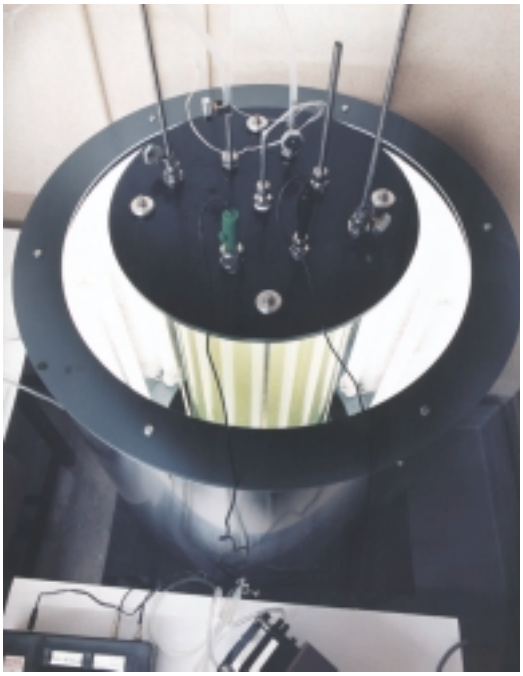
PHOTOBIOREACTOR TECHNOLOGY FOR MICROALGAE CULTIVATION

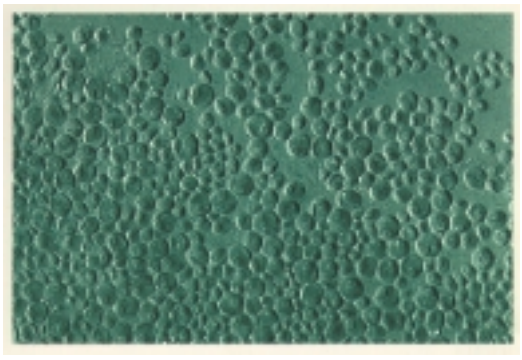
The cultivation of microalgae provides excellent perspectives for renewable energy production and as a source of 'green' products. Algae cultivation can thus contribute substantially to a reduction of CO_2 emissions.

Micro-algae are microscopic, single-celled plants, growing in aqueous environment. For growth algae make use of sunlight as energy source and simple inorganic nutrients, predominantly CO_2, soluble nitrogen components and phosphates. Characteristics of algae cultivation are:

- The areal productivity is 2 to 5 fold higher as compared with traditional agricultural crops and fast growing 'energy crops' such as willow and *Miscanthus*.
- Lower quality water can be used for growing algae, e.g. the effluent of biological waste water treatment facilities. Algae effectively remove nitrogen and phophate from these streams, which leads to a reduction of water treatment costs. After separation of the algae (and final conditioning) the purified water can be reused for industrial purposes.
- Algal systems can remove CO_2 (and NOx) from flue gases. The flue gases from power plants can be directed through the algal bioreactor. CO_2 is taken up by the algae and directly recycled in the form of biomass and derived products.
- Many algal species produce valuable products, such as colorants, poly-unsaturated fatty acids and bioactive compounds. These 'fine chemicals' are applicable as a natural ingredient in food products, pharmaceuticals, food supplements and personal care products. After extraction of these valuable compounds the remaining biomass (approx. 80%) can be used for production of 'green' electricity and heat. Alternatively, microalgae can be used for the production of methylesterfuel ('bio-diesel').



The ECN bench scale photobioreactor

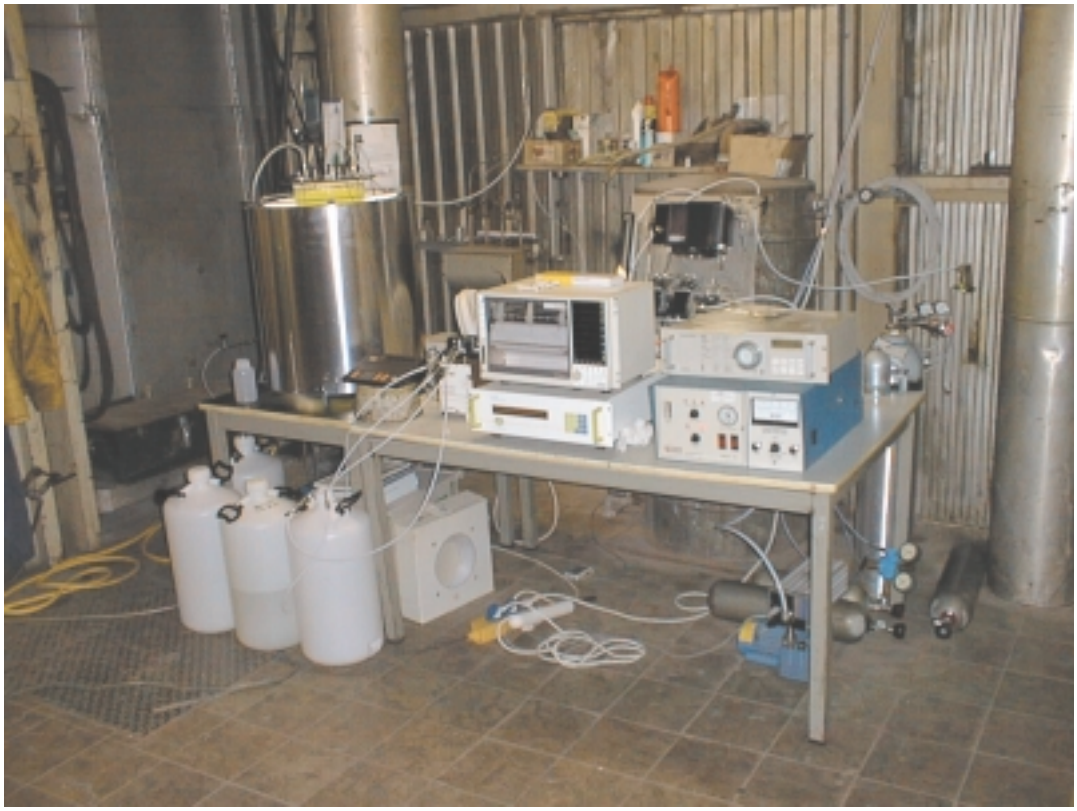


Microalgae of the species Chlorella pyrenoidosa. *The actual cell size is 3-5 mm (1 mm = 0.001 mm)*

The high biomass yield, the possibilities for co-production of fine chemicals and biofuel and the perspectives for purification of water and flue gases by algae are the basis of the research programme at ECN.
The programme is aimed at the development of photobioreactor technology for algae cultivation because closed reactor systems enable stringent process control which leads

to high productivity and good product quality. As a first step in the programme a bench-scale tubular bioreactor with a volume of 30 liter was constructed. The reactor can be used as a 'bubble column' or as an air-lift reactor by the use of an internal riser. The reactor is equiped with an adjustable lighting system and gas supply. In the reactor the productivity of different types of algae is studied by variation of the growth conditions (light climate, culture density, pH, gas supply rate, mixing regime). The results are used for the design of a pilot installation. In a project with Suiker Unie the possibility to use flue gas from a natural gas fired boiler as a CO_2 source has been successfully shown. Furthermore, the application of algae cultivation for wastewater purification has been confirmed.

A commercial system for algae cultivation is developed within the framework of the project 'Sustainable co-production of natural fine chemicals and biofuels from microalgae' in collaboration with industry and R&D institutes. The project is financially supported by the *Programme Economy, Ecology and Technology*. In this project ECN will construct a scaled up photobioreactor which will be placed outdoors. Tests under realistic, outdoor conditions will be performed as a next step towards development of full scale commercial systems.



Test facilities at the Suiker Unie location Dinteloord for testing of CO_2 and NOx removal from flue gas produced by a natural gas fired boiler. The test set-up consists of the ECN bench scale reactor (left) and equipment for on-line sampling and monitoring of flue gas composition (CO_2, CO, O_2, CH_4, NOx) before and after passing the algae reactor.

References

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2. De Boer, A.J., and J. van Doorn (1998). *Combined production of chemicals and biomass with microalgae in a closed photobioreactor*. ECN Contribution to the 10th European Conference: 'Biomass for energy and industry'. ECN—RX-98-003, pp. 27-29.
3. Reith, J.H., Van Doorn, J., Mur, L.R., Kalwij R., Bakema,G. and G. van der Lee (2000). *Sustainable co-production of natural fine chemicals and biofuels from microalgae.* Conference Biomass for Energy and Industry, Sevilla, June 2000

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