Knick

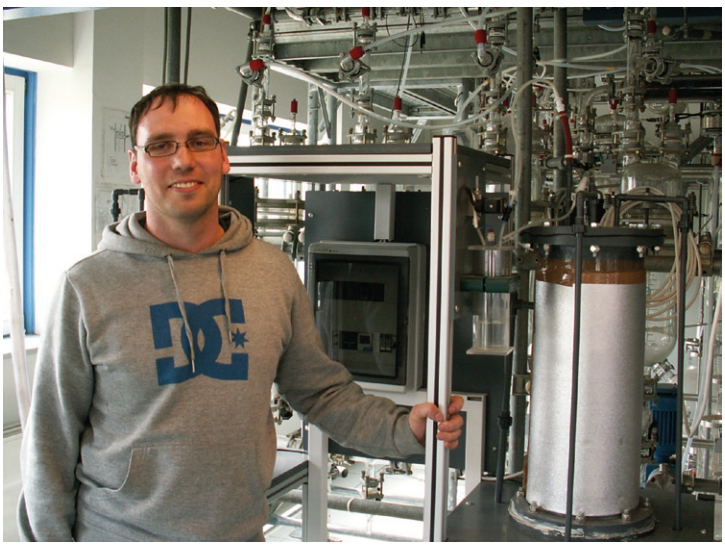
Chlorophyll - the "solar cell" of the future

Since 2010, TH Wildau has been operating an algae farming pilot plant south of Berlin, in which a photobioreactor, a methane gas reactor, and a combined heat and power plant have been connected in a closed cycle for the first time. The main goal of the project – which is intended to provide data for a large-scale plant down the road – is the optimal configuration of the process technology components and reduction of the external energy input to a minimum. In order to measure the pH and oxygen levels, the TH Wildau technicians are deploying Knick Memosens sensors and Memorail analyzers.

Photobioreactor at TH Wildau

Too valuable to burn

In the search for biofuels, science has been focusing on microalgae for a few years now. A variety of methods exist for obtaining combustible fuels from algae: Catalytic processes can be used to obtain fuel from specific types of algae, and fermentation process can be used to convert carbohydrates from algae into bioethanol. Another approach is the production of methane through anaerobic fermentation of the algae mass. This is the method used in the pilot plant in Wildau. "But algae are really too valuable to burn them as fuel in engines", explains Diplom-Ingenieur (FH) Roberto Lisker from the Competence Center for Renewable Energy, who administers the project at the University of Technology. "Because in principle, algae have the potential of contributing to solutions of global food problems. The microorganisms can provide us with starch, high value proteins, and nutritional supplements such as fatty acids, antioxidants, and vitamins." And the energy efficiency of algae, meaning the photosynthesis conversion per growing area, is higher than for all other renewable raw materials, and their productivity with regard to starch, oils, and fatty acids is even up to seven times higher than for the high output plant corn. According to Lisker, the area currently used for agriculture could be reduced by 9/10 if the world's population were to produce all of its food with algae reactors. In addition – and depending on the type of algae – a variety of other valuable materials can be produced. But all the things one can do with algae are secondary in the Wildau pilot plant. The main goal here is the testing and improvement of the process technology cycle: This includes increasing the energy efficiency, testing suitable materials, and of course maximizing the algae yield..



Roberto Lisker from the Competence Center for Renewable Energy in front of the methane gas plant

In the spotlight: Scenedesmus Rubescenss

"Algae farming is already being performed and researched in many places today. The individual process steps are known, and the components required for cultivation are readily available", Lisker explains. "The novel thing about the project here in Wildau is that we are for the first time connecting all of the individual steps into a cycle and researching how the overall efficiency of the system can be optimized." The actual challenges are not faced by the biologists, but by the engineers, even if everything at the pilot plant revolves around a biological agent: the single-celled green algae Scenedesmus Rubescens, which with a diameter of just 10 µm is around one-hundredth the thickness of a human hair. Why this particular species of algae? "There are estimated to be around 340 000 species of microalgae, around 150 000 of which we currently know about. A few hundred of these can be cultivated", Lisker outlines the current level of knowledge. "Scenedesmus Rubescens made it into the final selection on account of its stable nature. And the longer we work with this algae, the more we like it." This microalgae is relatively undemanding and robust, grows quickly, produces many oils and fatty acids, and it has both a photo as well as a heterotrophic metabolism – so it can obtain its energy either from light or from salts. The only other thing this frugal algae still needs to live is CO_2. In Wildau, it receives this from a combined heat and power plant with a single-cylinder free piston Stirling engine which also provides the energy for all process steps. .

The "nursery": The algae have to be cultured over a period of approx. 3 months before they are placed in the bioreactor. The orange color of the bottle in the middle indicates that the algae have a high carotene content.

The cycle

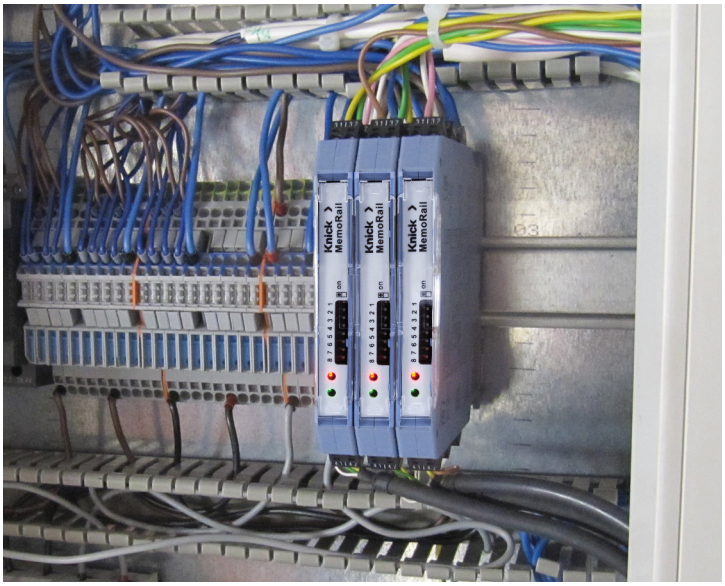
A specific amount of algae which are grown in an external laboratory beforehand are required before the bioreactor can be started. It takes approximately three months until the targeted amount of algae are available. Then the algae population can be placed in the photobioreactor, which in Wildau consists of a piping system which is permeable to light and has a volume of 250 liters. In between the pipes, low-energy fluorescent tubes emit the precise wavelength of light required by the algae for photosynthesis. The electricity for the lights and the CO_2 for the algae is provided by the combined heat and power plant. However, the CO_2 rich exhaust gases from the power plant cannot be fed directly into the bioreactor tubes, since they are too hot at a temperature of approx. 90 °C and contain sulfuric acids which must be filtered out first. Therefore the exhaust gases are passed through a container filled with zeolites – crystalline minerals similar to ceramics – to filter, cool, and also dry them. Then they are fed into the tubes of the reactor filled water and algae. In addition to providing CO_2, they also have the important function of keeping the water in motion: the constant "sloshing" of the water prevents layers of algae from depositing on the walls of the tubes and slowly making them opaque. For every cultivation of the reactor with a new generation of algae – which require ten days until harvest – the chemical equilibrium in the salt water has to be checked and adjusted first. "Initially we also monitored the conductivity of the water, but we quickly discovered that the small amounts of nitrates and phosphates added as fertilizer don't have a critical effect on the chemical equilibrium.""

Memosens monitors oxygen and pH

The pH value and oxygen content of the water is very important: The algae require an acidic environment, but the CO_2 supply must be reduced in case of over acidification. The engineers use Memosens sensors from the Berlin measurement technology manufacturer Knick to measure the oxygen content and pH value. "This is very practical for us, because we can pre-calibrate the digital sensors in the lab and don't have to perform the calibration in the close confines on the reactor", Lisker explains. The sensor values are also transmitted to the control room by Knick products: In a control cabinet beside the measuring points, MemoRail series analyzers by Knick receive the values from the Memosens sensors.

Measuring point with Memosens sensors to measure the pH, conductivity and oxygen values

The resource and space saving instruments, which are mounted on DIN rails, feature a scant 12.5 mm wide modular housing and are restricted to the essential functions, since the use of pre-calibrated Memosens sensors and the provisioning and visualization of the measurement values in the control room eliminates the need for on-site visualization on the transmitter. The measured process values and the temperature are output on two standard signal floating current outputs which can be connected to all common controllers or analysis devices.
In Wildau, the MemoRail units transmit the analogue values to a data logger in the control cabinet, which in turn sends the recorded data to the computers in the control room via TCP/IP. "The key factor for us was that we can mount the analyzers on the DIN rail in the control cabinet – a feature only offered by MemoRail", Lisker summarized. In addition, the competence center will soon expand its instrumentation equipment by adding Portavo series portable analyzers. These Knick devices are currently the only portable analyzers with Memosens technology which can measure pH values, conductivity, or dissolved oxygen. In the event that faults or an interruption in the transfer of data should occur, Portavo is able to perform quick and simple reading of the sensors and values directly at the measuring point. These handy devices recognize the sensors automatically and store all relevant data at the push of a button. Then all values can be uploaded from the device to the control room computers via the USB interface.



A view of the control cabinet showing the three MemoRail analyzers for the pH, oxygen, and conductivity values

Processing the algae

Harvest time approaches after ten days of growth in the bioreactor. Since filters would plug up due to the small diameter of the algae, they are separated from the water by a centrifuge and then solubized in a high pressure homogenizer at 650 bar to extract the valuable substances. The cultivation conditions in the reactor determine what percentages of which substances the algae produce. A low concentration of nitrate in the water, for example, promotes the production of fatty acids. But if the light intensity is increased, the algae react by increasing the production of carotenoids. After all valuable substances have been extracted from the algae emulsion, biomass is harvested and used to produce methane gas in a type of biogas system. The methane gas, in turn, is fed into the combined heat and power plant. The cycle is closed.

Conclusions

"Unlike our pilot system which is used for research purposes and in which we only use artificial light, using a photo bioreactor economically requires that the systems are located outdoors and therefore act as a biological storage medium for solar energy. In the end, this requires a considerably larger scale than that of our system", Lisker explains. The pilot plant in Wildau produces the following results: The harvest from 250 liters of "algae water" is around 2 liters of algae sludge, from which between 100 and 200 grams of high quality nutrients can be harvested. The methane gas produced from the biomass is sufficient to operate the combined heat and power plant for ten minutes. A third of the total energy used by the system is required for harvesting, so for operation of the centrifuges and homogenizer.

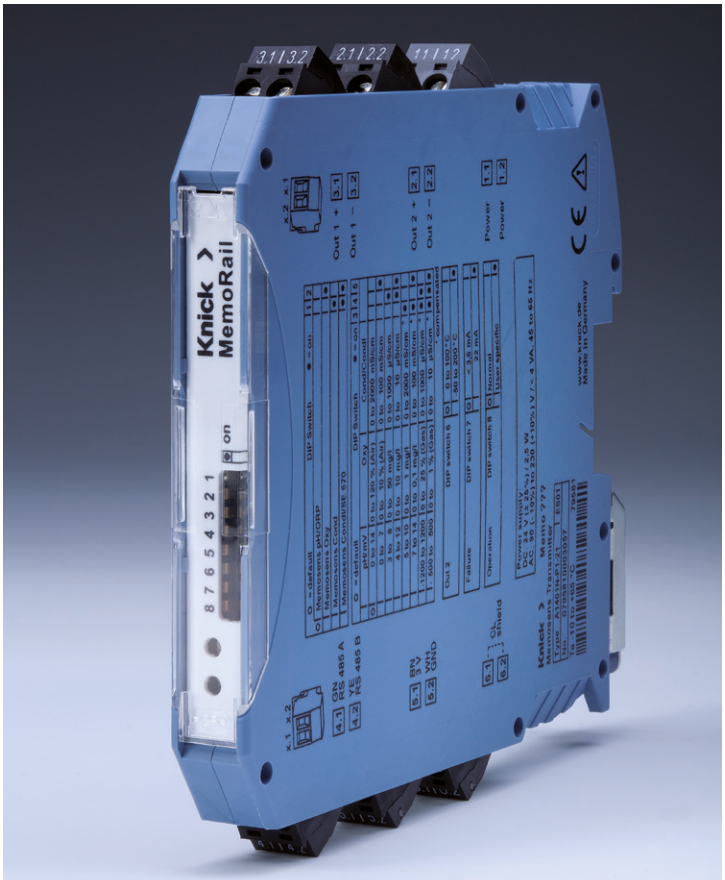
What's next?
One has to consider that we operate our combined heat and power plant primarily to produce the exhaust gases – for research purposes – and not to produce electricity or heat," Lisker explains. "This is because we were primarily interested in a closed CO_2 cycle". Energy efficiency will play a central role in the next step. Then the excess heat generated during cooling of the exhaust gases will be used in a secondary generating system based on an organic Rankine cycle. Further current research at the Competence Center for Renewable Energy deals with the suitability of different lamps – LEDs are currently being tested – as well as the material and surface structure of the bioreactor tubes. Soon the competence center will be using tubes with a special surface structure for one of the bioreactors. These should be even better at preventing adhesion of the algae.

In this reactor, the ability of LEDs is tested to be a light source of energy for the algae

Memosens connector

Memosens, MemoRail and Portavo

Memosens sensors feature toroidal, wireless data transmission and power supply. Since the intelligent electrodes are able to store and process sensor-specific data directly in the sensor head, they can be pre-calibrated easily and under ideal conditions in the laboratory. The already pre-calibrated sensors have a longer service life than conventional products and reduce the likelihood of downtime. The sensor system is also distinguished by a bayonet coupling, which connects and disconnects easily and transmits the digitalized measurement values wirelessly from the sensor to the process device. With conventional sensor technology, factors such as moisture, corrosion, and deposits on the contacts can falsify the measurement values. Unlike the Memosens toroidal coupling system, which guarantees perfect galvanic isolation, interference-free data transmission, and problem-free handling of the sensors under rough conditions – the system can even be connected under water. The MemoRail series analyzers support easy measuring of pH values, conductivity, and oxygen levels with pre-calibrated Memosens sensors which eliminate the need for on-site visualization. The analyzers with the 12.5 mm wide modular housing support all Memosens sensors – pH glass, ISFET, oxygen, conductivity, or digital toroidal sensors – and can be configured easily via DIP switches. The measured process values and the temperature are output on two standard signal floating current outputs which can be connected to all common PLCs. MemoRail is available in two versions: a 24V DC version which can be connected directly or via the DIN rail bus, and in a VariPower version for 90...230 V AC/DC. In addition to MemoRail, Knick also offers a family of Memosens components. These include MemoSuite, a software tool for calibration, troubleshooting, and documentation, and the Portavo device for troubleshooting and on-site diagnostics. With the new Portavo Models 902, 904(X) and 907, Knick is presenting the first portable analyzers in the market for measuring pH value, conductivity or dissolved oxygen with Memosens technology. Depending on the model, analog sensors and optical oxygen sensors can also be used in addition to the digital Memosens sensors. All Portavo housings are made of high-strength plastic and are designed for rough industrial use thanks to IP 66 protection. An integrated protective cover that protects the display against scratches and damage in the field can be used as a bench top stand in laboratory applications. The housing also features an integrated sensor quiver that protects the sensor against drying out.



MemoRail transmitter by Knick

The Portavo series form Knick:
the first portable analyzers for Memosens sensors.

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