Transforming Algae into Fuel

The full algae biofuels production process will have a range of environmental implications that the industry must consider at each stage of the production process:

- **Cultivation:** Algae cultivation at commercial scale could have significant environmental consequences, based on how water, nutrients, land, and light are supplied and managed. At a minimum, criteria for sustainable cultivation should consider the impact of water, land, and genetically modified organism (GMO) usage on biodiversity and ecosystem health, as well as the environmental impacts of infrastructure fabrication, materials toxicity, electricity demands, and waste treatment.
- **Harvesting:** Harvesting involves recovering, dewatering, and drying algal biomass. Most recovery processes require chemical or mechanical manipulation to separate the biomass from the process wastewater. The criteria for sustainable biomass harvesting should consider the potential toxicity of chemical additives, environmental

management of output water, and the energy and carbon balance implications of energy-intensive drying techniques.

■ **Extraction:** Algal oil extraction (removing oil from the algae biomass) can be achieved via a number of techniques, but there is limited information about the chemical and energy inputs in this process. The criteria for sustainable oil extraction should consider energy inputs and potential environmental toxicity of chemical solvents.

■ **Conversion:** Oil and residue conversion pathways have been employed in conventional biofuel refining for some time, so data are available, although not necessarily related specifically to algae biofuels. The criteria for sustainable conversion should consider potential energy usage and the handling of low-value coproducts or byproducts. In the near term, industry may need to embrace biological services (e.g., wastewater treatment) and high-value nonfuel coproducts to make algae biofuels economically viable.

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www.nrdc.org/policy

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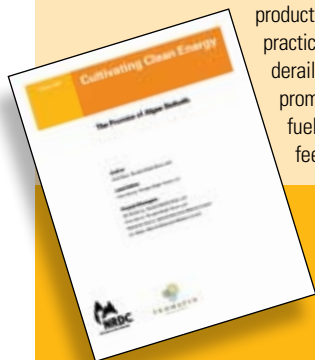
New Report Shows the Promise of Algae Biofuels

NRDC's recent technical report lays out the big picture steps needed to make algae biofuels a viable option:

- Providing a framework for comprehensive environmental analysis of algae biofuels
- Identifying key ecological issues to be considered across all stages of production
- Summarizing the known and unknown environmental impacts of each production process
- Recommending areas of future research and action

Our findings show that it is vital, working with stakeholders across business and non-business sectors, to develop a clear picture of the environmental pros and cons of algae biofuel systems. Otherwise, much as with earlier generations of biofuel technologies, the economic, technical, and political challenges brought on by unsustainable

production practices could derail this promising fuel feedstock.



Read the full report online at <http://www.nrdc.org/energy/cultivating.asp>

Environmental Impacts Must Be Fully Examined

The key to making algae a successful biofuel is reducing impacts on primary ecological resources—water, land, soil, biodiversity, and air—as well as balancing the energy produced against the carbon used in the production process. NRDC examined potential areas of environmental concern that the biofuels industry should fully address:

■ **Water:** The effect of algae biofuel production on regional water sources is not yet fully understood. Fortunately, early emphasis by the algae biofuels industry on water impact could mitigate many potential issues. Concerns include aggregate water consumption, systems discharge and water quality, and reduction of groundwater infiltration. The ability of algae to thrive in and treat wastewater and potentially eliminate the need for agriculturally-based biofuels offers one promising path to mitigate some water issues, but further study and technology development is needed.

■ **Land:** Algae biofuels can be produced on non-arable land, which is a strong advantage over agriculture-based biofuels. However, claims regarding yield per acre are often exaggerated and certain algae cultivation processes could have far more land impact than others. For example, open systems will likely have a relatively larger land use footprint than other systems, while heterotrophic systems (which use sugar to grow algae) could have significant indirect land use impacts.

■ **Soil and Biodiversity:** As with all industrial systems using hazardous substances, algae production could contribute to soil contamination unless non-chemical methods are used for harvesting and other processes. Poisoning soil with salt is also a concern for algae cultivated in briny or brackish water. Overall biodiversity could be threatened by producing algae biofuels unsustainably (e.g., through land transformation, water and soil contamination, air pollution, and use of alien species).

■ **Air:** Similar to soil and biodiversity, the pathway of biofuel production and the technologies used will determine impact on air quality. One

potential area for future research is the impact of evaporation from open-pond cultivation on local and regional humidity, and local ecosystems.

■ **Energy and Carbon Balances:** The potential energy and carbon balances of algae biofuels are highly uncertain calculations, and range widely depending on production system, type of biofuel produced, and energy savings realized by the coproducts. It is critical to consider the *net* impact of greenhouse gases (GHGs), which includes all direct and indirect inputs and outputs from all production processes employed.

From Idea to Reality

There are a number of steps that regulators, policymakers, and industry can take to proactively encourage sustainable algae biofuel production.

From a regulatory and policy standpoint, this includes:

- clarifying roles and responsibilities within government agencies;
- establishing information resources; and
- specifying sustainability metrics and industry standards, encouraging industry collaboration and assisting in life cycle analysis (LCA) at the fuel product design phase.

Additionally, the algae industry can proactively address sustainability issues by:

- publishing economic analyses of different technologies or pathways under one technology, as well as life cycle analyses, water balances, and energy and carbon balances;
- adopting low-impact development, operations, and maintenance practices; and
- improving understanding of how relationships between production processes define resource consumption and management.

Although the process will not be simple, and the environmental implications must be fully addressed, algae biofuels hold promise as a clean energy fuel of the future.