Energy:
Renewable Energies
and Energy Efficiency

Biomass

1.4

2E a division of GUNT HAMBURG

This product area is one of GUNT's current areas of development. If you have any ideas for future teaching and research equipment in this field, please get in touch. We would love to work with you.

Visit our website at:
www.gunt2e.de

Subject Areas
Biomass

General biomass is an extremely versatile starting material. You can use the various plants and fruits as food, as animal feed, as fuel for heat generation, as fertiliser, as an additive or base of creams and lotions and as fuel for mobility purposes.

Many of the uses listed overlap with other areas, so that any by-products created may be used as starting material in another branch.

We offer three devices in the biomass field, which provide a practical representation and illustration of the fundamental processes. Use of any by-products created is also possible. For example, with CE 640 on the biotechnical production of ethanol, you gain ethanol as the main product and mash as the by-product. You can either discard the mash or use it as substrate in the CE 642 biogas plant. When you operate the biogas plant, you receive biogas as the main product and a high-quality fertiliser, the digestate, as a by-product. This digestate is low in odour compared to manure and the nutrients are better absorbed by plants.

The main product of the CE 650 Biodiesel Plant after the optional purification process is biodiesel. With optional treatment of the by-products you can also obtain glycerin, which is used in the food and cosmetics industries, and a portion of additives.

Subject Areas	2E0 Products
Bioethanol	**CE 640** Biotechnical Production of Ethanol The anaerobic degradation of plant components (e.g. pota-toes) through enzymes and yeasts can produce bioethanol, which can be used as a fuel. The waste gas is in turn absorbed by the plants and the circuit is closed.
Biogas	**CE 642** Biogas Plant Biogas can be produced by the anaerobic degradation of plant components (e.g. maize) through biomass and, for example, be converted into electricity in combined heat and power plants and the waste heat used for heating purposes. The waste gas is in turn absorbed by the plants and the circuit is closed.
Biodiesel	**CE 650** Biodiesel Plant Both glycerin and the desired biodiesel are obtained with the transesterification of plant-based oils, and with the help of a few additives. The waste gas is in turn absorbed by the plants and the circuit is closed.

Basic Knowledge
Bioethanol

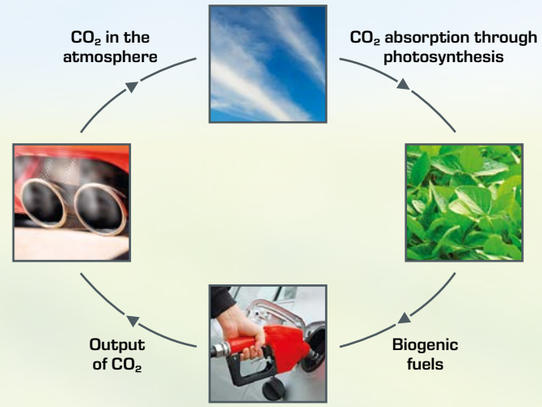
The consumption of fossil fuels (coal, petroleum, natural gas) has risen sharply in recent decades. The outputs required to cover the energy demand are leading to an ever more rapid depletion of deposits. Newly discovered deposits are difficult to extract due to the location and frequent impurities. Therefore alternatives are being sought.

Replenishable biomass can be used to produce storable carbon neutral energy sources. These energy sources play an important role alongside discontinuous sources such as solar and wind in realising a carbon-neutral and renewable energy supply.

Different biological and thermal processes are used to convert the biogenic energy feedstock into a storable energy source.

The CO_2 cycle of bioethanol

Photosynthesis, with the aid of sunlight, enables plant growth. In this process CO_2 from the atmosphere, as well as water and inorganic substances from the plants, are absorbed and converted into energy-rich organic compounds. This biomass can be regarded as the product of a biochemical process, in which a portion of the absorbed sunlight is stored in the form of chemical energy. Being able to use the biomass as an energy source in various technical processes requires special treatment processes. These include simple physical process-es as well as more complex thermochemical and biological processes.



Biofuels for carbon-neutral energy

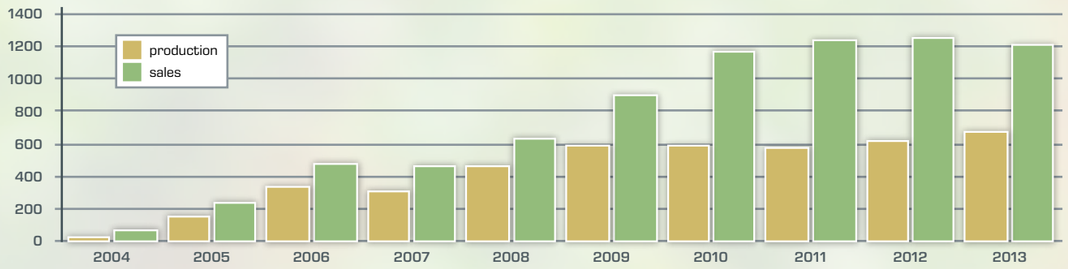
In addition to the simple mechanical processes such as comminution and press agglomeration used to produce solid energy sources (pellets), complex biological processes are used to produce biofuels and biogas.

These methods are applications of natural processes on an industrial scale. Factors such as temperature, pH value, mixing and residence time play an important role in these processes, so as to achieve the greatest yield of energy sources from the biomass.

Biofuels are substitutes for super unleaded and diesel fuels, which are either mixed with fossil fuels or used directly with appropriate engine technology. The basis of biofuel is ethanol for super unleaded fuel and vegetable oil for diesel fuel.

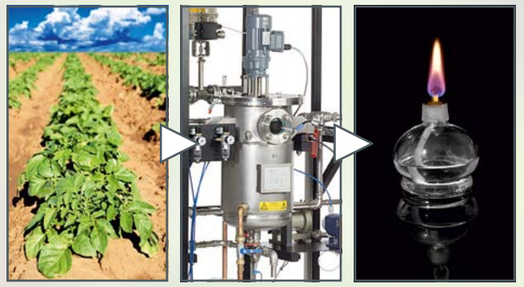
For the field of biofuels, we supply a complete system that uses enzymes and yeasts to convert starch ethanol. The integrated distillation system is used to separate the ethanol from the digestate.

Another system for the conventional production of biodiesel by means of transesterification is in development.

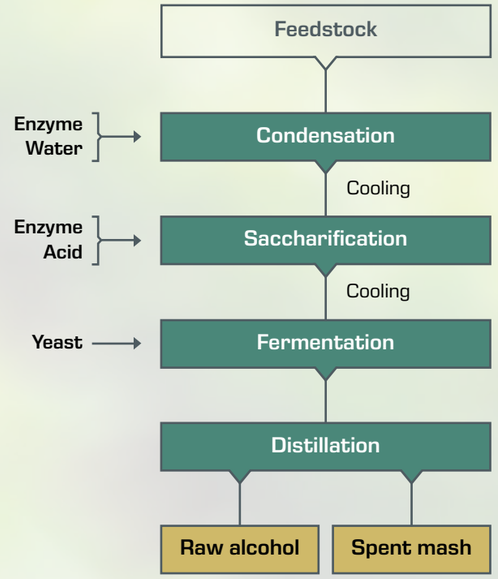


Growth of bioethanol in Germany (in 1000 t) (Source: BDBe/FNR)

Starting materials for bioethanol are the carbohydrates (sugars) contained in the plants, from which alcohol is created with the aid of enzymes and yeast fungus. While plants containing sugar are fermented directly, in the case of starchy plants it is the actual alcoholic fermentation of the enzymatic digestion of the plant material that comes first.



The fermentation process is completed once either the sugar is consumed or a maximum alcohol concentration is reached. The resulting bioethanol is separated by distillation. The product of distillation is called raw alcohol.



Fundamental principle of bioethanol production

CE 640 Biotechnical Production of Ethanol

Understand the production process of bioethanol in a laboratory experiment

The experimental plant on the biotechnical production of ethanol is ideal for teaching professionals and students in the fields of chemical and bioprocess engineering. Bioethanol will be the world's leading biofuel in the future. Students learn the complete process from feedstock to end product.

Using the CE 640 Biotechnical Production of Ethanol experimental plant, you can follow and investigate all necessary process steps from condensation and saccharification of the feedstocks, through to the conversion of sugar into ethanol and distillation.

Addition of the yeast into the fermentation tank

Preparation of the yeast

Addition of feedstocks into the mash tank

Satisfied customers

AGRICULTURAL RESEARCH INSTITUTE
Nicosia/Cyprus

Dr. Polycarpos Polycarpou

Agricultural Research
Officer Head of Soils and Water Use Department
Agricultural Engineering
Agricultural Research Institute

Fachhochschule Münster University of Applied Sciences

Chemical Engineering Department in Steinfurt (Germany)

The production of ethanol with CE 640 is offered as a practical course in the laboratory for chemical process engineering at the Münster University of Applied Sciences. Two sessions are scheduled so that all participants can follow both the preparation of the mash and the results of fermentation in their own experiments.

An interesting film and a brochure for CE 640 can be found on our 2E website www.gunt2e.de

CE 640 Biotechnical Production of Ethanol

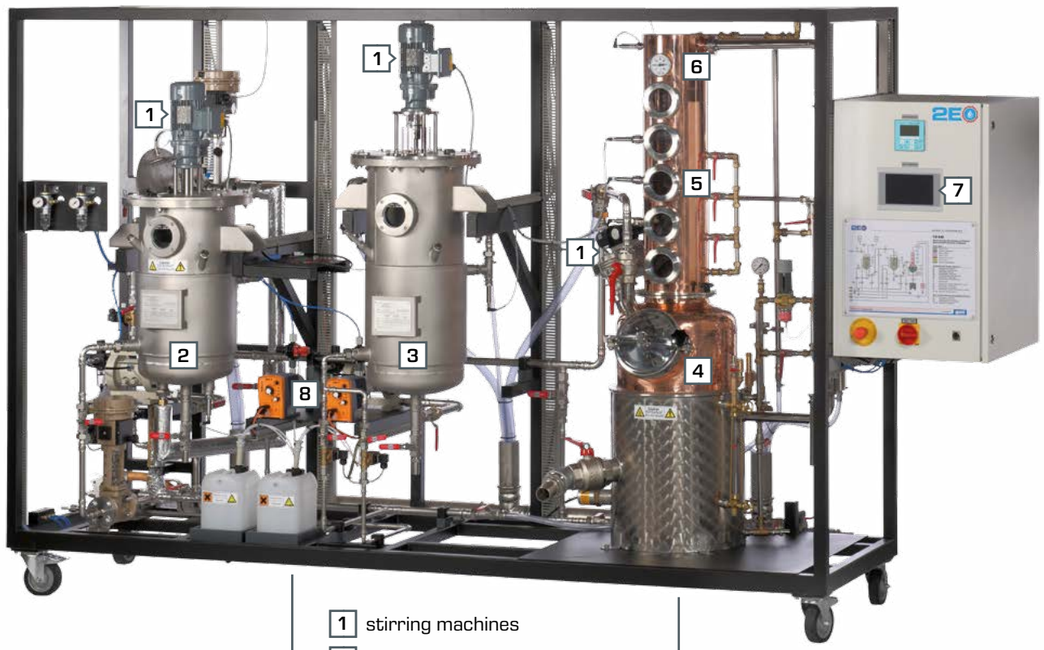
From plant to biofuel

Using the CE 640 trainer you can go through the whole process used to produce ethanol in the laboratory. Ethanol is produced from raw materials containing starch and sugar, as a starting material for biofuels and many other products. When converting starch to ethanol, different conversion processes have to be conducted using enzymes and yeasts.

The starch is converted into sugar in the first tank by glucoamylase and alpha-amylase enzymes. The temperature and pH value are monitored and controlled while this process takes place.

After the material has been pumped over into the second tank and yeast has been added, the fermentation process takes place sealed off from the outside atmosphere. The yeast converts the sugar into ethanol and carbon dioxide. The carbon dioxide escapes into the environment via a fermentation lock. The temperature in the fermentation tank is monitored and regulated throughout the process.

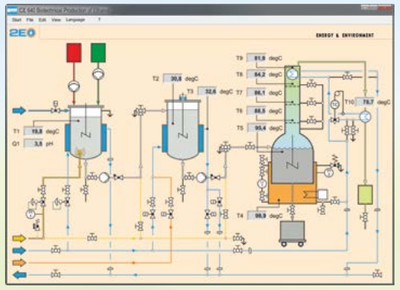
Once the fermentation process has ended, the ethanol is separated from the waste materials using a distillation unit (still).



1 stirring machines
2 mash tank
3 fermentation tank
4 distillation kettle
5 column
6 dephlegmator
still
7 PLC with touch panel
8 metering pumps for acid or caustic solution

Product No.
083.64000
More details and technical data:
gunt.de/static/s3336_1.php

Thick-walled, highly polished and hammered pure copper distillation kettle.



Software

The software for CE 640 allows the most important variables to be captured

- temperature
- pH value

mash tank

- fermentation temperature
- water temperature

fermentation tank

- boiler temperature
- bubble tray temperatures
- dephlegmator temperature
- condenser temperature

still

Learning objectives

- gelatinisation by steam injection
- liquefaction by use of alpha-amylase
- saccharification by use of glu-co-amylase
- fermentation: conversion of sugar into ethanol by yeast cultures under anaerobic conditions
- distillation: separation of ethanol from the mash

Basic Knowledge
Biogas

Rising energy requirements and the limited availability of fossil energy sources make new energy supply concepts necessary. Energy production from biomass plays an important role in future energy concepts besides solar and wind energy.

In a biogas plant, microorganisms biologically degrade the organic starting substances (substrate) under exclusion of light and oxygen. The product of this anaerobic degradation is a gas mixture which primarily consists of methane. This gas mixture is called biogas.

The complex processes of anaerobic degradation can be simplified as four consecutive phases.

Phase 1: Hydrolysis
The substrate used in biogas plants is available as undissolved, high-molecular compounds such as proteins, fats and carbohydrates. Therefore these compounds first have to be broken down into their individual components. Hydrolysis products are amino acids, sugars and fatty acids.

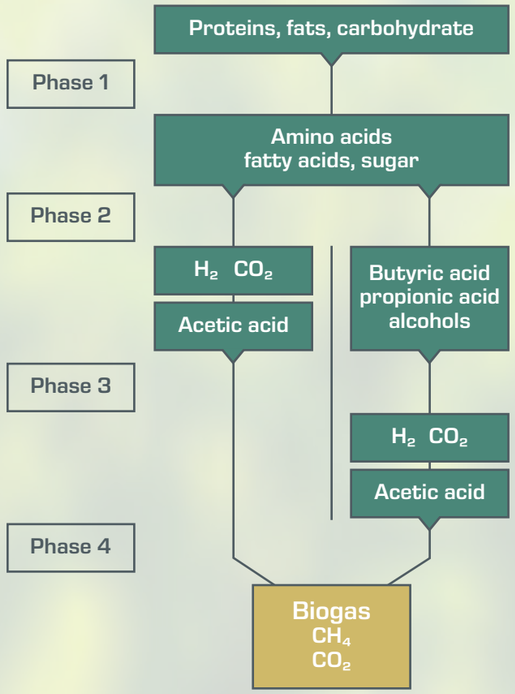
Phase 2: Acidification
The hydrolysis products are then biochemically decomposed further, primarily into propionic acid, butyric acid, acetic acid, alcohols, hydrogen and carbon dioxide.

Phase 3: Formation of acetic acid
The products of the previous phase are now converted into acetic acid, hydrogen and carbon dioxide.

Phase 4: Formation of methane
Methanogens can use either acetic acid (CH_3COOH) or carbon dioxide and hydrogen for their metabolism. So methane (CH_4) can be produced in the following two reactions:

$CH_3COOH \longrightarrow CH_4 + CO_2$

$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$



Fundamental principle of anaerobic degradation

Ambient conditions

The microorganisms involved in the anaerobic degradation have different requirements regarding the ambient conditions. This applies primarily to the pH value and the temperature. Especially methanogens are very sensitive to deviations of these two process variables from their respective optimal value.

If all 4 phases of the degradation take place in one reactor, a compromise regarding the pH value and temperature needs to be found. This results in a lower biogas yield. From a process engineering point of view, a two-stage process in two separate reactors is more practical as this enables the ambient conditions to be adjusted more specifically to the respective bacteria.

Use of biogas

The biogas produced can now be combusted in a combined heat and power plant. This converts the energy stored in the biogas to mechanical energy. A connected generator then converts this mechanical energy into electric power. In addition to electrical energy, a combined heat and power plant also produces heat which can, for example, be used to heat the reactor or buildings.

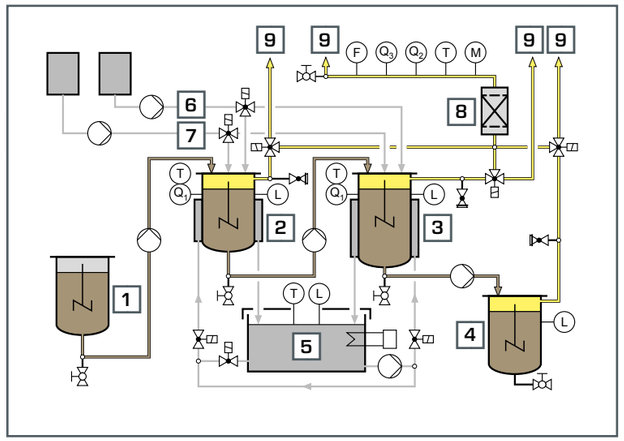
How a biogas plant works:

1. slurry from livestock husbandry
2. renewable raw materials (e.g. maize)
3. storage for shredded raw materials
4. storage for feeding the bioreactor
5. bioreactor (fermenter)
6. storage for digestate
7. biogas treatment
8. combined heat and power plant
9. water circuit to heat the bioreactor
10. feed of the current into the public power grid
11. digestate (use as fertilizer)

CE 642 Biogas Plant

In CE 642 we have developed a practical system for the production of biogas under laboratory conditions. CE 642 allows you to study all important factors that influence biogas production. The necessary process steps can be controlled and automated via the PLC. The plant is equipped with extensive measurement technology and data acquisition in order to capture all necessary process variables.

A suspension of comminuted organic solids is used as the substrate. Hydrolysis and acidification of the substrate take place in the first stirred reactor. Here, anaerobic microorganisms convert the long-chain organic substances into short-chain organic substances. In the second stirred reactor, biogas is created in the final step of the anaerobic degradation. This biogas primarily contains methane and carbon dioxide. This two-stage method means you can adjust and optimise the ambient conditions in the two reactors independently of each other. The digestate is collected in a separate tank.

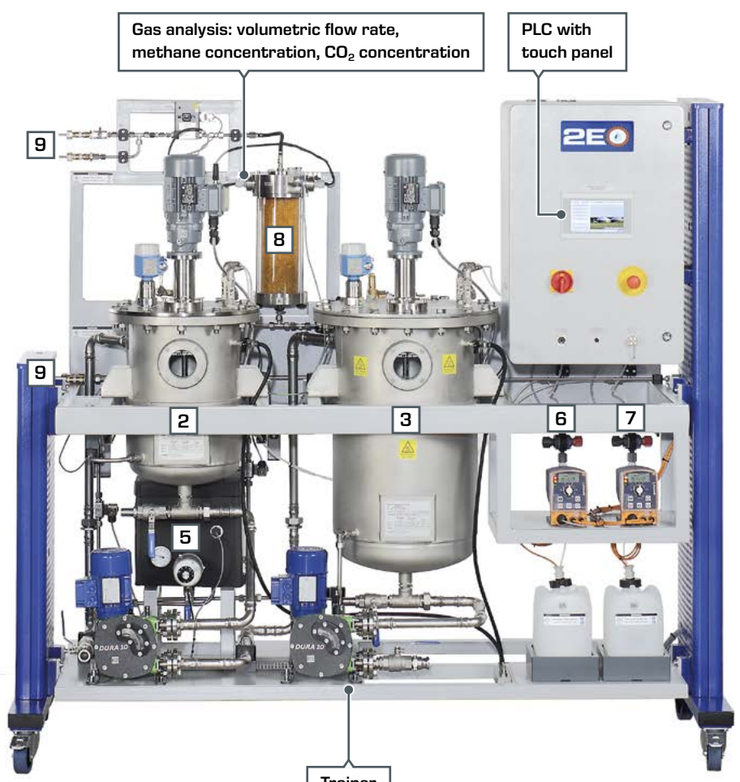


1 substrate tank
2 reactor 1
3 reactor 2
4 digestate tank
5 heating water tank
6 acid dosing
7 alkaline dosing
8 drying column
9 biogas

F flow rate
L level
M humidity
Q_1 pH value
Q_2 methane concentration
Q_3 CO_2 concentration
T temperature

Industrial peristaltic pump

Supply unit



Trainer

Secondary treatment unit

Learning objectives

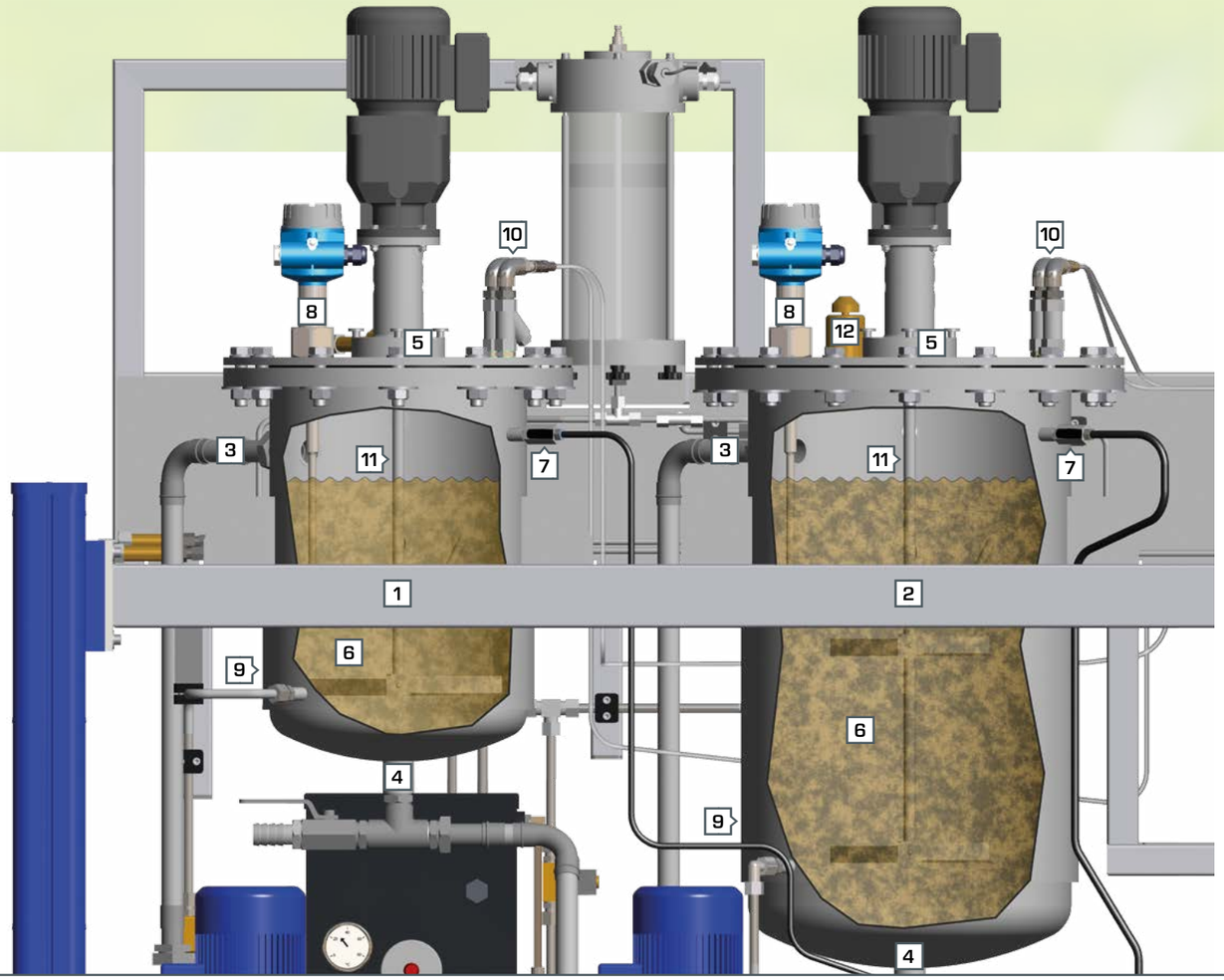
- achieving a stable operating state
- influence of the following parameters on the biogas generation:
  - temperature
  - substrate
  - volumetric loading
  - pH value
- influence of the operation mode on the biogas yield
  - single stage or dual stage
  - with and without post-fermentation
  - continuous and discontinuous
- determining the following parameters depending on the operating conditions:
  - biogas yield
  - biogas flow rate
  - biogas quality

Silica gel in the drying column

Connectors for biogas with gas analysis

Product No.
083.64200
More details and technical data:
gunt.de/static/s5354_1.php

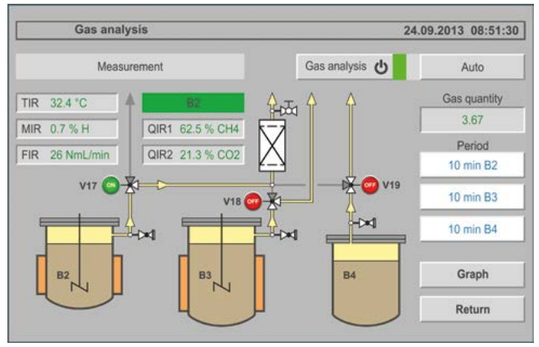
CE 642 Biogas Plant



Each reactor can measure fill level, pH value and temperature. Substrate and biomass are pumped by peristaltic pumps typical of biogas plants. Temperature is controlled via a double jacket with heating water. The biogas can be analysed or passed directly for consumption.

1 reactor 1
2 reactor 2
3 inlet
4 outlet
5 fill opening
6 biomass
7 connector for inert gas
8 level control
9 double jacket for heating
10 acid and alkaline dosing
11 stirring machine
12 safety valve

Software



In the gas analysis menu in the PLC user interface, you are given a summary of the current flow direction of the gas and the current measured values of the gas analysis. Further-more, this menu is where you select the auto or manual measuring mode, with the measurement times for each tank. You can also retrieve saved measured values via this menu.

The software for CE 642 allows the most important variables to be captured:

- temperature
- pH value
- level
- speed of the stirring machines
- volumetric flow rate

per reactor

- methane concentration
- carbon dioxide concentration
- temperature
- humidity
- volumetric flow rate and quantity

gas analysis

Product No.
083.64200
More details and technical data:
gunt.de/static/s5354_1.php

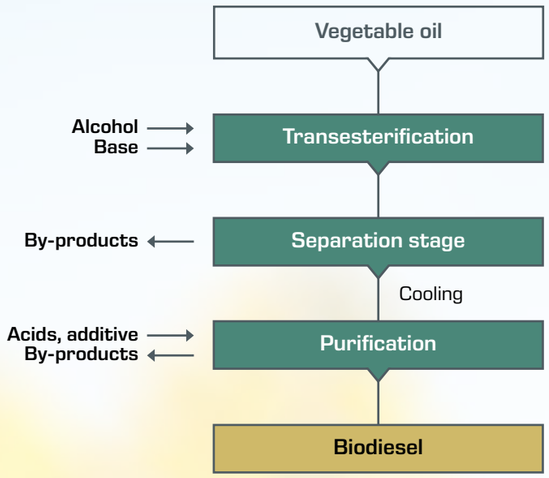
Basic Knowledge
Biodiesel

Biodiesel is an important element in the biofuels field. Biodiesel can be produced from a wide variety of raw materials, which mainly vary by region.

It is mainly vegetable oils which are used, and these are chemically or biologically converted into biodiesel. In temperate regions, rapeseed oil is used in many cases. In sub-tropical regions on the other hand, palm oil is often used.

Furthermore, various input materials such as short-chain alcohols and bases are required for the chemical process of transesterification.

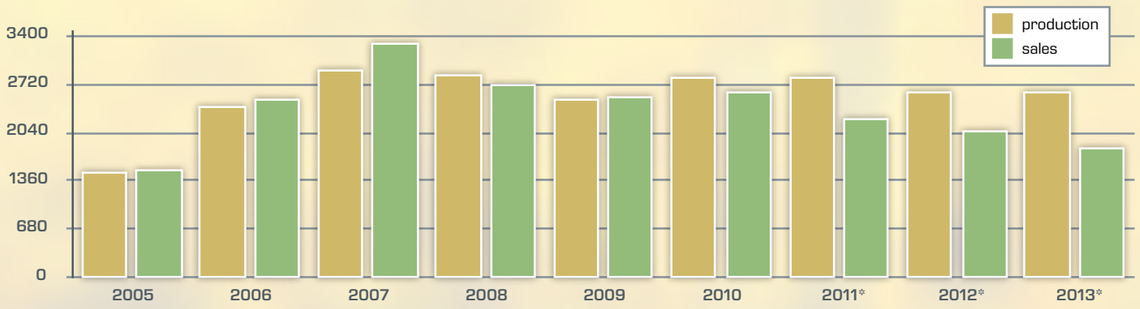
After biodiesel has been successfully produced, it is necessary to clean the biodiesel for use in engines. It is mainly water which is separated out in the additional step. The main by-product is glycerin. A variety of processes are currently being developed to use this glycerin. Thanks to the high level of biodiesel production, large quantities of glycerin which exceed the demand from conventional use as antifreeze and a base for ointments are available.



Fundamental principle
of chemical biodiesel production

Growth of biodiesel

The growth of biodiesel production and biodiesel sales in Germany is linked to political targets. The proportion of biodiesel has been steadily rising for a few years due to the tax benefits and admixtures, and in 2007 reached its peak of 12% of the German diesel fuel market. Production and sales fell in subsequent years due to the declining price advantage and rising raw material costs.



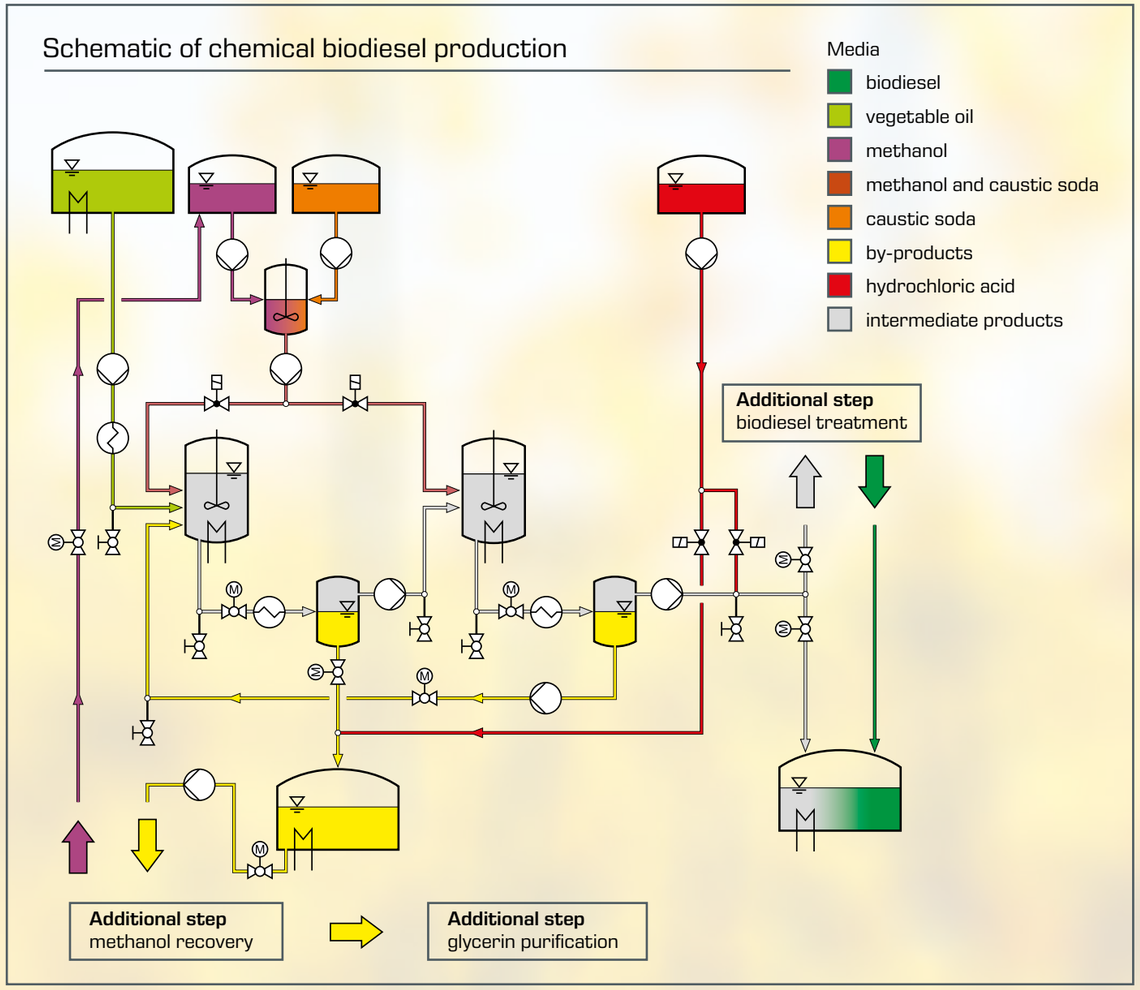
Growth of biodiesel in Germany (in 1000 t)

*Sales excluding hydrogenated vegetable oils
Source: Ufop, VDB, BAFA, BMF, FNR (April 2014) © FNR 2014

CE 650 Biodiesel Plant

Biofuels for carbon neutral energy

In addition to the biotechnical production of ethanol (CE 640), an experimental plant for biodiesel production from vegetable oils is being developed. Biodiesel is produced with a chemical reaction, namely transesterification. With the added alcohol, e.g. methanol, the vegetable oil feedstock is separated into biodiesel and the by-product glycerin. CE 650 offers you the traditional chemical production method for biodiesel and unwanted by-products can be removed by the optional treatment.



Product No.
083.65000
More details and technical data:
gunt.de/static/s5449_1.php

Energy

Biomass: bioethanol

CE 640
Biotechnical production of ethanol

Discontinuous conversion of starch-containing bio-resources into ethanol

Order No.: 083.64000

Energy

Biomass: biodiesel

CE 650
Biodiesel plant

Chemical transesterification of vegetable oils

Order No.: 083.65000

Energy

Biomass: biogas

CE 642
Biogas plant

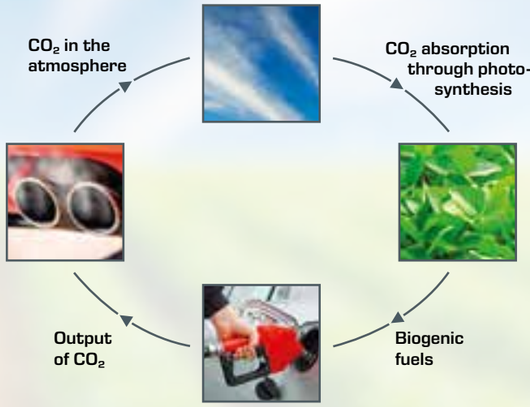
Two-stage continuous degradation of organic substances.
First stage: hydrolysis and acidification, second stage: anaerobic degradation

Order No.:
083.64200

Biomass

The CO_2 cycle

Photosynthesis, with the aid of sunlight, enables plant growth. In this process CO_2 from the atmosphere, as well as water and inorganic substances from the plants, are absorbed and converted into energy-rich organic compounds. This biomass can be regarded as the product of a biochemical process, in which a portion of the absorbed sunlight is stored in the form of chemical energy. Being able to use the biomass as an energy source in various technical processes requires special treatment processes. These include simple physical process-es as well as more complex thermochemical and biological processes.



Bioethanol

CE 640
Biotechnical production of ethanol

Discontinuous conversion of starch-containing bio-resources into ethanol

- familiarization with the necessary individual steps and system components for production of ethanol:
  - gelatinisation by steam injection
  - liquefaction by use of alpha-amylase
  - saccharification by use of gluco-amylase
  - fermentation: conversion of sugar into ethanol by yeast cultures under anaerobic conditions
  - distillation: separation of ethanol from the mash

Biogas

CE 642
Biogas plant

Two-stage continuous degradation of organic substances. First stage: hydrolysis and acidification, second stage: anaerobic degradation

- achieving a stable operating state
- influence of the following parameters on the biogas generation
  - temperature
  - substrate
  - volumetric loading
  - pH value
- influence of the operation mode on the biogas yield
  - single stage or dual stage
  - with and without post-fermentation
  - continuous and discontinuous
- determining the following parameters depending on the operating conditions
  - biogas yield
  - biogas flow rate
  - biogas quality

Biodiesel

CE 650
Biodiesel plant

Chemical trans-esterification of vegetable oils

- production of biodiesel from vegetable oil
  - influence of dwell time
  - influence of temperature
- chemical transesterification
- phase separation in the gravity field
- distillation
- liquid-liquid extraction
- approach of a continuous process consisting of several basic operations