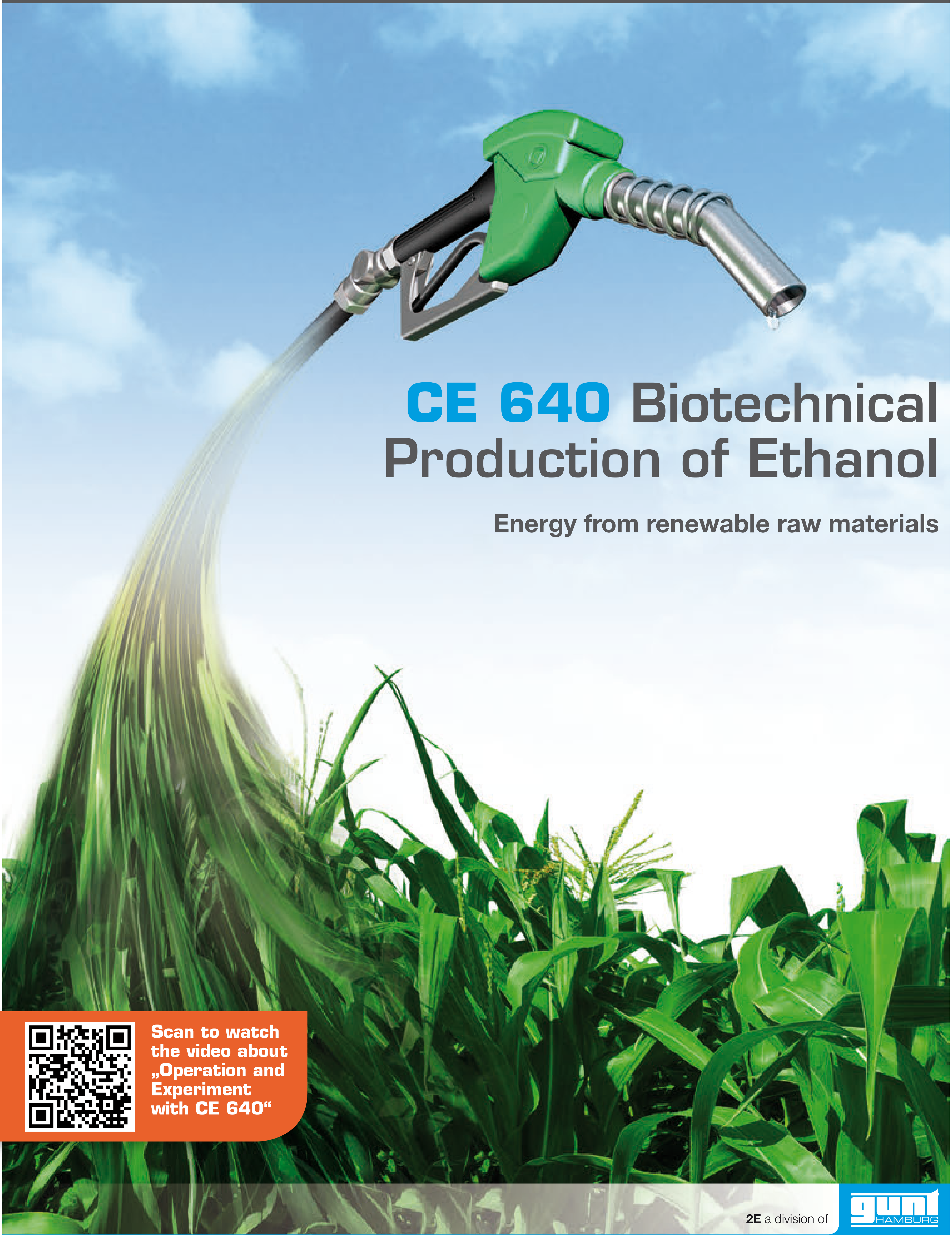

CE 640 Biotechnical Production of Ethanol

Energy from renewable raw materials

Scan to watch the video about „Operation and Experiment with CE 640“

2E a division of gunt HAMBURG

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Energy and environment are essential for a sustainable development

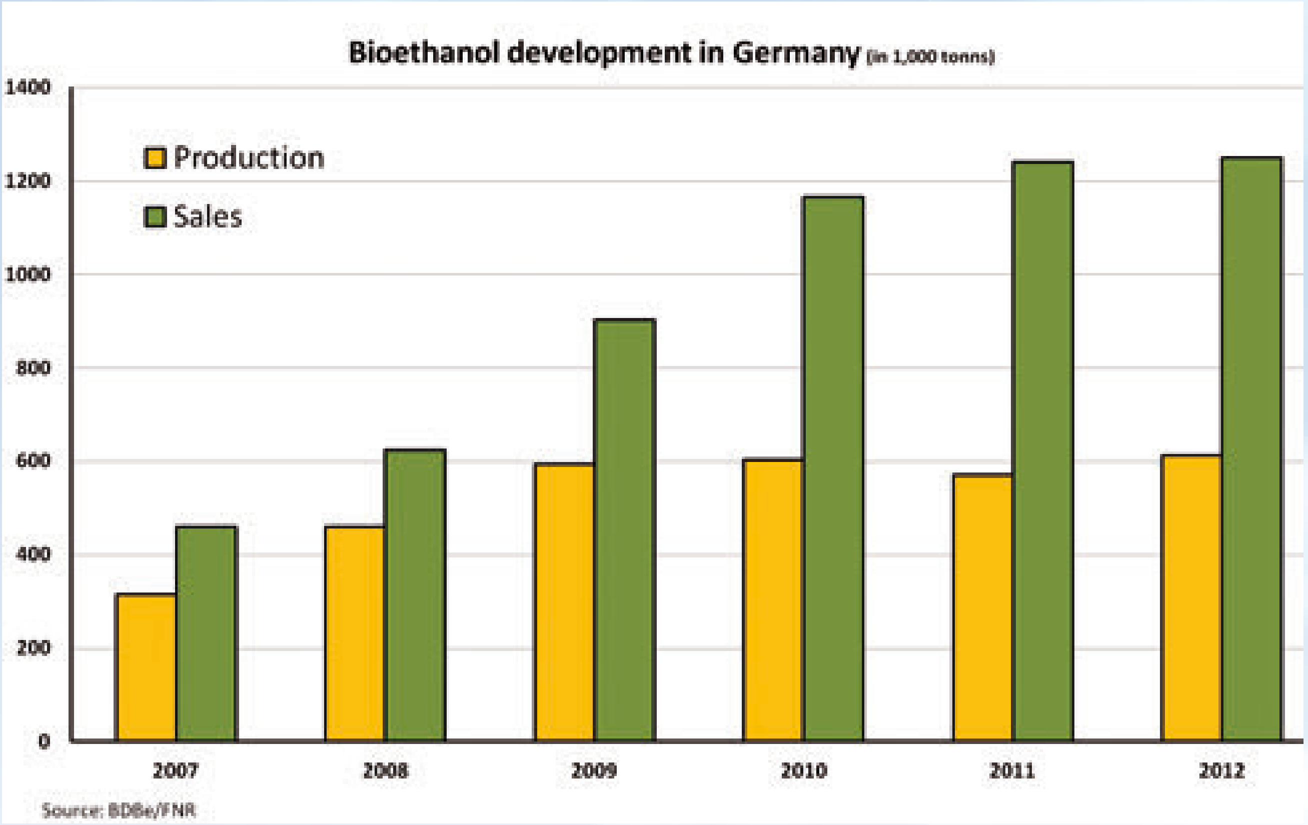
"The next 10 years will be critical for the future of our planet. Radical measures must be taken both on climate change mitigation and adaptation before we are locked into potentially irreversible, catastrophic climate transformations, whose impacts are expected to substantially change the environment and our lives on this planet."

Excerpt from the United Nations Development Programme
Charting A New Low-Carbon Route To Development
Yannik Glemarec

Engineers, scientists, technicians and experienced specialists will play an important role in the transition to sustainable development. They will need a sound education which includes practical experience.

GUNT is a leader in the development of innovative education and training systems for sustainable energy production and environmental pollution control.

The importance of water for the protection of health and the environment is highlighted by our complete programme of experimental units for water treatment.



CE 640
Developing the bioethanol production in the laboratory

The experimental plant for the biotechnical production of ethanol is ideally suited for training students and professionals in chemical and biochemical engineering. The plant has been designed to perform a wide range of didactic topics. Bioethanol is, and will remain, the leading biofuel worldwide. Students will get to know the entire process, starting with the raw materials up to the end product.

Various processes, such as shredding, fermentation and distillation, can be studied. Conditions and possibilities for the technological, material and the energetic combination of processes in a method can be conveyed.

Technicians and engineers are always faced with the same questions: What needs to be measured, regulated and controlled, where and how? This plant is ideally suited to provide the answers.

The experimental plant demonstrates a functional and elegant solution to equipment design. I know from experience that trainees and students will appreciate the level of detail that has gone into designing the plant. The plant control via PLC will also help them to learn to operate large technical systems.

Prof. Dr.-Ing.habil Kurt Gramlich
University of Applied Sciences Anhalt

CONTENTS

ENERGY FROM BIOMASS

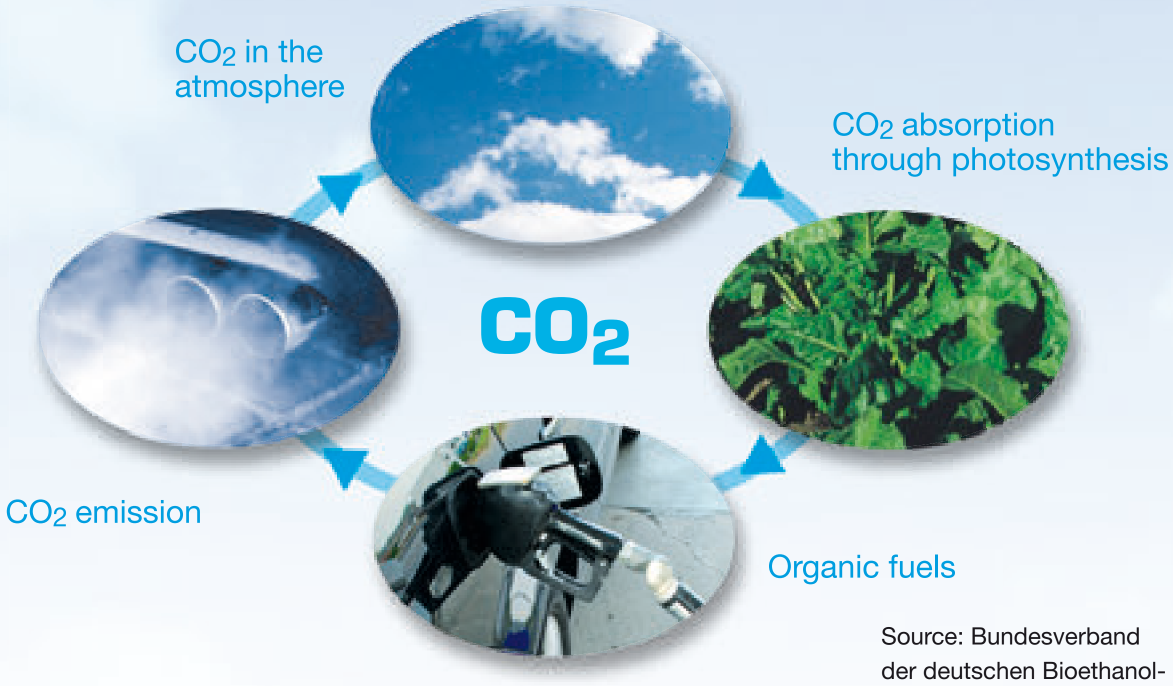
Development of bioenergy sources

Photosynthesis enables plant growth with the help of sunlight. In this process, the plant absorbs CO_2 from the atmosphere, water and minerals, and converts it into more energy-rich organic compounds.

This biomass can be seen as the product of a biochemical process during which part of the absorbed sunlight is stored as chemical energy. Special treatment methods are required to be able to use the biomass as an energy source in various technical processes.

This includes simple physical but also more complex thermochemical and biological methods. After treatment, the bioenergy sources will be available as solid, liquid or gaseous energy sources.

The CO_2 cycle of bioethanol

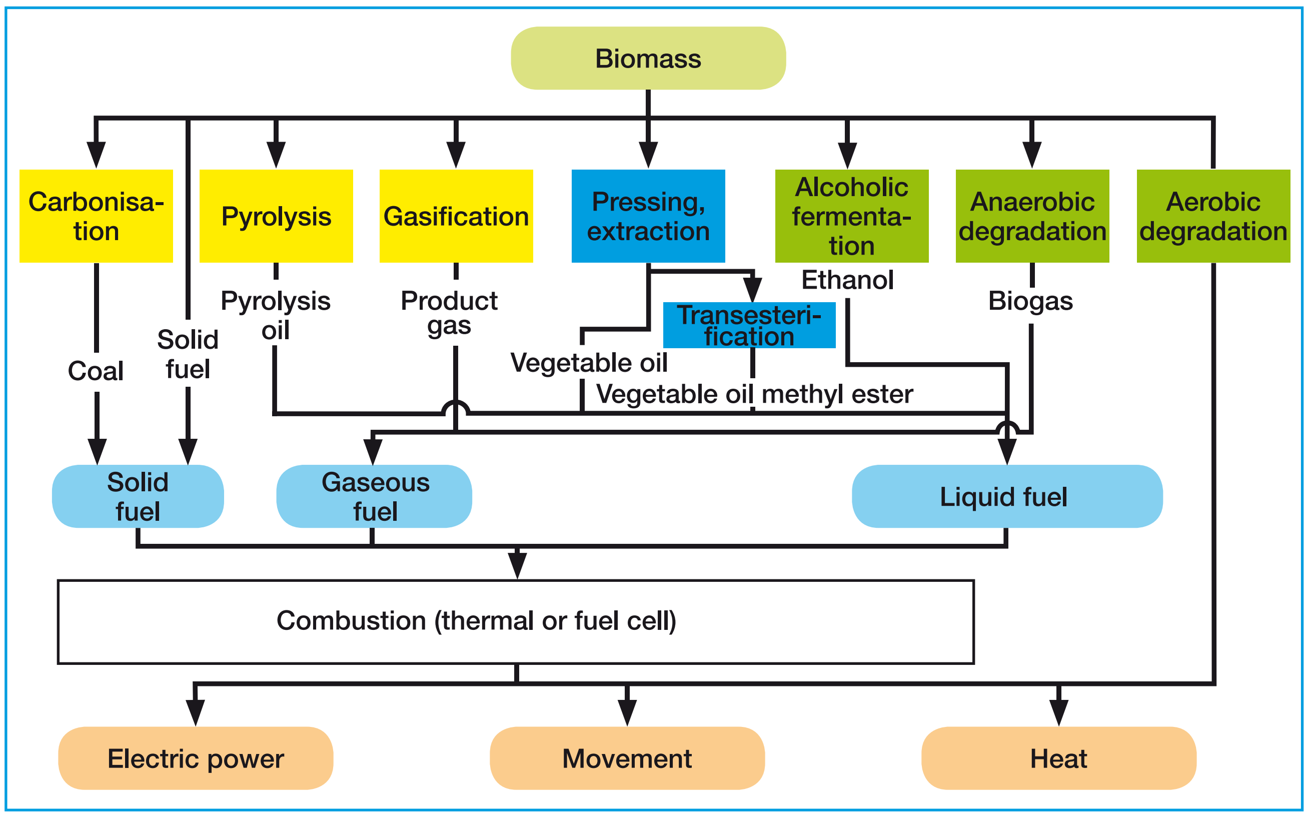


Source: Bundesverband der deutschen Bioethanolwirtschaft (BDBe)

Sustainability of bioethanol

- The ecobalance is highly dependent on the chosen plant raw material
- During the combustion of ethanol, the CO_2 that was previously bound is released
- It is important to look at all of the steps in the process chain
- Using untapped plant biomass is clearly better than cultivating energy-optimised monocultures

Using biomass for the generation of energy



Source: www.salzburg.gv.at/themen/lf/bioenergie/was_ist_bioenergie.htm

Classification of bioenergy sources

Energy source	Solid	Liquid	Gaseous
Products	Wood Plant residues	Alcohol Vegetable oils	Biogas Fuel gas Low-temperature carbonisation gas
Use	Heat and power generation	Organic fuels	Heat and power generation

Bioethanol as an alternative to fossil fuels

The following points outline the importance of bioethanol as an alternative energy source:

- **Climate protection due to less greenhouse gas emissions**
  Bioethanol, which is produced from renewable raw materials, is CO_2 neutral, apart from the energy consumption required for production.
  The CO_2 which is released during the combustion of bioethanol had been bound by the plants from which it was produced by photosynthesis during their growth. Up to 70% of greenhouse gas emissions can be saved in this way.
- **Protection of fossil resources**
  Every litre of bioethanol that is produced from renewable raw material means that one litre of non-renewable, fossil fuels, such as petrol or diesel, is saved.
- **Technology with possibilities for rural areas**
  The economy and public authorities benefit from supporting local bioethanol producers through value-adding and the creation of new jobs. In addition, new markets are opened up for agriculture.
- **More powerful than conventional petrol**
  The great advantage of bioethanol in this area is its excellent chemical properties. It has a significantly higher octane number than petrol, is virtually sulphur-free and is biodegradable.

BIOETHANOL
Raw materials for production

Raw materials	Biomass yields (FM)	Fuel yields	Required biomass per litre fuel
Grain maize	9,0	3.740	2,4
Wheat	7,2	2.760	2,6
Rye	4,9	2.030	2,4
Triticale	5,6	2.230	2,5
Sugar beets	58,0	6.250	9,3
Sugar cane	73,0	6.380	11,4
Straw	3,0	990	3,0

Source: meo/FNR FM = fresh mass

A gigantic distillery

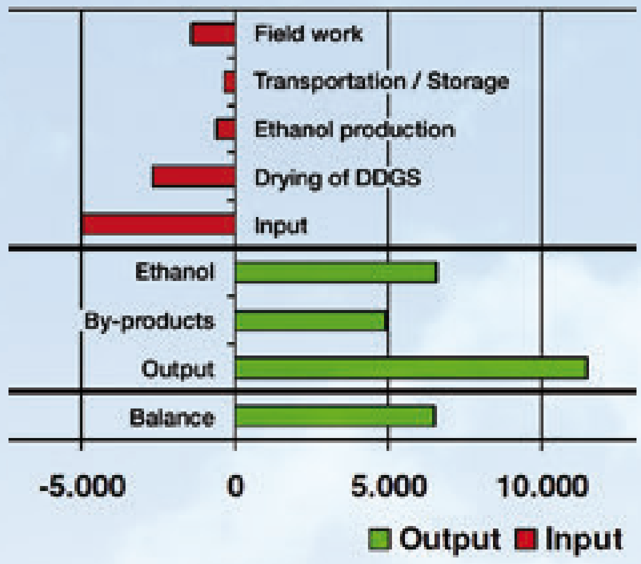
If you take a close look at a modern bioethanol plant, you will find that the bioethanol production process is the same as that in a distillery – but in unbelievably large proportions and with completely different technological standards. Whereas small distilleries process raw material by liters, large bioethanol plants move thousands of tons a day.

But the principle is the same. If the raw materials are not already available in a liquid, sugar-containing form, they need to be shredded and liquefied first. In a grain mill, the raw material is ground and mixed with water.

The carbohydrates in this mixture must first be converted into sugar using enzymes. Yeasts then convert the sugar in the mash into alcohol – the fermentation process starts. After the end of the fermentation process, the alcohol is separated from the mash through distillation.

The bioethanol is distilled in a multiple-stage distillation process and then further purified and concentrated through rectification. The end product is alcohol with a purity of approximately 96 vol.%. However, to be used as fuel, pure bioethanol is required in Europe.

Energy balance of an industrial bioethanol plant (Südzucker, Zeitz plant)



Source: Presentation by Dr. Wolfgang Wach, Südzucker AG "Bioethanol Production – Today and Tomorrow" on the 4th May 2006, FAL Braunschweig

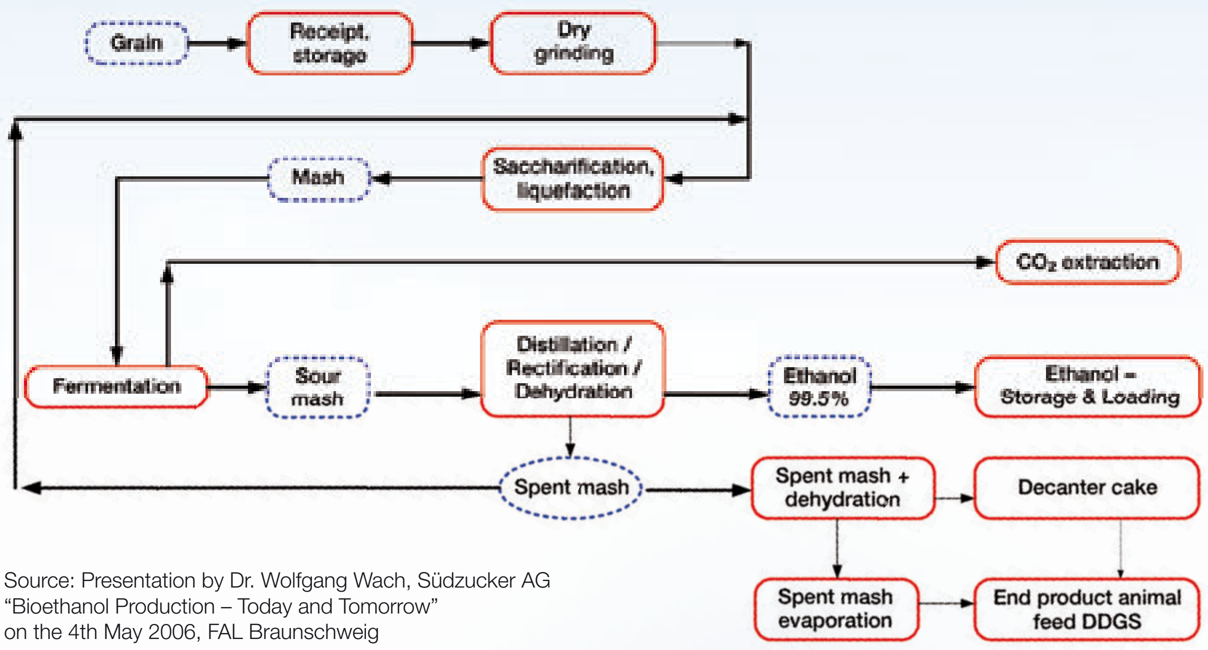
The ethanol production process is divided into five steps:

Shredding of the raw materials → Liquefaction → Saccharification → Fermentation → Distillation

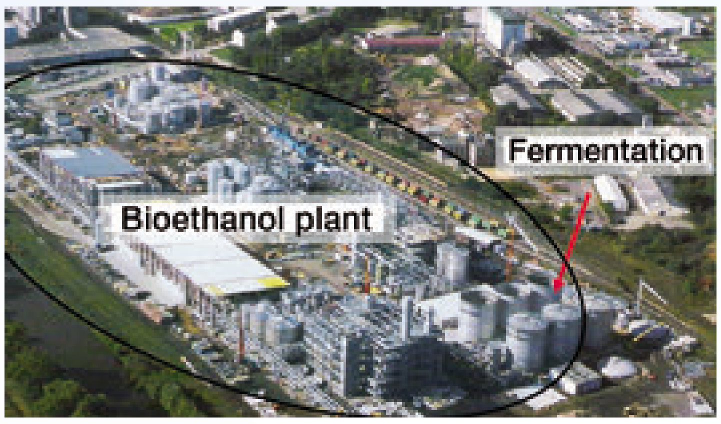
Each of these steps requires different process conditions to ensure an optimum yield.

Structure of a bioethanol plant

Raw material: wheat



Source: Presentation by Dr. Wolfgang Wach, Südzucker AG "Bioethanol Production – Today and Tomorrow" on the 4th May 2006, FAL Braunschweig



Industrial bioethanol plant under construction (Südzucker, Zeitz/Saxony-Anhalt plant)

A new generation of biofuels

First-generation biofuels (biodiesel, bioethanol from sugar, starch) compete with the food market and illustrate the problems of an intensified agriculture. The resulting disadvantages can be resolved by a new generation of biofuels.

So-called **lignocellulosic** biomass is used for **second-generation biofuels**. Refined enzymes and special treatment processes enable the conversion of the lignocellulose contained in typical plant residues into bioethanol.

BIOTECHNICAL PRODUCTION OF ETHANOL WITH CE 640

CE 640 – Schematic Process

The CE 640 “Biotechnical Production of Ethanol” trainer allows all of the important processes, from liquefaction and saccharification of the raw materials to the conversion of sugar into ethanol and to distillation, to be monitored and examined.

During the mashing process the starch of the raw materials is turned into glucose. A mash-tun containing water and the raw materials is heated up to 95–98°C and constantly stirred.

The addition of the enzyme alpha-amylase enables the liquefaction of the starch slurry. This process step takes approximately 0.5 hours and should be performed at a pH value > 6.5.
To subsequently start the saccharification by adding the enzyme glucoamylase, the tank content must have a temperature of 55–60°C and a pH value of 4.5–5.5.

The entire liquefaction and saccharification process of the mash, including the required resting times of approx. 0.5 hours each, takes about 2–3 hours.

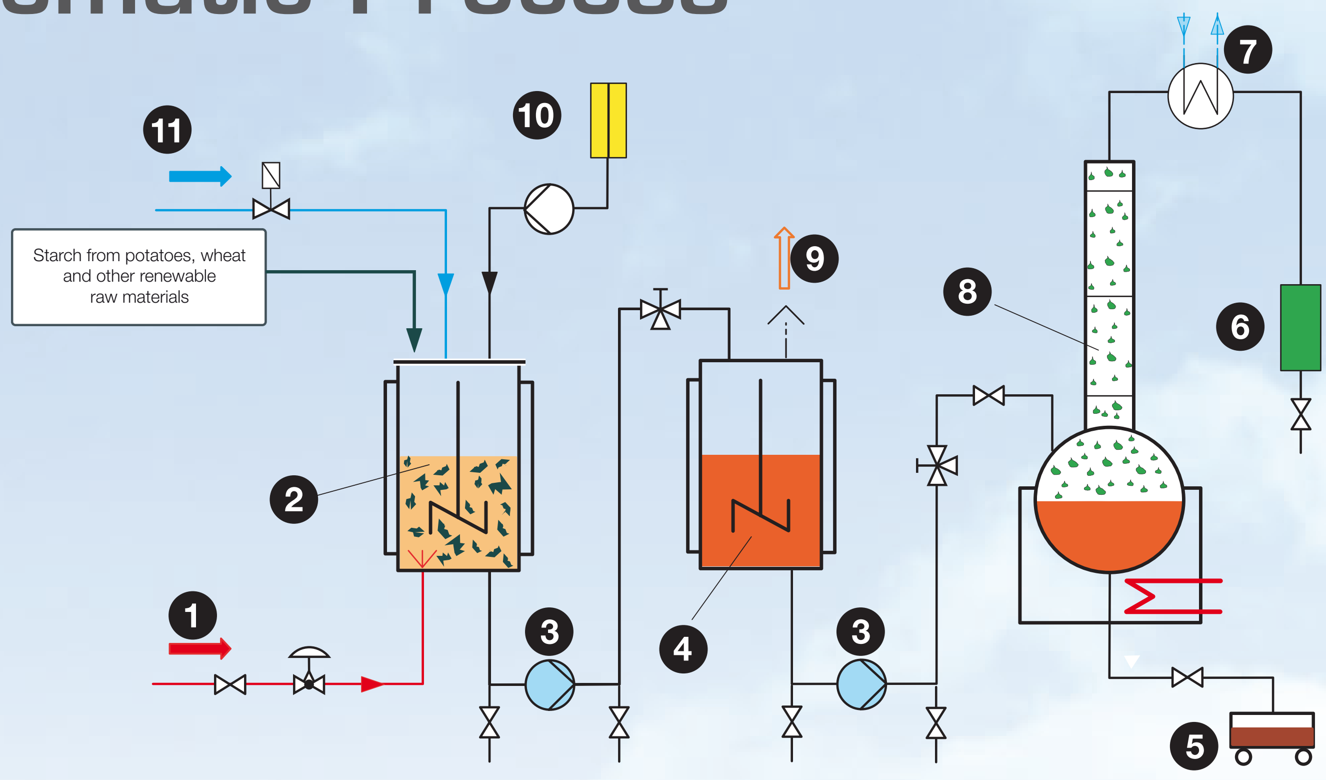
The preparation is now cooled down to 28–32°C and pumped into the fermentation tank.

After the addition of yeast, the fermentation process takes about 68–72 hours. CO_2 is produced during this process, which can be clearly seen at the fermentation airlock of the tank.

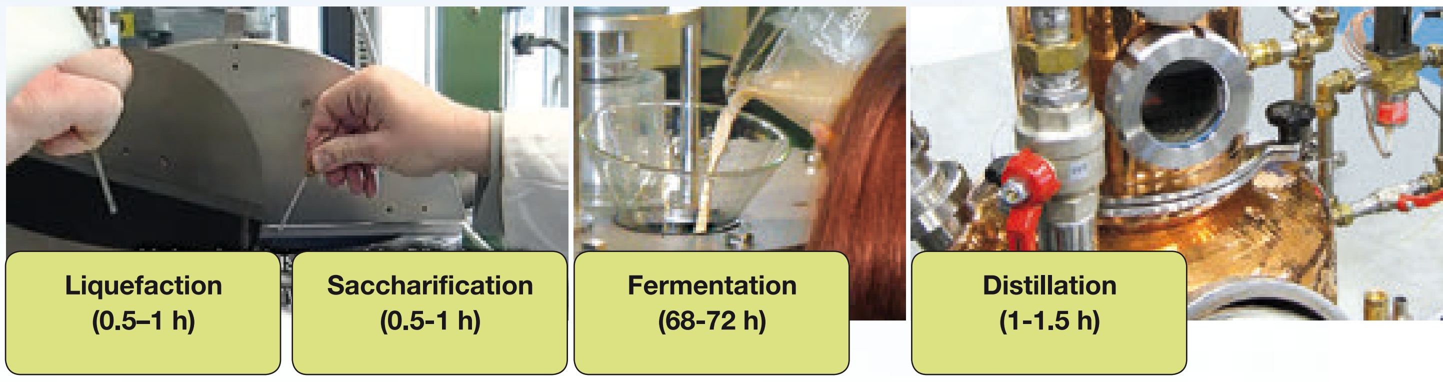
The distillation process utilises the different volatilities of the components to be separated. To separate the components, the liquid mixture is brought to the boil. The resulting vapour phase contains mostly highly volatile mixture components.

The vapour phase is separated from the liquid phase and condensed (distillate). The low-volatility components remain in the liquid phase.

In principle, the ethanol content can be increased in the CE 640 plant until an azeotropic mixture of substances is achieved. In this process, the compositions in the gaseous phase and in the liquid phase are equal. The ethanol content that can be achieved in experiments using the CE 640 is approximately 80%. To be able to use the produced distillate as a fuel additive (e.g. E10, E85), further processing steps are required that must be completed outside the CE 640 plant.

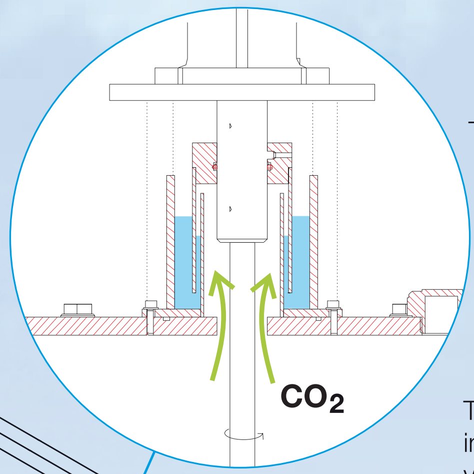


1. Steam
2. Mash tank
3. Pumps
4. Fermentation tank
5. Spent mash tank
6. Ethanol tank
7. Condenser
8. Distillation unit
9. Fermentation airlock / CO_2 release
10. Acid / caustic tank with metering pumps
11. Water infeed

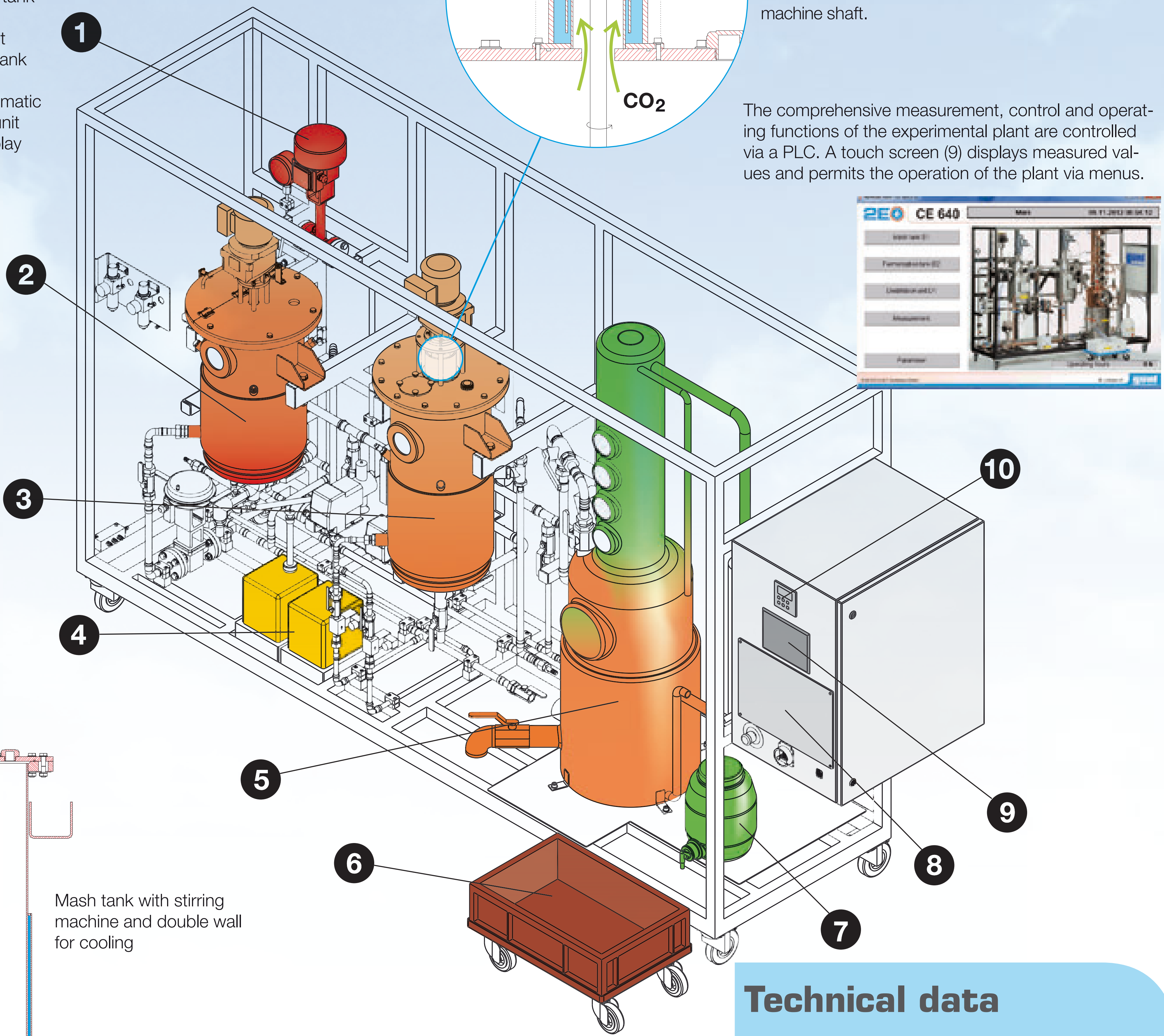


Plant Design

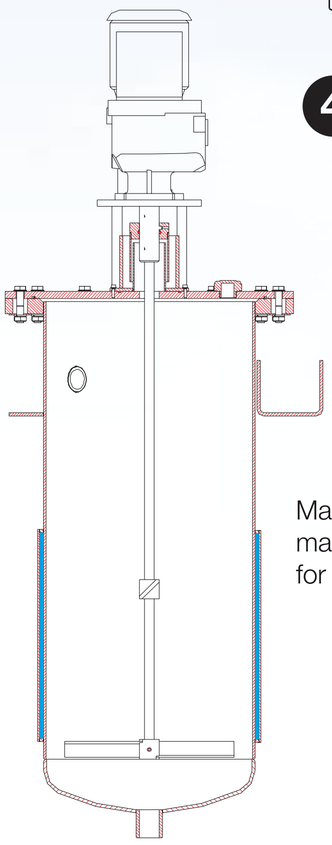
1. Steam pressure control valve
2. Mash tank
3. Fermentation tank
4. Acid tank
5. Distillation unit
6. Spent mash tank
7. Ethanol tank
8. Process schematic
9. PLC control unit
10. pH value display



The **fermentation airlock** releases the CO_2 that forms during the process and protects the fermentation process from unwanted germs. It also functions as a seal for the stirring machine shaft.

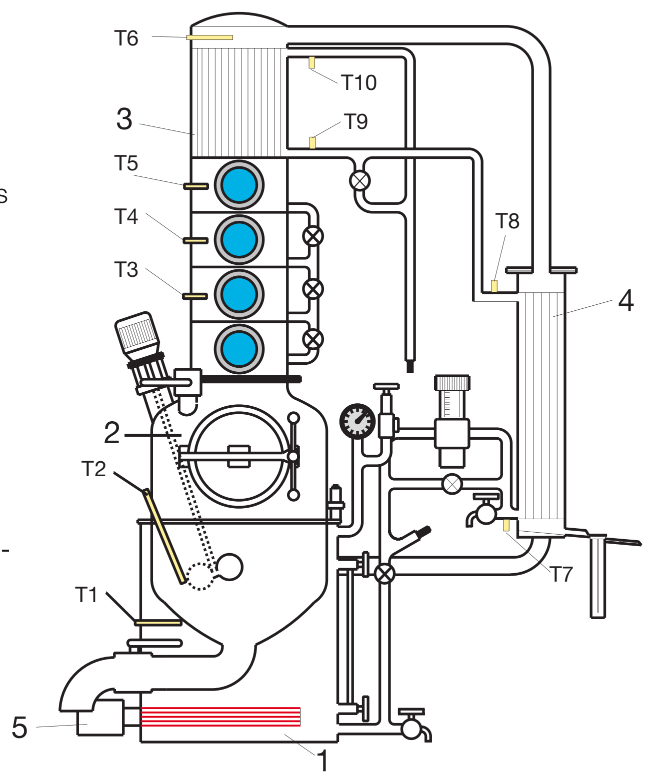


The comprehensive measurement, control and operating functions of the experimental plant are controlled via a PLC. A touch screen (9) displays measured values and permits the operation of the plant via menus.



Mash tank with stirring machine and double wall for cooling

The **mash tank** has a stirring machine and can be heated by introducing hot steam. A check valve prevents the ingression of mash into the steam supply pipe. If required, cold water for cooling the mash can be pumped through the double wall of the tank. The tank is equipped with a pH measuring probe and inlets for acid and caustic to enable adjustment of the pH value.



The **distillation unit** is a modified distillation facility with a water-bath (1). It contains the still (2), bubble tray column with dephlegmator (3), condenser (4), heating element (5) and all valves and fittings required for operation. The designations T1–T10 show the position of the individual temperature sensors in the plant.

Technical data

Tanks
- Mash tank, fermentation tank: 40 L each
- Ethanol tank: 10 L
- Spent mash tank (removable): 30 L

Distillation unit
- Column: Dxh: approx. 220 x 1200 mm
- Sump heater: 0...7500 W

Pumps

2 double head diaphragm pumps driven by compressed air
- max. head (2 bar drive pressure): 20 m
- max. flow rate (2 bar drive pressure): 15 L/min
- max. solid lump size: 4 mm

Metering pump (acid)
- max. head: 160 m
- max. flow rate: 2.1 L/h

Measuring ranges
- 9 temperature sensors: 0...120°C
- Water flow rate meter: 1...25 L/min
- pH value: 1...14

Dimensions and weight
- l x w x h: 3189 x 800 x 1985 mm
- Weight: approx. 500 kg

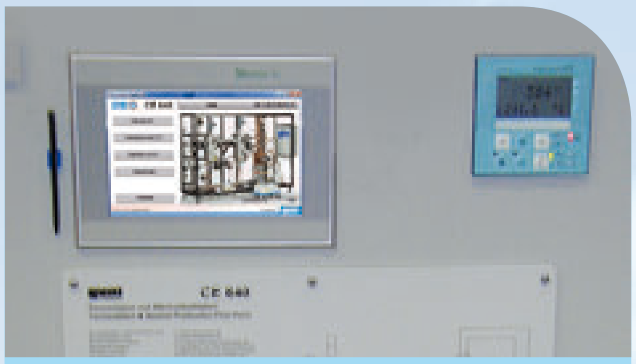
BIOTECHNICAL PRODUCTION OF ETHANOL WITH CE 640

Technology and Components

Quality in engineer training means more than just good laboratory equipment. Set high standards: We do!

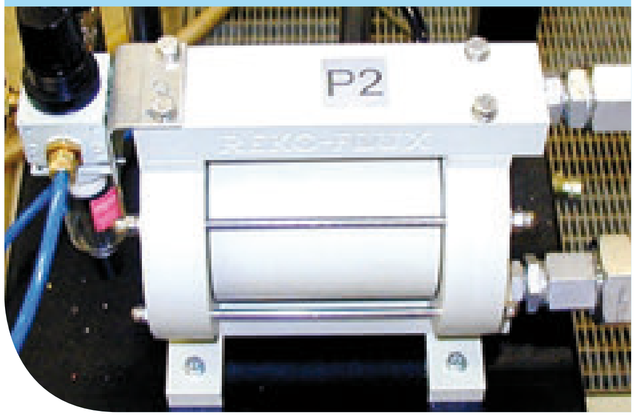
In the mash tank, the starch is mixed with water and gelatinised through the introduction of steam. After that, enzymes are used for liquefaction and conversion to glucose.

The start of the distillation process can be directly monitored through the inspection glasses of the bubble tray column.



The plant is controlled via a PLC and operated by means of a touch screen. In addition the switch cabinet contains a pH value display, a main switch and an emergency stop switch.

The CE 640 plant is equipped with two double head diaphragm pumps driven by compressed air to transfer the tank contents from the mash tank into the fermentation tank and then into the distillation unit.



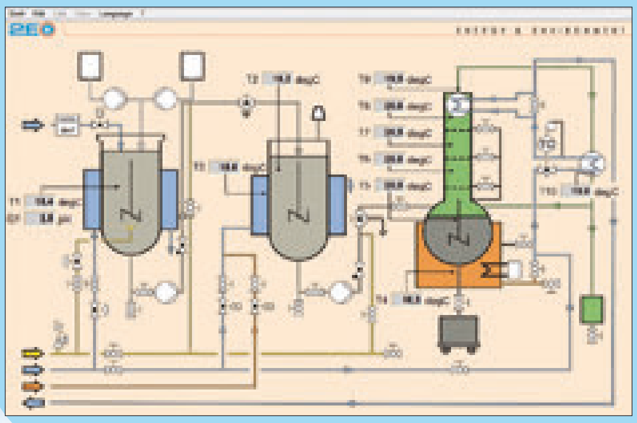
The pH value is controlled via a control circuit to optimise saccharification using a metering pump to transfer precise amounts of acid into the mash tank as required.

The Automation and Measuring Technology Plant Concept

The main educational area is biochemical engineering. It also teaches the basics of modern automation technology.
This plant offers many interesting possibilities to do so.

Data acquisition

The data acquisition complements the PLC control system. The system diagram provides an overview of the most important measured values in a clearly laid out process schematic. Another menu item allows the recording of temperature values and other important factors over time during the production process.



CE 640

Biotechnical Production of Ethanol

Media

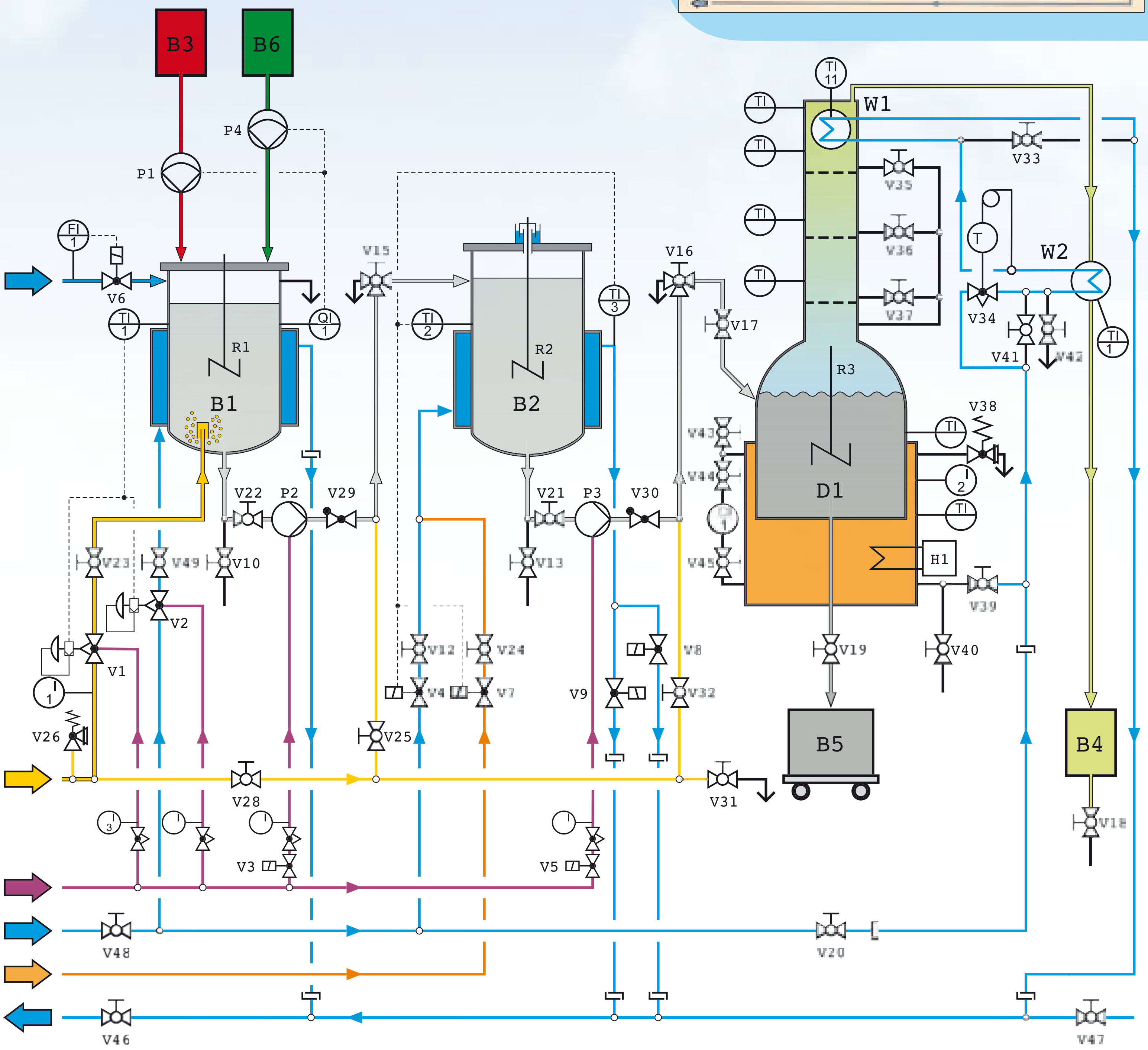
- Mash
- Spent Mash
- Ethanol
- Water
- Steam
- Hot Water
- Acid
- Caustic
- Compressed Air

Main Components

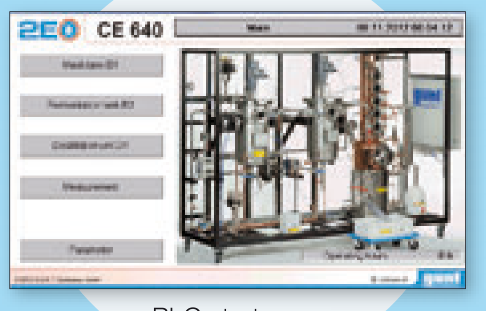
B1	Mash Tank
B2	Fermentation Tank
B3	Acid Tank
B4	Ethanol Tank
B5	Spent Mash Tank
B6	Caustic Tank
D1	Destillation Unit
H1	Heater
P1	Metering Pump 1 (Acid)
P2	Pump 1
P3	Pump 2
P4	Metering Pump 2 (Caustic)
R1-R3	Stirrer
W1	Dephlegmator
W2	Condenser

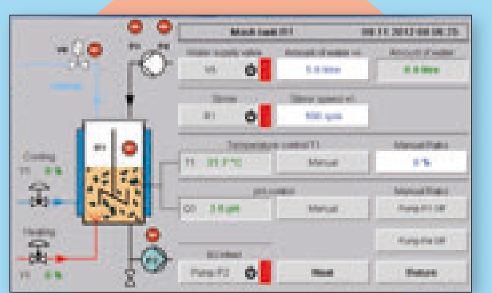
Instrumentation and Control

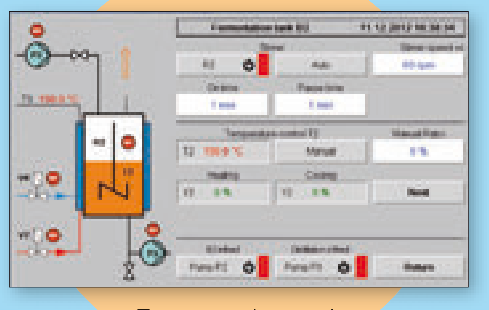
FI1	Process Water Flow Rate
LI1	Water Bath Level
PI1	Steam Pressure
PI2	Water Bath Pressure
PI3-PI6	Compressed Air Pressure
Qi1	Mash pH Value

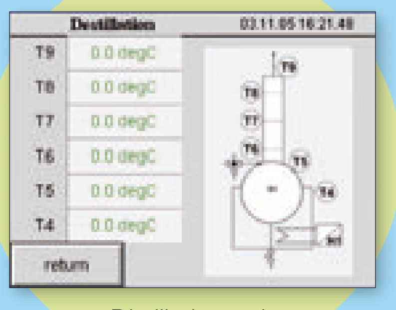


Plant control via PLC with touch screen


PLC start menu


Mash tank


Fermentation tank

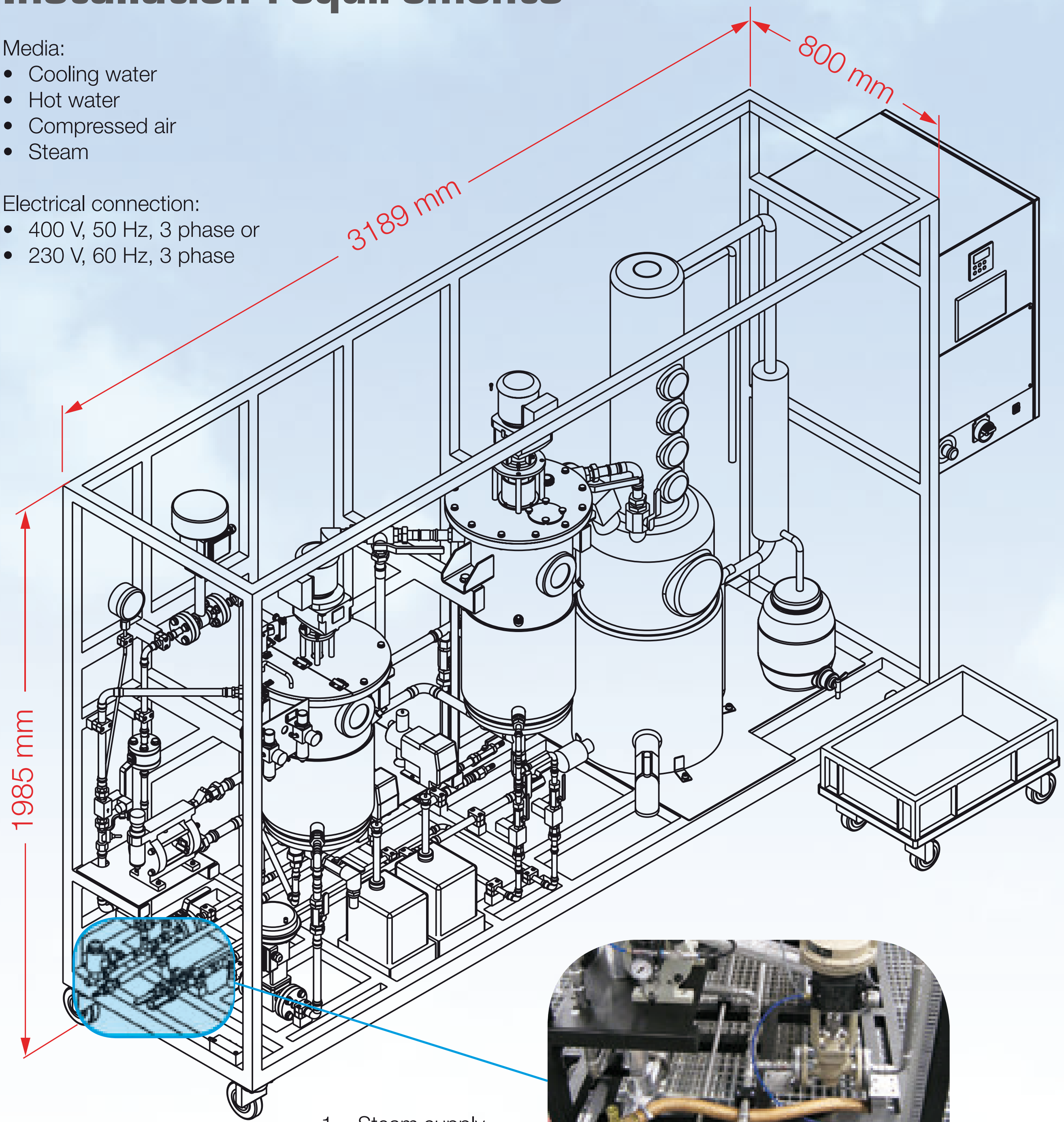

Distillation unit

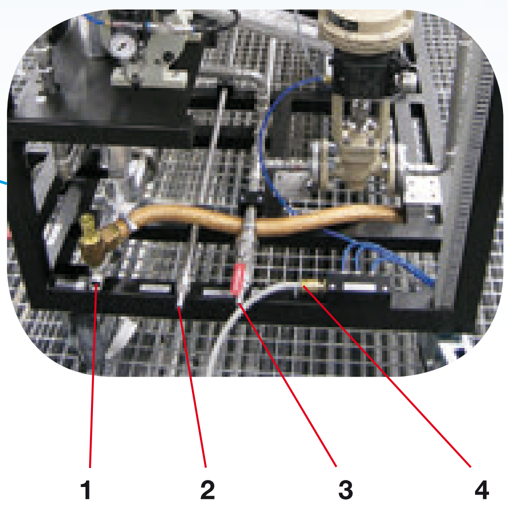
INSTALLATION AND SPACE REQUIREMENTS OF THE PLANT

Installation requirements

Media:
- Cooling water
- Hot water
- Compressed air
- Steam

Electrical connection:
- 400 V, 50 Hz, 3 phase or
- 230 V, 60 Hz, 3 phase





1 Steam supply
2 Hot Water
3 Water
4 Compressed Air

Dimensions of a suitable steam generator that should be placed to the left of the plant. The device shown is available from GUNT as an accessory (ET 813.01).

For operation and maintenance, the plant should be accessible at least from the front and both sides.

The footprint of the plant incl. the steam generator is approx. 4.2 m x 1 m.

Two additional work desks are recommended for the PC for measured data and the preparation and analysis.

Accessories and analysis techniques

Typical laboratory accessories and analysis techniques are required for the preparation of the raw materials and analysis of the products. We suggest that you also consider the following information in order to complete your CE 640 system.
These accessories and devices are not included in the scope of delivery.

Accessories:
Balance, beaker, pipettes, glass cylinder

Analysis devices:
Refractometer, hydrometer

Required preparations:
Enzyme preparation for liquefaction:
e.g. Schliessmann-VF “Kartoffel”

Enzyme preparation for saccharification:
e.g. Schliessmann-VF

Enzyme preparation for proteolysis:
e.g. Schliessmann-EX-Protin

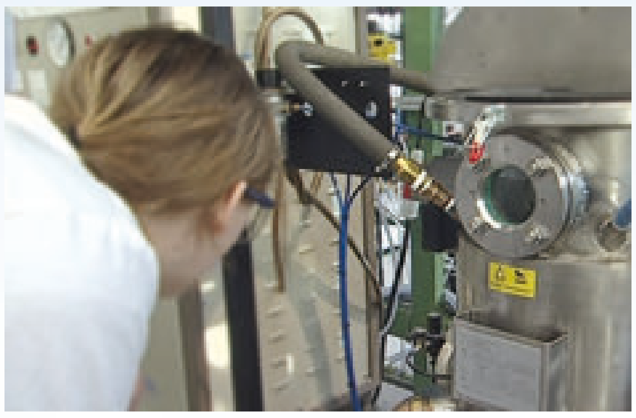
Commercially available baker's yeast can be used for the fermentation process.

CE 640 in the Lab at Münster University of Applied Sciences

Preparing the yeast

The laboratory for chemical engineering at Münster University of Applied Sciences offers practical training courses in the production of ethanol with the CE 640. Two dates are scheduled for the course, so that all participants can prepare the mash and monitor the result of the fermentation and distillation process of their own experiments.

An overall conclusion can be drawn after the completion of the experiments. The ethanol content can be determined using a refractometer or a hydrometer. The actual yield can be determined from the amount of ethanol produced, compared to the theoretical yield of a complete fermentation.



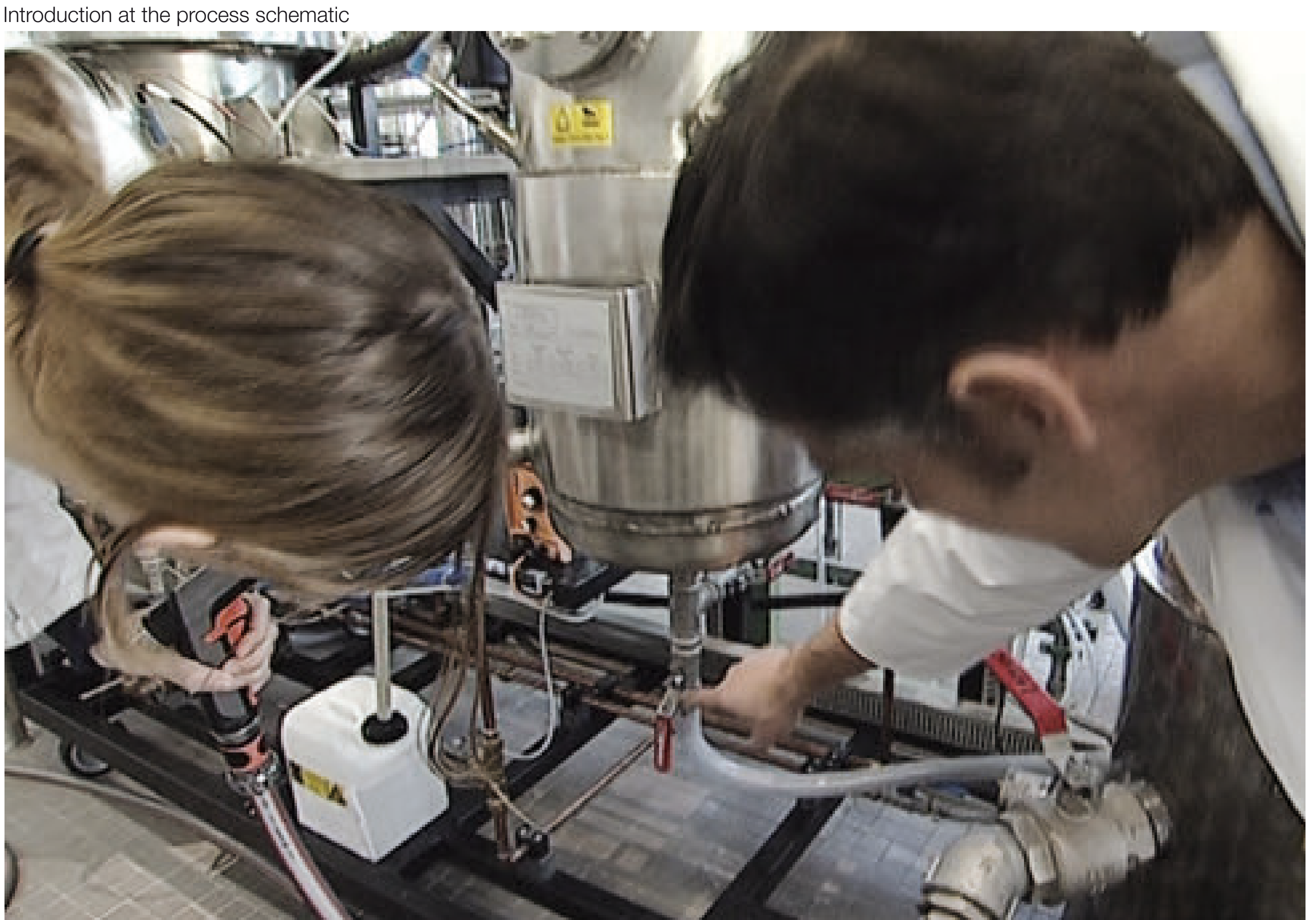
The enzymes are working

Fachhochschule Münster University of Applied Sciences

Institute of Chemical Engineering in Steinfurt

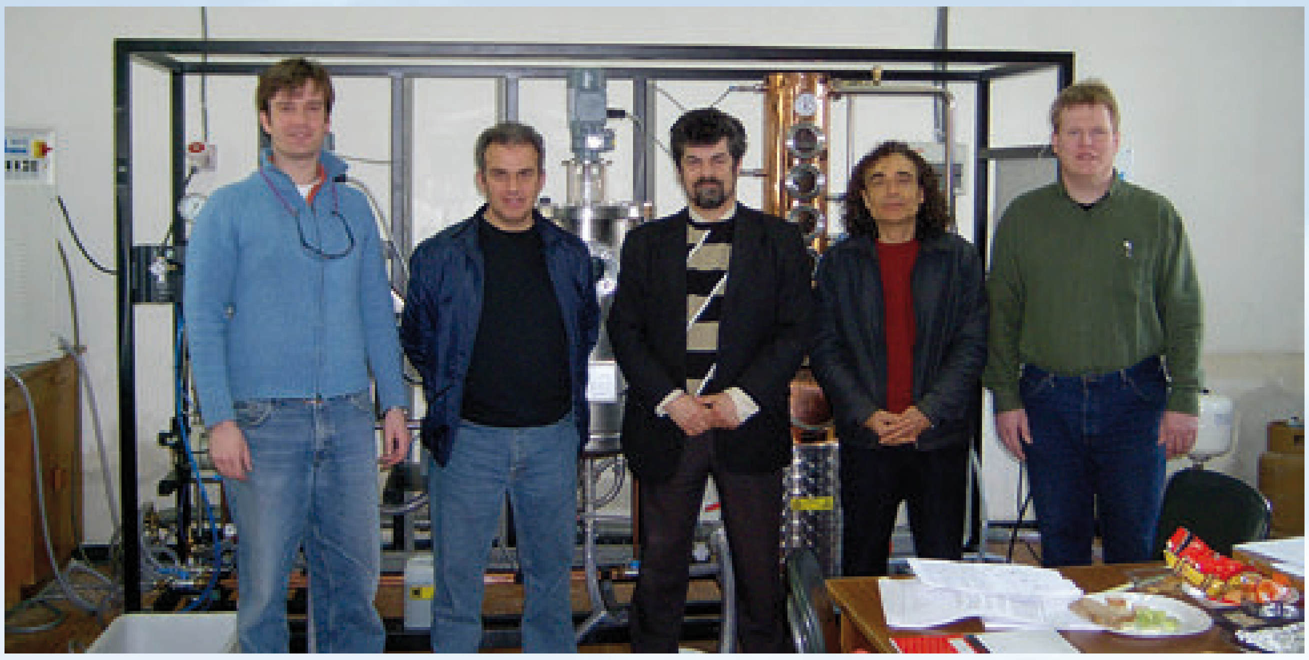
Introduction at the process schematic

Filling the tank



CE 640 – REFERENCES

CE 640 at the Agricultural Research Institute Nicosia



A very satisfied customer

AGRICULTURAL RESEARCH INSTITUTE

Nicosia / Cyprus

Dr. Polycarpos Polycarpou

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

Didactic Concept, Installation and Training

The CE 640 Biotechnical Production of Ethanol trainer has been developed by GUNT for use in vocational schools, universities of applied sciences and research institutes. The plant concept clearly shows the individual steps of the production of ethanol and enables to understand the functioning of the required plant components. The users will get to know the meaning of the process parameters and will be able to see the effects of system changes after an introduction.

A variety of raw materials can be used as starch sources in processes that can be carried out in different ways, the flexible concept behind the trainer allows to investigate the optimisation of process parameters for later large-scale applications.

Learning objectives – biochemical engineering

Familiarisation with the necessary individual steps and plant components for the production of alcohol:

- Gelatinisation by steam injection
- Liquefaction by use of alpha-amylase
- Saccharification by use of glucoamylase
- Fermentation: conversion of sugar into ethanol by yeast cultures under anaerobic conditions
- Distillation in batch operation: separation of ethanol from the mash

Experiments – plant operation and automation

- Process control via PLC
- Using touch screen control in automation technology
- Controlling the temperature in the mash tank
- Controlling the pH value in the mash tank
- Controlling the fermentation temperature and the column head temperature during distillation
- Setting the control parameters
- Controlling the stirrer speed
- Controlling the mash pump and fermentation tank pump
- Monitoring of all relevant measured data via PC
- Data acquisition and processing in tables and files

Educational support material

The comprehensive instructions offer:

- Explanation of the basics
- Description of the unit
- Reference experiments
- Original instructions by the manufacturers of the integrated components
- Data sheets for the recommended enzymes

Updates: GUNT will inform its customers if improvements or additions are available for the CE 640 trainer – especially regarding the educational material and the software.

Training for teachers

We recommend a multi-day training course by a qualified GUNT engineer. This will help you to make the most of your new bioethanol experimental plant in no time at all.

Plant installation

Have the plant installed and commissioned by a qualified GUNT specialist.

ENERGY

Limited resources and growing contamination from fossil energy sources are pushing renewable energies, in particular, into the centre of the energy supply discussion. The 2E demonstration and training units enable clearly defined experiments on current energy topics for all levels of experience – from beginners to experts.

Training focuses in the energy field

- Biomass
- Solar energy
- Geothermal energy
- Wind
- Hydropower
- Energy efficiency

ENVIRONMENT

One of the biggest challenges is keeping the environment clean. A number of techniques exist to reduce the contamination of the environment.
Our training units enable trainees and students to learn these techniques in a concrete and practical manner.

Training focuses in the environment field

- Water
- Soil
- Waste
- Air

EQUIPMENT FOR ENGINEERING EDUCATION

The 2E philosophy

2E is a logo, an abbreviation of ENERGY and ENVIRONMENT. And, as always with GUNT, it is about technical education and training systems.

The objective is to get trainees and students acquainted with subjects they are likely to face in practice. 2E expresses our integrated concept: questions regarding energy (renewable energy, of course) cannot be separated from environmental topics.

For example, if we produce ethanol with our CE 640 plant, we need electric energy, steam, water and compressed air for this process. We release CO_2 into the environment, and heat losses occur. Process residues (spent mash, water) must be disposed or used.

This integrated concept – one might also call it an ecological concept – is one of the key elements of the 2E philosophy.

Another important element of the GUNT 2E philosophy

Through experiments and research projects with our experimental plants, we want to provide trainees and students with a solid foundation for the future. This foundation, made of basic technological know-how and facts, will give them good competence for the future and provide a sound basis to make their own decisions.

We do not represent any specific interest groups and do not favour any specific technology. We are not engaged in any lobby work or politics; we provide basic knowledge for technicians and engineers and are here to help develop and improve competence in this important field.

How to get in touch

- **Visit us on the Internet at www.gunt.de**
- **Visit our plant in Hamburg**
- **We can visit you at your school and give you individual and competent advice**
- **We can give a presentation on selected topics for you and your colleagues at your school**

Visit our website
www.gunt.de

Imprint

Editor:
G.U.N.T. Gerätebau GmbH
Fahrenberg 14
D-22885 Barsbüttel
Phone: +49 40 / 670 854-0
Internet: www.gunt.de

Managing Director:
Rudolf Heckmann

Expert Team:
Dr. K. Boedecker

Editor-In-Chief:
Rudolf Heckmann

Layout:
K-Kontor Hamburg Werbeagentur

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