



RWE'S ALGAE PROJECT IN BERGHEIM-NIEDERAUSSEM

Production of micro-algae using power plant flue gases to bind CO₂

MOTIVATION

The capture of CO₂ from the waste gases of CO₂-emitting industries will in future play an important role in lowering CO₂ emissions.

Besides the options available for capturing CO₂ from processes and for storage below ground, specialist circles, and the general public as well, are increasingly thinking about the possibilities of converting and making use of CO₂. RWE has studied in detail various options for climate-beneficial recycling and trapping CO₂ in order to identify potentials and obtain recommendations for action. One result of these investigations is the project launched by RWE for binding CO₂ using micro-algae.

Micro-algae are unicellular, plant-like organisms that absorb CO₂ by photosynthesis in order to grow. One crucial advantage is that they have much higher growth rates than any land-based plant, enabling them to convert CO₂ into biomass faster than plants on land. Moreover, marine micro-algae grow in salt-water, which significantly increases the stability of production compared with freshwater algae.

In our latitudes, micro-algae produce 60 to 100 t/(ha x a) dry substance, with 120 to 200 t/(ha x a) of CO₂ being bound. The growth rate of micro-algae is much higher than that of fast-growing energy crops, like willows or poplars from short-rotation plantations with 12 t/(ha x a) or Miscanthus with 15 t/(ha x a) dry substance.

Marine micro-algae can be produced in closed systems, and use can be made of locations which, owing to their soil characteristics, are not suitable for growing plants. This avoids site competition with the cultivation of food and feed.

The aim is to use the specific capabilities of micro-algae to bind CO₂ from flue gases at lignite-fired power plants.

Before commercial-scale deployment becomes feasible, however, numerous points still have to be resolved. Besides technical issues associated with the development of this technology, it will have to be shown above all that the total energy balance from algae production to conversion is positive and that a net CO₂ reduction is obtained.

It is with a view to investigating these points systematically and to developing solutions that RWE – together with noted partners – has launched a project: flue gases from the Niederaussem power station are fed into an algae production plant in the vicinity of the station to convert the CO₂ from the flue gas into algae biomass. On the basis of the algae biomass thus produced, a further aim is to investigate different conversion routes for the algae involving energetic and material use, e.g. for construction materials or fuels.

PLANT DESCRIPTION

Near the Niederaussem power plant, RWE Power has erected a system for binding CO₂ from the power plant in micro-algae.



Fig. 1: Outside view of the BoA cooling tower and the flue-gas ducts in Niederaussem

In the process, flue gas is withdrawn from a power-plant unit and transported through pipes to the micro-algae production plant. The CO₂ contained in the flue gas is dissolved in the algae suspension and absorbed by the algae for growth. The algae are removed (harvested) and further investigated for conversion into chemically or energetically usable products.

Flue-gas withdrawal

The flue gas to provide the algae with the CO₂ is withdrawn from a conventional lignite-based power-plant unit. The amount of flue gas needed is diverted downstream of the flue-gas desulphurization (FGD) system, i.e. in a state in which it is normally released into the environment.

The flue gas downstream of the FGD contains high shares of water vapour. To ensure that this water vapour does not condense in and corrode the flue-gas pipes, the flue gas is dried before being transported. The flue gas is then propelled with the aid of a fan through a pipe to the greenhouse. Fig. 2 shows a diagram.

Flue-gas pipe

The pipe consists of PE. This plastic was selected to prevent any corrosion from the condensation of residual amounts of water vapour.

The greenhouse in which the algae production system is built stands on a site adjacent to the power plant. The flue-gas pipe is approx. 750 m long in all.

Bubble reactor

The flue-gas pipe ends in front of the greenhouse in which the algae production plant is located. The flue gases are fed into a so-called bubble reactor outside the greenhouse using a process from Novagreen Projektmanagement GmbH. The container has an algae suspension consisting of saltwater and the micro-algae in it. The flue gases mix with

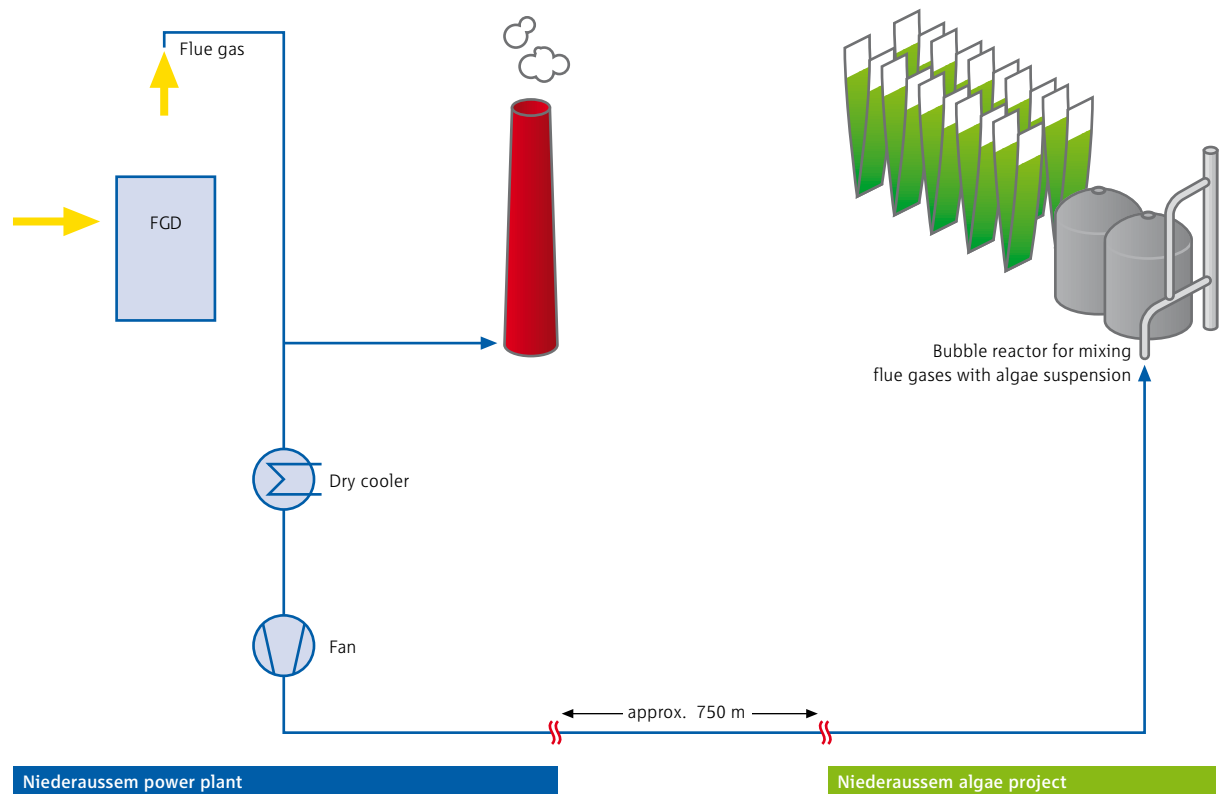


Fig. 2: Schematic diagram of the flue-gas link-up



Fig. 3: Arrangement of the photobioreactors in the greenhouse

the suspension, absorbing CO_2 from the flue gas up to saturation. The gas exiting the suspension at the top is reduced by the corresponding amount of CO_2 and is released into the environment via a chimney.

Thanks to the bubble-reactor process, no flue gas, but only the CO_2 dissolved in the algae suspension, is fed into the greenhouse.

Photobioreactors

The CO_2 -enriched algae suspension is conducted into the greenhouse and fed into the photobioreactors (Fig. 3) developed by Novagreen Projektmanagement GmbH. These consist of clear plastic hoses that are fixed in V shape to supports.

To optimize growing conditions, the bioreactors are located in a greenhouse. There, relatively constant temperatures as well as optimal nutrition and lighting conditions, can be set for the algae's high growth rates. The required heat is made available by the neighbouring power plant from unused cooling-tower waste heat (Hortitherm). The photobioreactors are currently erected on an area of 600 sq.m., and up to 1,000 sq.m. is available for extensions.

The first extension stage to 600 sq.m. contains approx. 52 cbm algae suspension. From above, suspension is fed in by a small hose, and suspension is drained off at the bottom, again by hose. In the transparent photobioreactor, the algae come into contact with light and grow. The CO_2 needed for photosynthesis is dissolved by the micro-algae from the suspension and absorbed. So that all micro-algae receive the same amount of light, the photoreactors are stirred by blowing air bubbles into the reactor from below that pearl through it.

The suspension's pH indicates the CO_2 content. It is measured in representative photobioreactors and used to control the feed-in of CO_2 -enriched suspension from the bubble reactor. The drained-off suspension is fed into the bubble reactor again. The algae amount is established by measuring the suspension's optical density. If this is sufficiently high, the algae suspension is conducted to a harvest container, instead of the bubble reactor. The algae are then separated from the saltwater. The separated micro-algae have a paste-like consistency and are now available for further processing. The saltwater is re-introduced into the cycle. Fig. 4 shows the process in a diagram.

The system can produce up to 6,000 kg algae (dry substance) per year. This binds 12,000 kg of CO_2 .

Algae project data

Cooperation partners in the algae project	<ul style="list-style-type: none"> ▪ RWE Power AG ▪ Jacobs University Bremen ▪ Forschungszentrum Jülich GmbH ▪ Phytolutions GmbH
Contractors	<ul style="list-style-type: none"> ▪ Bong, gardening firm ▪ Novagreen Projektmanagement GmbH, Vechta, algae reactors
Location of the algae project	<ul style="list-style-type: none"> ▪ Bergheim-Niederaussem, in immediate vicinity of RWE's Niederaussem power plant ▪ Pilot plants at Jacobs University Bremen and the Jülich Research Centre
Link-up to power plant	750 m flue-gas pipe with compressor
Max. area of photobioreactors	Approx. 1,000 sq.m.
Expected production	Approx. 6 t/a dry algae mass (on 600 sq.m.)
Expected CO ₂ binding	Approx. 12 t/a from power-plant flue gases (on 600 sq.m.)
Term for overall project	3 years
In operation since	2008

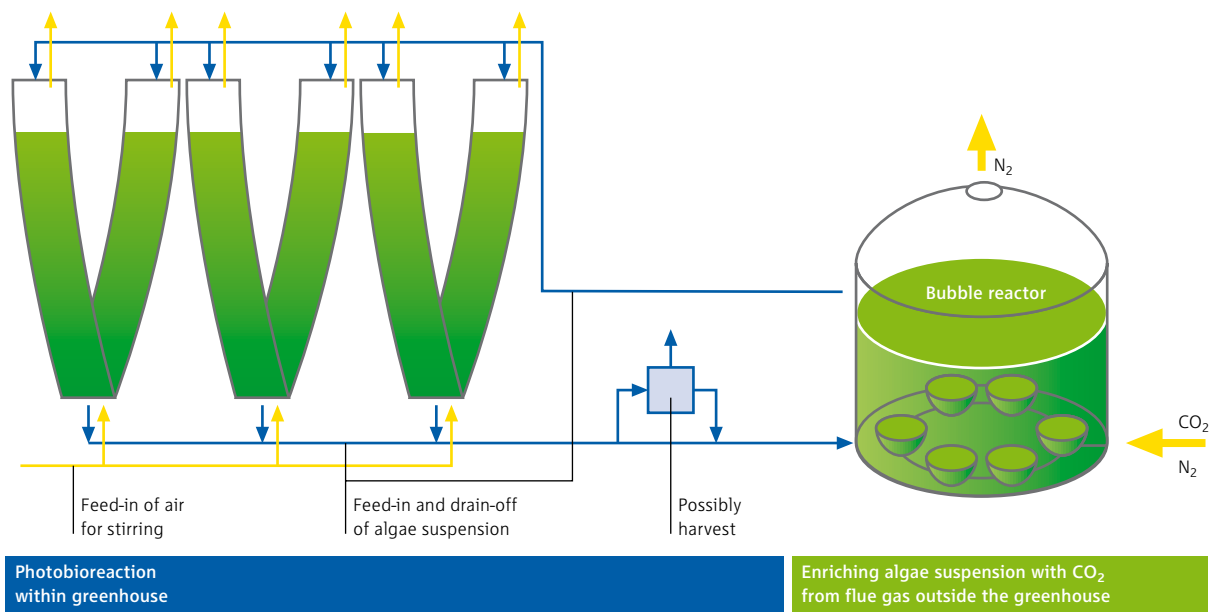


Fig. 4: Process diagram of photobioreactor with bubble reactor

STUDY PROGRAMME

The system for algae production with flue gases erected by RWE Power at its Niederaussem power plant offers unique opportunities for studying this option of CO₂ binding in a project involving noted partners. The main objective of the study is the long-term energetic, ecological and economic balance of the entire algae production process and subsequent conversion and use options.

Initial project phase

In the project's initial phase, the algae growth rates are to be increased by using different algae cultures, optimized growth conditions and improved greenhouse technology. Also, the entire process management is to be optimized with the aim of ensuring the lowest possible energy required to achieve the greatest possible biomass production and net CO₂ reduction.

Another focus is on the development of concepts for using the algae. A process for converting the algae biomass into energetically usable products is already being investigated. Some of the algae is also to be used in a biogas plant. Further promising conversion routes are being established for a follow-up project phase.

For future applications, overall concepts with suitable locations are to be developed and assessed using cost, benefit and potentials analyses.

To implement the programme, notable project partners were won: Prof Dr Thomsen, Jacobs University Bremen, provides the project's scientific leadership. Prof Dr Schurr and Prof Dr Ulbrich, Jülich Research Centre, are in charge of optimizing the environmental conditions for algae production using innovative greenhouse technology. Phytolutions, a spin-off of Jacobs University, operates the algae production system jointly with the greenhouse owner and operator, Bong.

Activities at Jacobs University Bremen and at the Jülich Research Centre

In addition to the comprehensive work on the algae production system at Niederaussem, studies are being conducted of reactors identical in design at Bremen and Jülich (in order to optimize the production conditions and the innovative greenhouse technology to be used). The number of photobioreactors and, hence, the size of the system, permit experimental investigations for any transfer of the results to the production plant in Niederaussem.



At Jacobs University Bremen, an algae plant is being erected for developing algae cultures. It is headed by Prof Dr Thomsen, a renowned oceanographer who has been involved in algae growing and CO₂ mitigation/sequestration for many years now. The remit of the researcher group in the algae project is to select suitable algae strains or mixtures of algae species that are especially suitable for the plant erected in Niederaussem and for local conditions (climate, light). Jacobs University, together with Phytolutions, is carrying out the ongoing process technology, conceptual and biological optimization of the algae production system at Niederaussem. The monitoring and, possibly, adjustment of the plant parameters is being implemented using a remote-controlled process control system. The scientific work on suitable overall concepts is being handled in Bremen. This includes the evaluation of the project results to detect opportunities for implementing major industrial algae growing projects at suitable sites with optimized site conditions.

Besides the search for suitable algae species for growing at Niederaussem, one group of researchers is focussing on optimizing greenhouses for algae production. At the Jülich Research Centre, innovative glazing systems have been installed for this purpose at two existing research greenhouse units. The Jülich Research Centre has many years of experience with greenhouse technology and optimized plant production. The greenhouses' novel glazing systems in Jülich are marked by high transparency and advantageous support for regulating air conditioning. In this way, the light offered by the sun can be used as efficiently as possible, and the energy consumption for air conditioning the greenhouses reduced perceptibly. The aim of the work is the integration of the lighting, CO₂, nutrition and temperature conditions to optimize the production situation. Using new non-invasive procedures, information about the state of the algae is to be collected and then used to control and, hence, largely automate biomass production. With the aid of these systems, insights are to be gained into how innovative greenhouse materials and novel sensor processes can help automate growth control in one integrated solution to optimize growth conditions and, hence, energy-efficient algae production. The photobioreactors erected in Jülich are fed with technical CO₂. To enable a more direct comparison between the greenhouse technology at Niederaussem and that used in Jülich as regards algae production, some of the photobioreactors in Niederaussem, too, are supplied with technical CO₂. At the same time, both locations record the factors that impact algae production, like hours of sunshine, light intensity and temperature.

Studies of algae conversion

Using the algae biomass produced, investigations include hydrothermal carbonization, in which biomass is heated under pressure, with water being added and oxygen cut off to obtain different hydrocarbon products. Basic research establishes and optimizes the process parameters for the algae input. Analysis shows which properties of the algae biomass favour its conversion by hydrothermal carbonization in order to optimize algae breeding using this feedback.

The fermentability of algae as monosubstrate is to be investigated within the scope of a study. Here, max. gas yield, the influence of the salt content and possible co-substrates and pretreatment are to be clarified. The experimental work uses the algae produced in Niederaussem.

Planning also calls for research into adding algae biomass to a biogas system.



Further course of the project

Expansion of the project is now envisaged. In addition to the activities described above, further promising conversion routes are to be trialled with the algae biomass, which will then be available in sufficient quantity. The conversion routes may include conversion into biodiesel, BtL, butanol and other options. To this end, the aim pursued is partnerships with other companies in this sector. Moreover, further algae production technologies in the same greenhouse are to be used to enable a direct comparison of the processes involved. The biological aspects of micro-algae production – selection of the species, mixed populations, nutrients – are to be worked out in depth in the further course of the project. Extensive activities are also planned in the area of optimizing algae production using improved greenhouse technology. ■

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