ENERGY & ENVIRONMENT

EQUIPMENT FOR ENGINEERING EDUCATION

One system – integrated and networked

Technical training equipment for energy and the environment based on a structured curriculum

2E a division of gunt HAMBURG

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Technical training systems for Energy and Environment

The adoption of Agenda 21 at the UN Conference on Environment and Development in Rio 1992 not only served to highlight in detail which global dangers are threatening the future of mankind, but also which solutions are necessary to combat these dangers effectively.

Our objective with 2E is to integrate these principles into the field of technical training, and to develop a carefully thought out spectrum of teaching and research equipment for the energy and environmental sectors that meets high didactic demands. This is our contribution to "Sustainable Engineering".

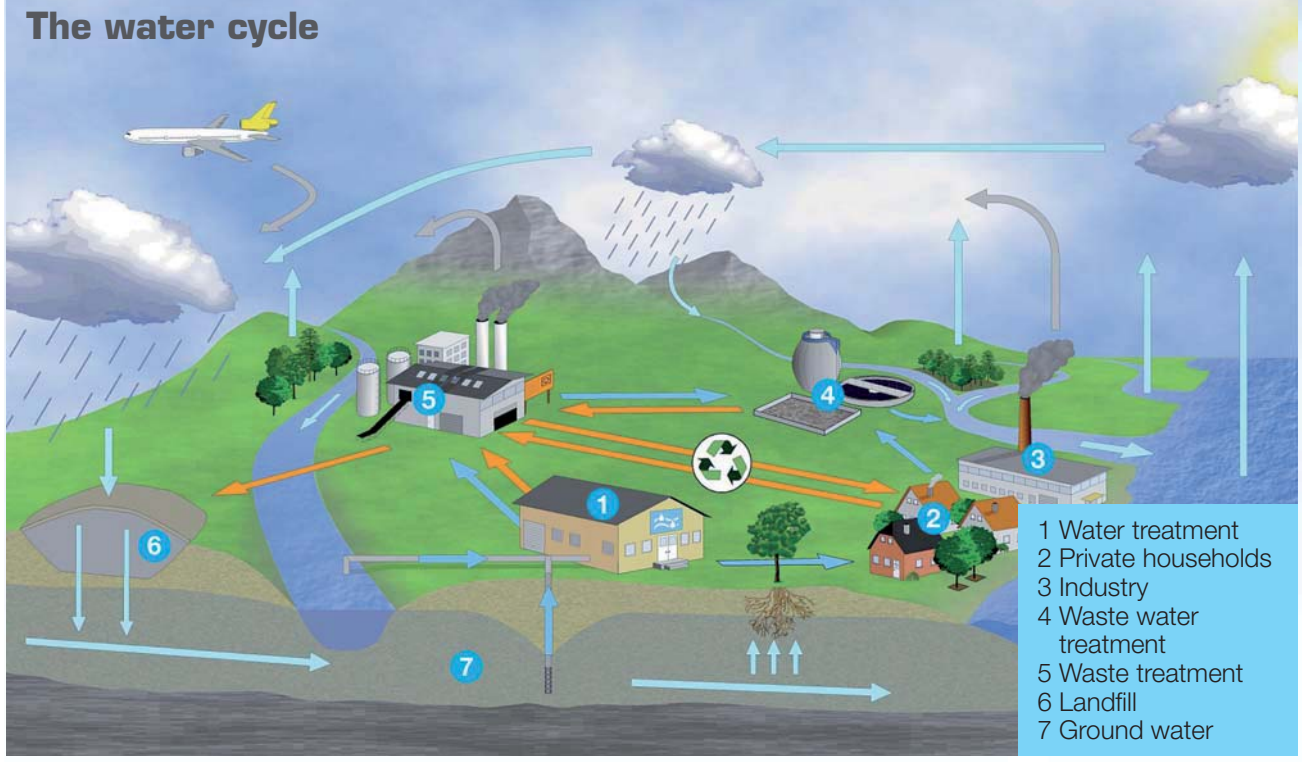
Learning to think in systems: material and energy flows in our environment

If we are to preserve the natural foundations of life, it will become more and more important to view our habitat as a networked system, and to understand the relationship between all the processes that take place. Any improvements will only be possible if potential interactions are identified.

The balancing of processes on the basis of their material and energy flows is particularly important for evaluating sustainability.

This holistic approach is evident in our 2E training concepts.

The water cycle



1 Water treatment
2 Private households
3 Industry
4 Waste water treatment
5 Waste treatment
6 Landfill
7 Ground water

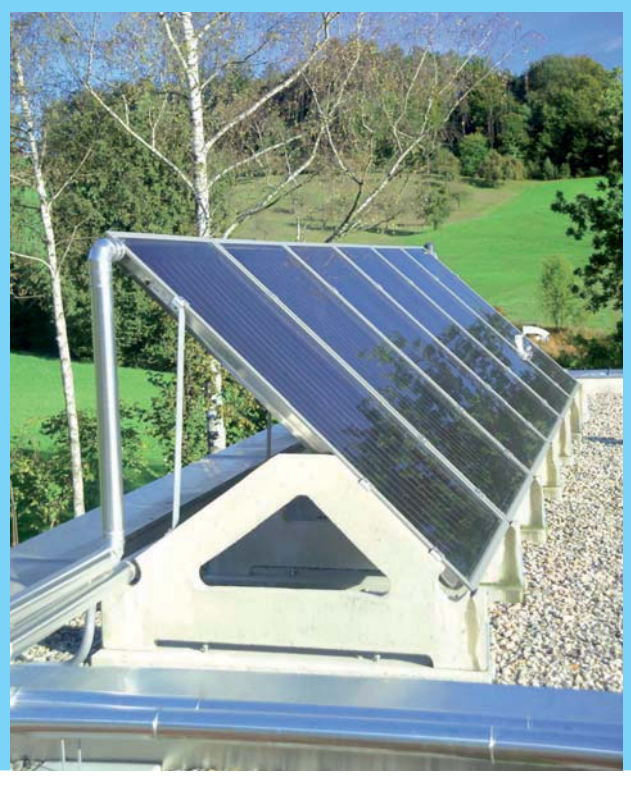
Contents

2E focuses on the fundamentals and background of renewable energies in context with conventional forms of energy

Climate protection through higher energy efficiency

In 2009, energy supply in Germany was still almost 90% dependent on different fossil energy sources. To make an immediate contribution to protecting the climate, more efficient use of both fossil and renewable energy sources is required. The measures for optimisation are identical in both areas. First, all the steps involved in a process need to be analysed individually to be able to determine the most effective opportunity for optimisation. Depending on the energy source, technicians and engineers often have to use common theoretical foundations and similar practical experiences.

Our teaching and research equipment offers the possibility to acquire in-depth engineering knowledge through practice-oriented lab experiments.
This supports the creation of a solid basis for making future-oriented decisions.



Energy sources for a cleaner environment

Renewable energy sources are a central building block in a sustainable economy. The largest proportion utilised thus far has been directly or indirectly based on solar energy. This includes wind energy and large parts of hydropower, which are created by solar-powered climate processes.

Recently the direct use of absorbed solar radiation has increased in importance. In addition to heat generation for heating and domestic water production, solar electricity generation has also made an economic breakthrough. Both photovoltaics and large-scale solar thermal electricity generation are becoming increasingly important. The development of biomass can be considered as the oldest process of converting solar energy. The tidal forces of the moon and geothermal processes are also primary sources of renewable energies.

BASIC STRUCTURE OF THE CURRICULUM

2E – for a sustainable development*

We need effective climate protection!

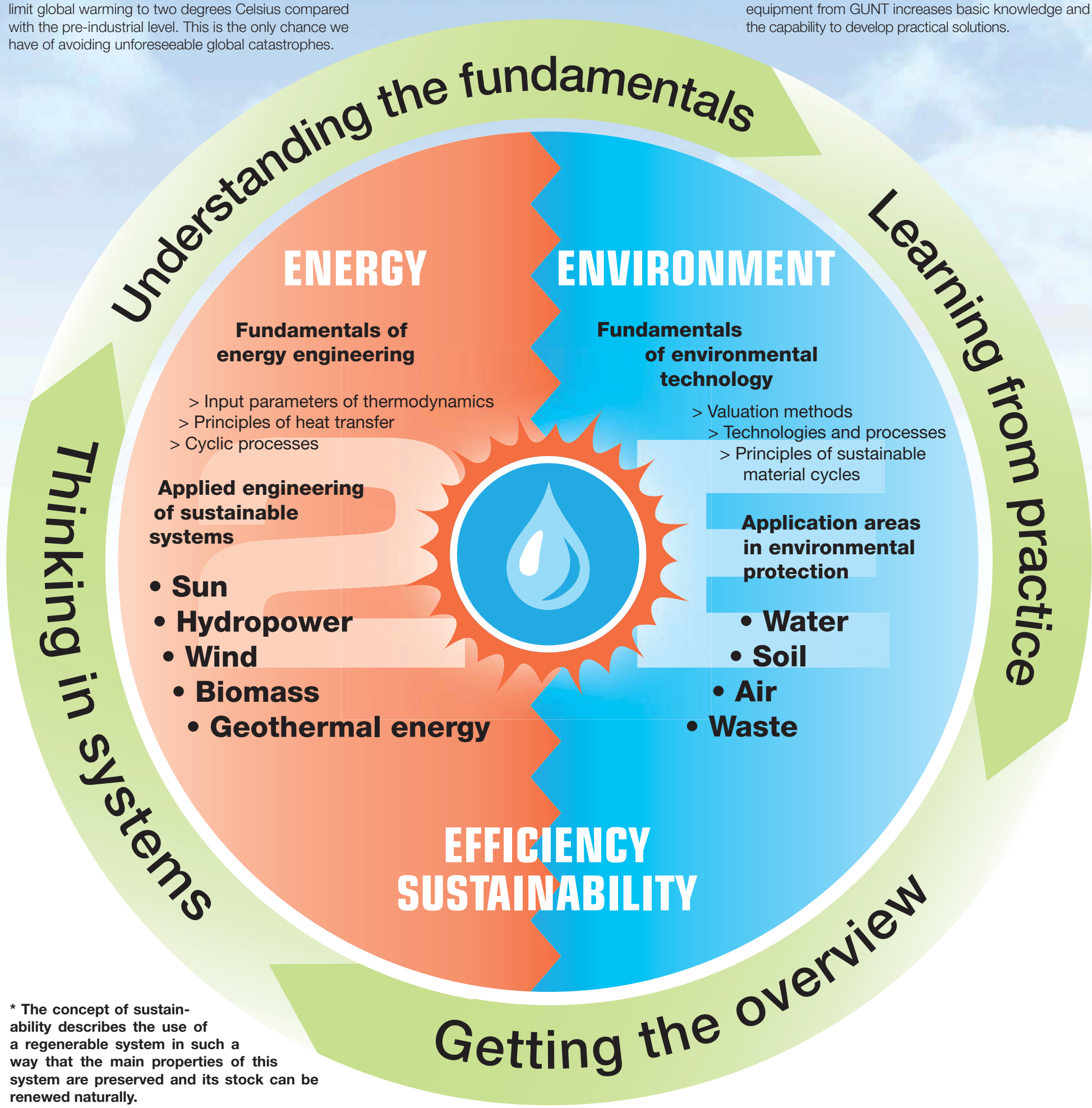
The predictions of climatologists are cause for concern. According to the Intergovernmental Panel on Climate Change (IPCC) there is an immediate need to limit global warming to two degrees Celsius compared with the pre-industrial level. This is the only chance we have of avoiding unforeseeable global catastrophes.

G.U.N.T. Gerätebau GmbH has restructured its teaching and research equipment for the fields of energy and environmental technology. A new logo serves to emphasize the importance of this area.

2E stands for Energy & Environment

This allows us to meet our responsibility to incorporate principles of sustainability and holistic thinking into our engineering education.

One thing you can always rely on: lab experiments and study projects conducted with teaching and research equipment from GUNT increases basic knowledge and the capability to develop practical solutions.



*** The concept of sustainability describes the use of a regenerable system in such a way that the main properties of this system are preserved and its stock can be renewed naturally.**

[German Parliament, 14th legislative period: Final report of the Enquete Commission "Globalization of the World Economy – Challenges and Answers" 14/9200, 12 June 2002]

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Engineering education equipment for energy and environment from one source

Competence based on a structured curriculum

Increase conversion efficiency

Improve distribution efficiency

Optimise utilisation efficiency

Protect resources

Reduce damage caused by civilization

Preserve habitats

Energy and Environment are essential for 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 transformation, whose impacts are expected to substantially change the environment and our lives on this planet."

United Nations Development Program
Charting A New Low-Carbon Route To Development
Yannik Glemarec

2E learning objectives of energy engineering

In the field of energy we are concentrating on the fundamentals of "classic" renewable energies: sun, hydropower, wind, biomass and geothermal energy.

Our teaching equipment is designed to help you and your students learn the basics through experiments, to increase the understanding of specific problems and to become familiar with the aspects of application. However, our approach to these questions is not isolated, as the focus is always on the generation of electrical and/or thermal energy. The established processes e.g. steam generation, condensation, the operation of turbo machines, heating, cooling, heat transfer etc. are necessary components of a complete 2E curriculum.

2E learning objectives of environmental technology

For the units from the field of environment we have developed experimental programmes with emphasis on communicating application-orientated knowledge as part of sustainable curricula.

Practice-orientated learning objectives from the fields of water, soil, air and waste complement previously learnt fundamentals. The didactic concept of the 2E area is, of course, based on networking, efficiency and sustainability.

The acquired knowledge and skills support students later on to work efficiently in the fields of planning, designing and operating environmental processes and plants. The experiments with the 2E units serve to strengthen their newly acquired knowledge by way of example and to develop decision-making competence.

Dawn of a new science

The term "ecology" was already coined by the German biologist Ernst Haeckel (1834-1919) in 1866 as the "the study of the relationship of organisms with their environment".

Jakob von Uexküll (1864-1944), founder of the "Alternative Nobel Prize", introduced the term "environment" as a central term of ecology in 1921.

Since then, a variety of established teaching disciplines have been added to the term "environment" to emphasise the focus on this key aspect. What they all have in common is their orientation towards a sustainable and hence future-proof development.

Change the way of thinking during training!

GUNT – Your Competent Partner for Sustainable Engineering

Like all GUNT training and research equipment, all systems in the 2E area are based on recognised curriculum principles. The basic principles and objectives of our 2E curriculum are universally recognised and used by leading colleges and universities. It forms the basis for the training of engineers in the field of energy and environmental technology.

THE 2E PRODUCT RANGE

Reliable and innovative

Vocational training institutes, colleges and universities have recognised G.U.N.T. Gerätebau GmbH as one of the world's leading manufacturers of teaching and research equipment for the training of skilled workers and engineers for decades.

Teaching and research equipment for renewable forms of energy and energy efficiency

Sun

Photovoltaics
- **ET 250** Solar Module Measurements
- **ET 252** Solar Cell Measurements
- **ET 255** Using Photovoltaics: Grid connected or Stand-alone

Solar thermal energy
- **ET 202** Principles of Solar Thermal Energy
- **HL 313** Domestic Water Heating with Flat Collector
- **HL 320** Module System for Solar Thermal Energy and Heat Pumps

Hydropower

- **HM 288** Radial-Flow Reaction Turbine Demonstrator
- **HM 289** Pelton Turbine Demonstrator
- **HM 291** Axial- Flow Impulse Turbine Demonstrator
- **HM 365.31** Francis and Pelton Turbine Modules
- **HM 430.C0** Francis Turbine Demonstration Unit, 1.5kW
- **HM 450.01** Pelton Turbine, 350W
- **HM 450.02** Francis Turbine, 350W

Wind

- **HM 170** Educational Wind Tunnel

Biomass

- Biogas
- Solid biomass
- Biofuels
- **CE 640** Biotechnical Production of Ethanol

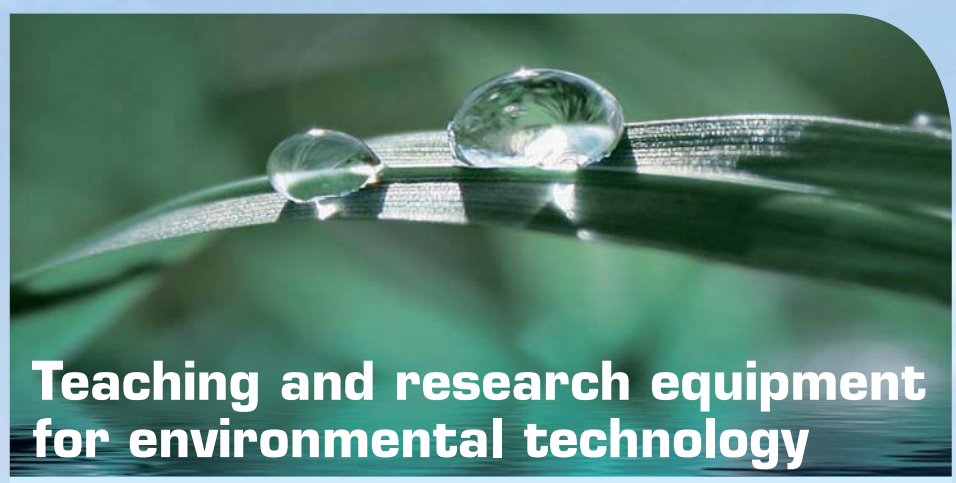
Geothermal energy

- **HL 320.07** Heating System with Geothermal Energy Absorber as Part of the Module System for Solar Thermal Energy and Heat Pump HL 320

Energy efficiency

Efficiency of systems
- **ET 420** Ice Stores in Refrigeration Technology
- **HL 305** Hydronic Balancing of Radiators
- **HL 630** Efficiency in Heating Technology

Thermal insulation
- **WL 376** Thermal Conductivity of Building Materials



Teaching and research equipment for environmental technology

Water

Basic methods of water treatment
- **CE 300** Ion Exchange
- **CE 530** Reverse Osmosis
- **CE 579** Depth Filtration
- **CE 581** Water Treatment Plant 1
- **CE 582** Water Treatment Plant 2
- **CE 583** Adsorption
- **CE 584** Advanced Oxidation
- **CE 586** Precipitation and Flocculation
- **CE 587** Dissolved Air Flotation
- **CE 701** Biofilm Process
- **CE 702** Anaerobic Water Treatment
- **CE 705** Activated Sludge Process
- **HM 142** Separation in Sedimentation Tanks

Soil

- **HM 141** Rainfall Hydrograph
- **HM 145** Measurement of Ground Water Profiles
- **HM 165** Permeabilty and Storage Capacity of Soils
- **HM 167** Ground Water Flow
- **HM 169** Flow in Permeable Media

Air

- **CE 235** Gas Cyclone
- **CE 400** Gas Absorption

Waste

- **CE 280** Magnetic Separation

Energy efficiency is, of course, not a specific renewable energy source, yet considering all aspects of this indispensable and overarching concept is always crucial.

"Today, energy efficiency, which also includes cogeneration, is the most cost-effective energy resource at our disposal, also the one which is which is quickest to implement"

Based on a quote by Al Gore "Our Choice" p.254

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Making direct use of the sun's heat

Solar thermal energy is defined as the use of solar energy to generate heat.

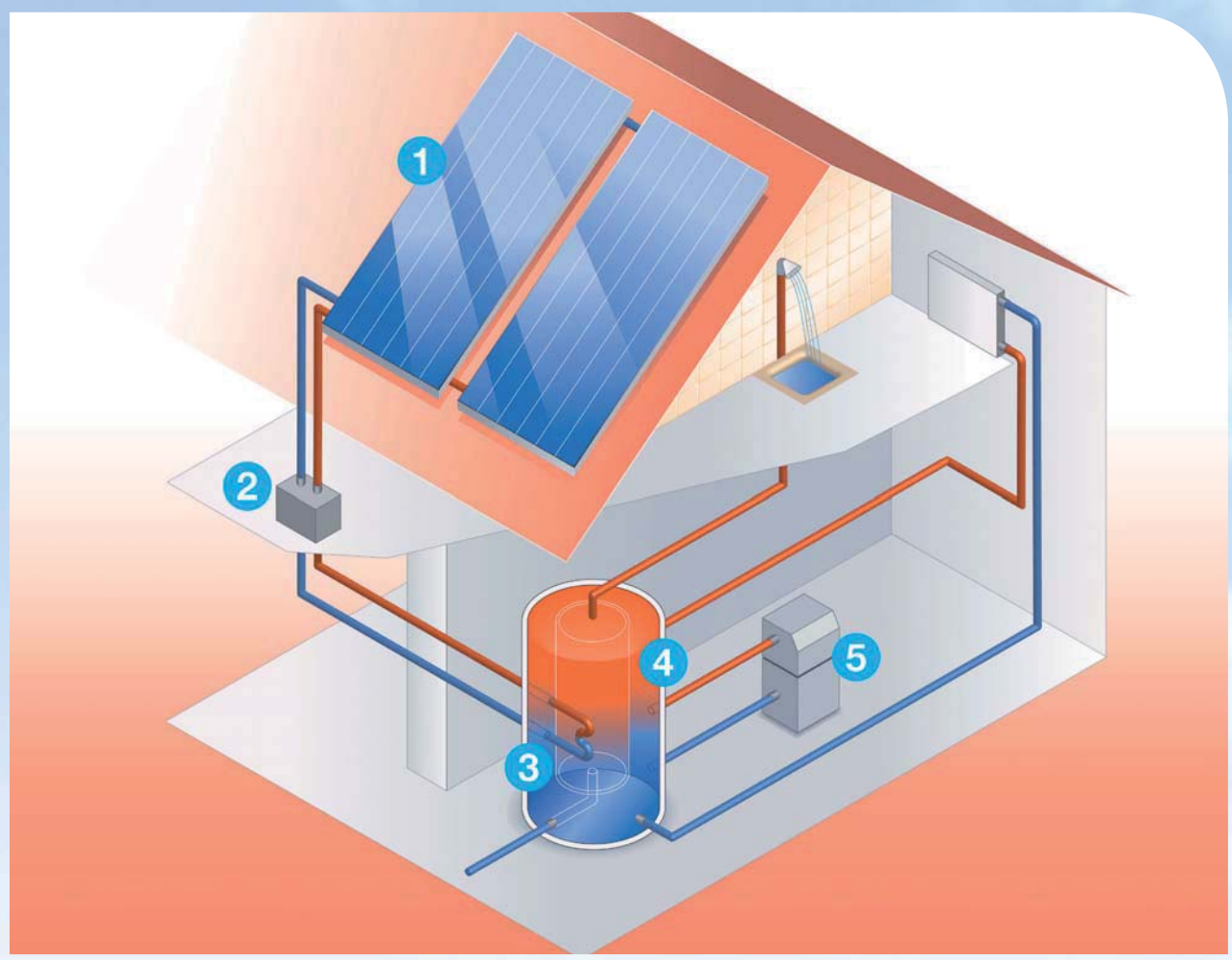
The heat can be used for space heating and domestic water heating, but also as process heat in industry, steam for generation in power stations and even for cooling.

Solar thermal energy in a one-family house

Roughly 60% of the domestic hot water required in a one-family house can already be met by 4 to 5 m² of a typical flat plate collector.

Larger-sized collectors with surfaces of 8 to 15 m² can also be used to support space heating, as shown in the figure. A tank (no. 4) serves to compensate for fluctuations in the supply and demand of heat.

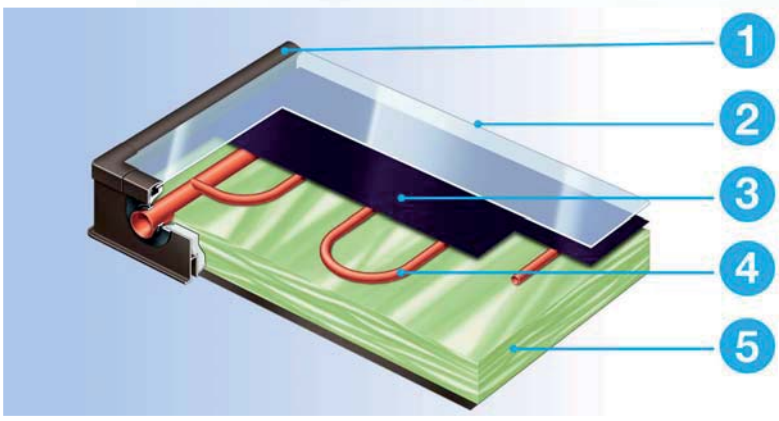
For a one-family house in Central Europe such systems can provide about a quarter of the total heating requirements.



Domestic water heating and heating support
Collectors (1), Solar circulation station (2), Tubular heat exchanger (3), Tank in tank for combined storage (4), Reheater (5)

Flat plate collectors

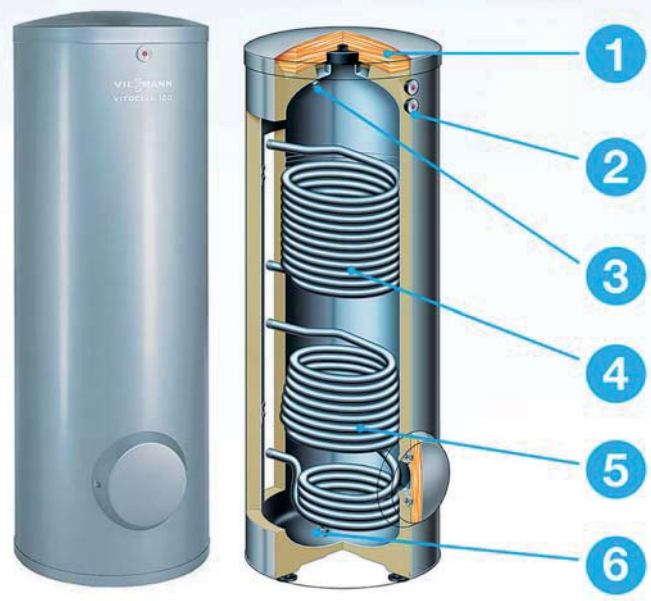
The most common type of collector is the flat plate collector with a market share of 90%. Its strengths lie in its comparatively easy construction and positive long-term experiences.



Construction of a flat plate collector (Viessmann)
Collector frame (1), Solar glass cover (2), Selectively absorbing coating (3), Copper tube (4), Thermal insulation (5)

Bivalent tanks

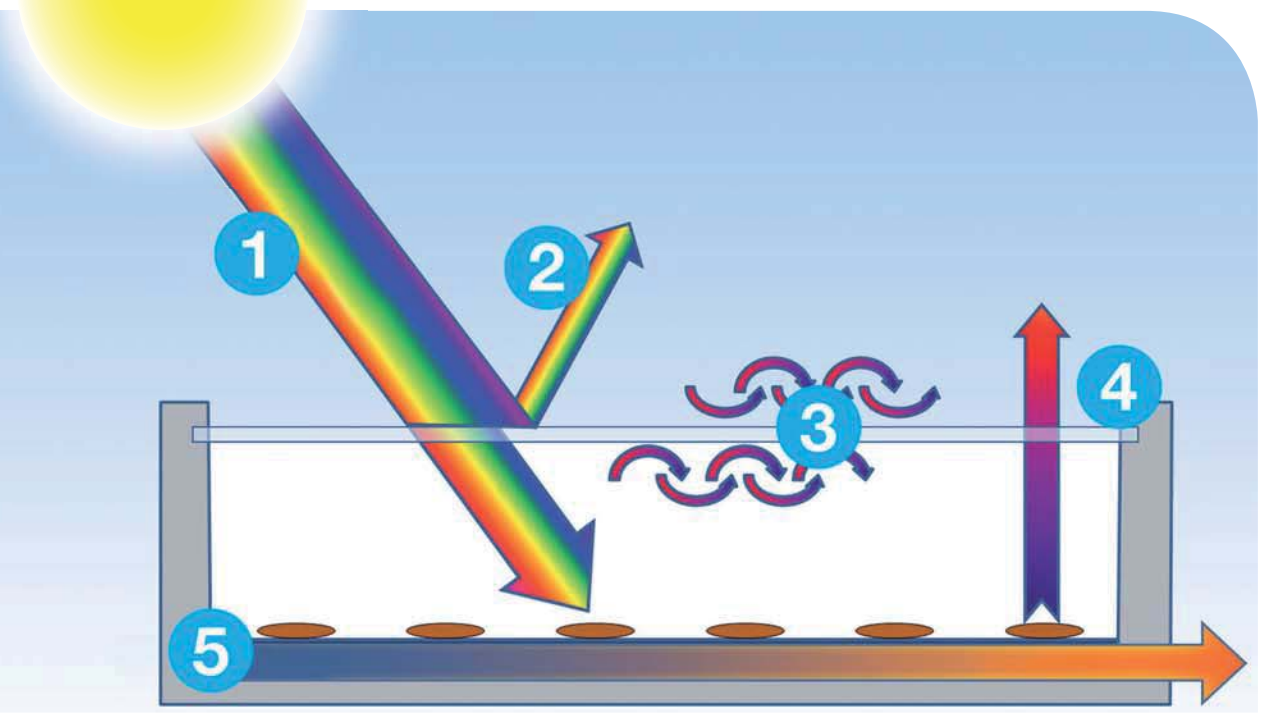
Bivalent tanks are used primarily in systems for solar domestic water production. They offer the option of efficiently integrating an additional heat source into the supply circuit.



Bivalent domestic water tank (Viessmann)
Thermal insulation (1), Thermometer (2), Hot water outlet (3), Smooth pipe heat exchanger for reheating (4), Smooth pipe heat exchanger e.g. for solar (5), Cold water inlet (6)

Collector energy losses

One of the most important aims in developing collectors is to minimise losses. In order to provide an understanding of such effects, the most important loss channels of a flat plate collector are illustrated in the following energy balance.



Energy balance of flat plate collector
Solar radiation (1), Reflected solar radiation (2), Heat loss by convection (3), Radiant heat loss (4), Effective power (5)

2E TEACHING EQUIPMENT FOR SOLAR THERMAL ENERGY

HL 313 Domestic Water Heating with Flat Collector

This trainer demonstrates the main practical components for solar domestic water heating. The didactic concept deals with the key training aspects from practice and theory, ranging from the correct filling process with a heat transfer medium through to the calculation and optimisation of effective power.

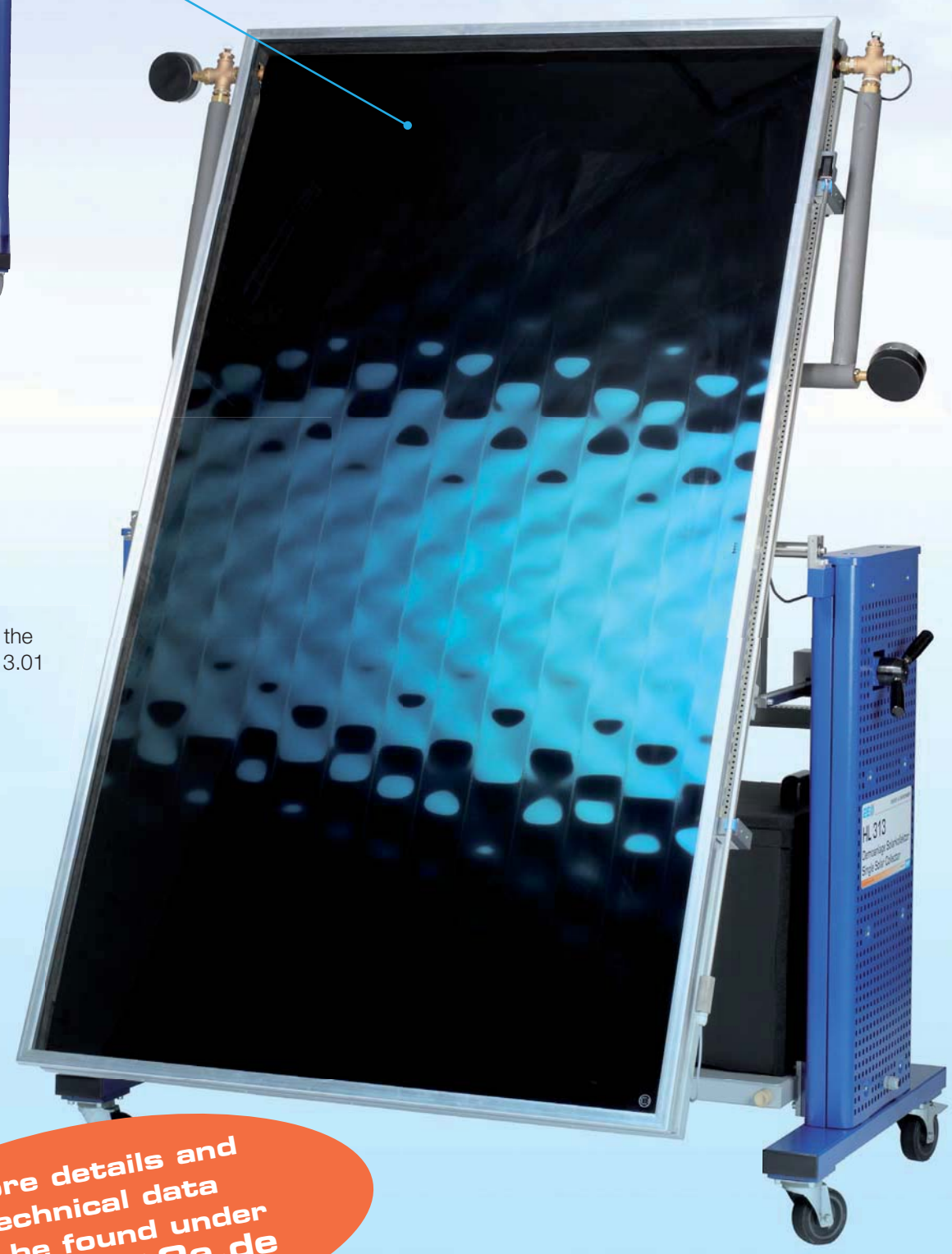
Principle of operation

The flat plate collector absorbs the solar energy and converts it into heat. The heat is transferred to a heat transfer medium in the solar circuit and then reaches the hot water circuit via a heat exchanger.
A solar controller controls the hot water circuit pump and the solar circuit pump. The solar circuit is protected by an expansion vessel and a safety valve.

Learning Objectives/Experiments

- Functioning of a solar collector and construction of the solar thermal circuit
- Correlation between collector efficiency and the difference in temperature to the ambience
- Calculating effective power

The unit can be operated with the optional lab light source HL 313.01 when natural solar radiation is unavailable.



2E product series Solar thermal energy

ET 202 Principles of Solar Thermal Energy

HL 313 Domestic Water Heating with Flat Collector

HL 320 Module System for Solar Thermal Energy and Heat Pumps

More details and technical data can be found under www.gunt2e.de

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From cell basics to grid connected systems

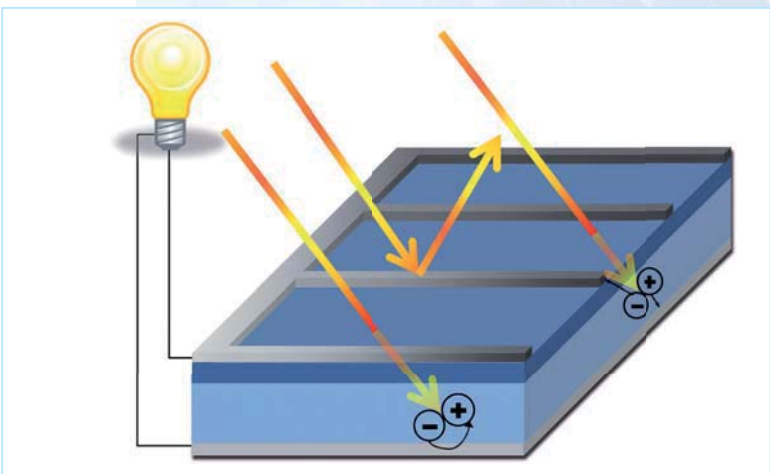
Photovoltaics (PV) offers the unique opportunity to convert the virtually inexhaustible light from the sun directly into electricity. This technology represents an ideal sustainable energy source that fits perfectly into the 2E philosophy.

Modern monocrystalline silicon solar cells can achieve a conversion efficiency of more than 22%. Due to the continuous optimisation of production processes, typical energy payback times are now less than 3 years. This means that within this period the solar cell has generated the energy that was required for its production.

Financial start-up assistance has served to establish this technology and continued strong growth is expected. Solar cell manufacturers have predicted a solar electricity share in Germany of 20-30% in the long term.

Principle of operation of a solar cell

A solar cell converts the radiant energy of light into electrical energy. In this process, the electrical charge carriers of a semiconductor are excited by the energy of light particles (photons). The internal structure of a semiconductor solar cell makes it possible to provide the charge carriers as an electrical current for a connected load.



Grid connected systems

While photovoltaics were initially limited to niche applications, such as supplying consumers in remote locations, today the majority are installed in grid connected operation. With grid connected operation, the generated solar electricity is converted into alternating current and then fed into a public mains grid. The delivered solar electricity is recorded by an electricity meter. The total electricity requirement for supplying a household has so far been mostly covered by the public grid and recorded by a second electricity meter. In order to promote self-consumption of solar electricity, this kind of use will receive a higher rebate in the future in Germany.

A typical mains parallel system consists of the following main components:
1 Photovoltaic generator (roof), **2** Power inverter (loft), **3** Energy meter (cellar)

Cell – Module – Generator – System

A solar cell is the smallest unit in a photovoltaic system. A single cell only delivers a low open circuit voltage of approx. 0.6V. This voltage is not enough to feed electrical energy into the grid or to use for electrical equipment.

A module groups together several interconnected cells into a useful unit. Common module open circuit voltages range from approx. 12 to 24V. Such voltages could be used to operate direct current (DC) load or to charge an accumulator. The module is thus the smallest form of photovoltaic generator. A photovoltaic system is defined as a complete system for generating and providing electrical energy.

Typical production process for solar cells

Monocrystalline and polycrystalline silicon solar cells are the most commonly available types to date. The basic material is produced by cutting block silicon into wafers.

The production of a finished cell still requires many further steps. The main processing stages are as follows:

- Doping (installation of electric field)
- Passivation (reduction of material faults)
- Bonding (screen printing with conductive pastes)

Isolated system

Isolated systems are employed primarily when no mains supply is available or mains independence is required. Isolated systems consist of the following main components:

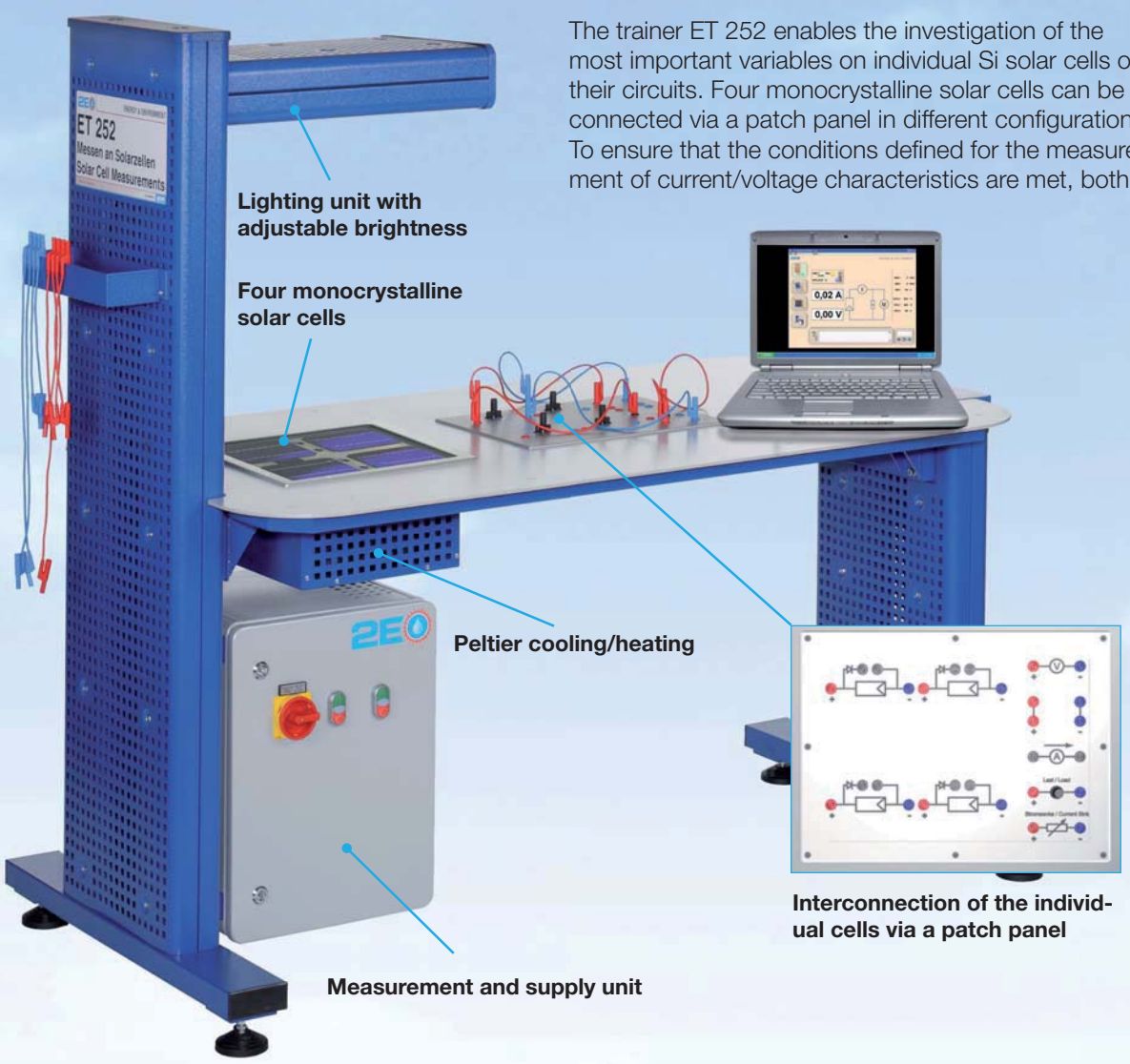
Photovoltaic generator, inverter, charge controller, accumulators.

Photovoltaic power stations

Photovoltaic power stations are large-scale grid connected systems. They are able to generate outputs of several megawatts. In principle their construction hardly differs from that of simple roof systems.

2E TEACHING EQUIPMENT FOR PHOTOVOLTAICS

ET 252 Solar Cell Measurements



Principle of operation

The trainer ET 252 enables the investigation of the most important variables on individual Si solar cells or their circuits. Four monocrystalline solar cells can be connected via a patch panel in different configurations. To ensure that the conditions defined for the measurement of current/voltage characteristics are met, both the brightness and the temperature can be selectively adjusted. The temperature of the solar cells is controlled via a Peltier module. The current/voltage characteristics can be measured manually with an adjustable load resistor or automatically via a LabVIEW controlled current sink.

Learning Objectives/ Experiments

- Current/voltage characteristics of solar cells
- Series or parallel connection of solar cells
- Effect of brightness, shading and temperature

Software with an integrated tutor

Using the comprehensive software, all unit functions can be operated from an external PC or laptop via USB interface. In addition to brightness and temperature control, the automated measurement of characteristics is also configured here via the LabVIEW controlled current sink.

The software also features an integrated tutor, which is designed to support the understanding of the fundamentals of photovoltaics and the different measuring options offered by the unit.

Animations illustrate the fundamentals of interconnected cells and the selectable options in the integrated patch panel.

ET 255 Using Photovoltaics: Grid connected or Stand-alone

Principle of operation

The trainer ET 255 enables the investigation of components from practical photovoltaics for grid connected and isolated operation under real operating conditions. It is possible to work with a real photovoltaic module (e.g. ET 250) or with the integrated PV simulator. The PV simulator is controlled and configured via a module in the software. Additional software functions enable the collection of measured data, thereby helping to achieve the stated learning objectives.

In order to investigate the operation of the system components in detail, the trainer ET 255 is equipped with measuring points for current and voltage in each relevant circuit.

Learning Objectives/ Experiments

- Application aspects of photovoltaic systems with grid connected and isolated operation
- Functioning of MPP trackers
- Functioning of power inverters
- Functioning of charge controllers

2E product series Photovoltaics

ET 250 Solar Module Measurements

ET 252 Solar Cell Measurements

ET 255 Using Photovoltaics: Grid connected or Stand-alone

More details and technical data can be found under www.gunt2e.de

A proven source of renewable energy

Hydropower has already been used for centuries as an energy source for a wide range of mechanical applications.

This makes hydropower a successful renewable energy supplier with a proven track record. Since the beginning of electricity generation by hydropower its share of electrical energy generation has increased to approximately a quarter of the world's consumption of electricity. However, the increasing size of the turbines and the dams have also partly revealed clear deficits as regards the ecological overall impact of this technology (1).

Due to geological conditions, some countries are able to cover a very high percentage of their electrical power needs by hydropower, for example, Norway (99%), Zaire (97%) and Brazil (96%). By comparison in Germany this figure is only 4%. The world's most powerful hydroelectric power station in operation today is located in Brazil: 18 turbines with a total generating capacity of 12600 megawatts.

(1) see e.g. IHA or "World Commission on Dams"

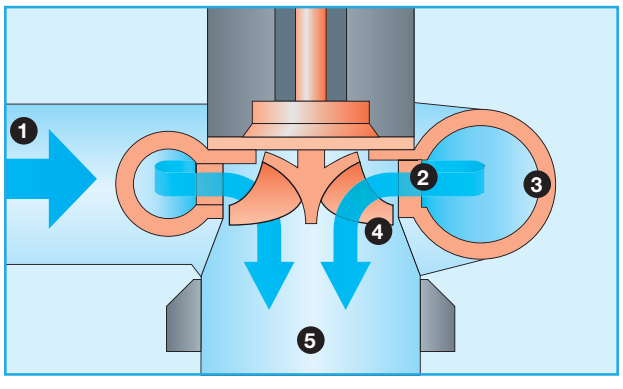
Construction

Typical hydroelectric power stations consist of a water reservoir at a higher level, turbines and generators. The water is dammed in the water reservoir from where it flows downhill through pipes. In the valley the turbines are powered by the water. They are mechanically connected to the generators by shafts. The rotary motion of the turbine powers the generator thus generating electricity.

Decentralised power supply by small-scale hydropower

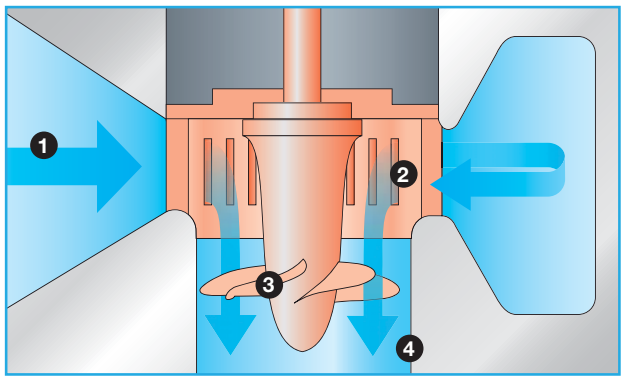
In regions without a centralised power supply, decentralised small-scale hydropower plants with a capacity of up to approx. 5kW, in particular, offer the possibility of supporting sustainable development, if adapted appropriately.
In addition to the typical characteristics, such as water head and volume flow, maintenance aspects and site accessibility are also important in the choice of turbine type.
Like in large-scale hydroelectric power stations, Pelton turbines are generally also used for small-scale hydropower where the available water head is 150m and more. For lower water heads, Francis or Kaplan turbines are used.

Turbine types in hydroelectric power stations



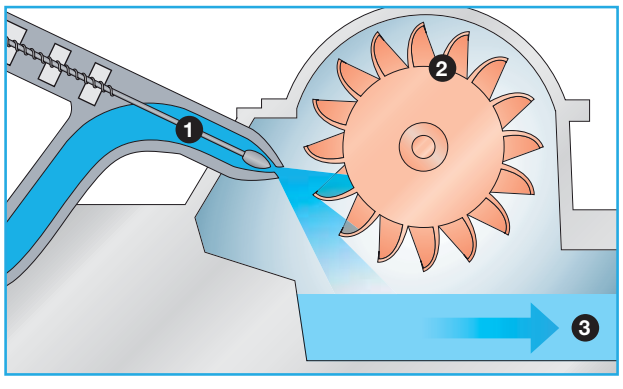
1. Water inflow, 2. Guide vanes, 3. Annular channel , 4. Blades, 5. Outlet channel

The **Francis turbine** works with positive pressure. The vanes of the control wheel are adjustable. Application area: Head 20–700m, volume flow of 0.3–1000m³/s, valley dams



1. Water inflow, 2. Adjustable control device, 3. Adjustable blades, 4. Water outlet

The **Kaplan turbine** works with positive pressure. The control device and the blades are adjustable. Application area: Head 2–60m, volume flow 4–2000m³/s, rivers



1. Water inflow with nozzle, 2. Impeller with blades, 3. Water outlet

The **Pelton turbine** works under normal ambient atmospheric pressure. The water is "fired" from one or several nozzles at the cup-shaped blades of the impeller.
Application area: Head 150–2000m, volume flow 0.02–70m³/s, storage power plants in high mountain regions

2E LAB EXPERIMENTS WITH HYDROPOWER

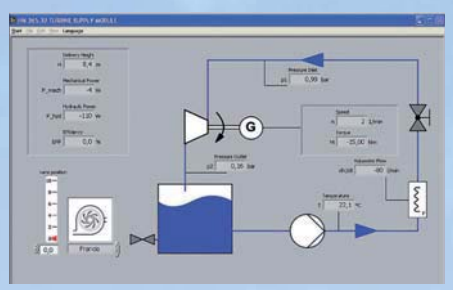
Modular system HM 365 Pelton and Francis Turbine

Principle of operation

The modular system HM 365 can be used to supply different turbines and to investigate their characteristic operating performance.

The basic unit is used for supplying water. A powerful pump, in a closed water circuit, replaces the water head of a hydroelectric power station in this lab experiment. You can use a choke valve to adjust the flow rate or the pressure applied to the turbine.

The basic unit is equipped with measuring transducers for pressure, temperature and flow rate. The energy generated by the turbine is measured via the force transducer of the braking unit.

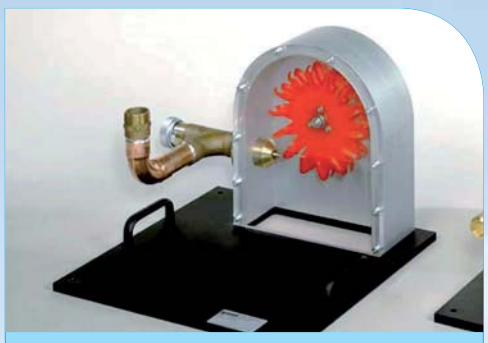


LabVIEW software enables data to be collected via a USB port. In order to monitor the current system status, the relevant measurements and the current configuration can be shown on the process diagram. Of course, the software also offers numerous graphic displays and calculations.

Learning Objectives/ Experiments

- Comparison of constant-pressure turbines and reaction turbines
- Recording of turbine characteristics
- Calculating output and efficiency
- Operating a Francis turbine with adjustable guide vanes
- Operating a Pelton turbine with an adjustable nozzle

Pelton and Francis turbines are interchangeable



Pelton turbine

Francis turbine

1. Measuring amplifier
2. Universal Drive and Brake Unit HM 365
3. Pelton Turbine HM 365.31
4. Tank
5. Pump
6. Measuring point for pressure
7. Measuring point for temperature
8. Valve
9. Flowmeter
10. Water inlet

All elements and functions match those of a "real" hydroelectric power station

2E product series Hydropower

HM 288	Radial-Flow Reaction Turbine Demonstrator
HM 289	Pelton Turbine Demonstrator
HM 291	Axial-Flow Impulse Turbine Demonstrator
HM 365.31	Francis and Pelton Turbine Modules
HM 430.C0	Francis Turbine Demonstration Unit, 1.5KW
HM 450.01	Pelton Turbine, 350W
HM 450.02	Francis Turbine, 350W

More details and technical data can be found under www.gunt2e.de

More than just a trend

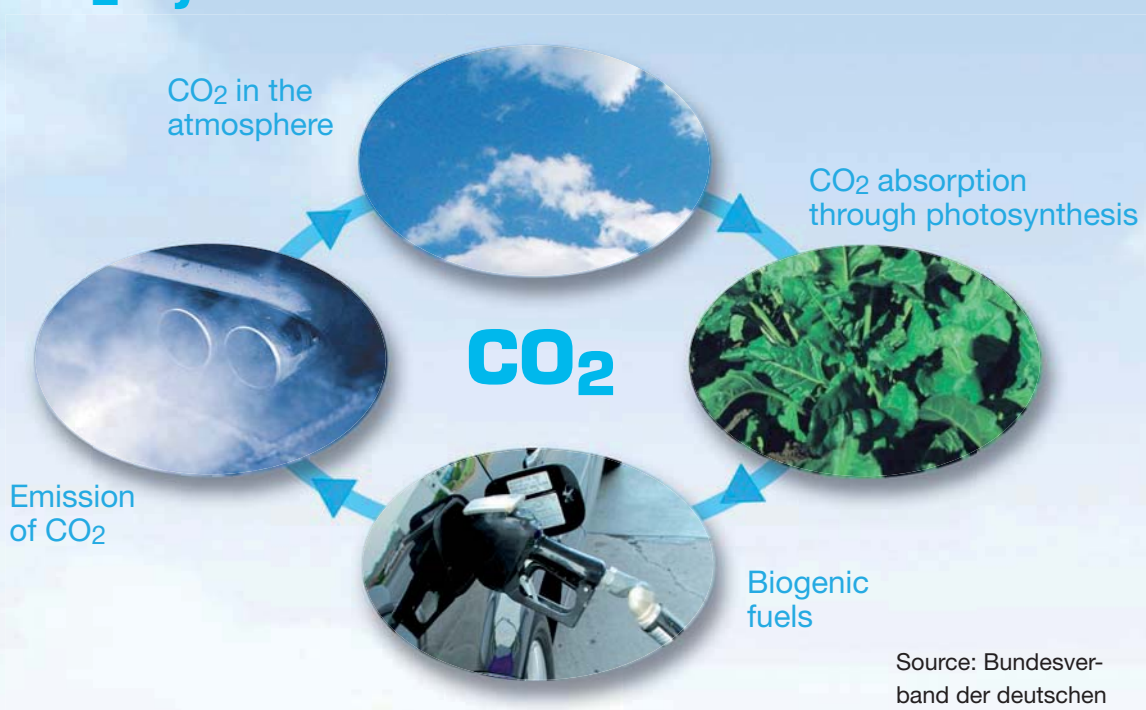
Development of bioenergy sources

Photosynthesis enables plant growth with the help of sunlight. In this process, the plant absorbs CO_2 from the atmosphere and together with water and minerals 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 processing 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

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 support 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. In favourable conditions, up to 70% of greenhouse gases can be saved.

- **Technology with possibilities for rural areas**

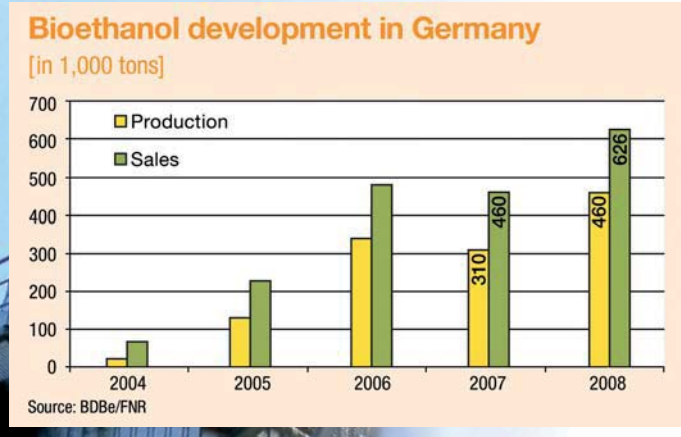
  The economy and public authorities benefit from supporting local bioethanol producers through increased value creation and the creation of new jobs. In addition, new markets are opened up for agriculture.

- **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.

- **Sustainable security of supply for applications without possibility of substitution**

  For land-based transportation it is expected that e.g. electric drives will lead to an improved energy balance in the long term. In view of their comparatively high energy density, biofuels are set to increase in importance, especially for all transport applications which are not able to rely on heavy electrical storage units or a ground-based power supply.



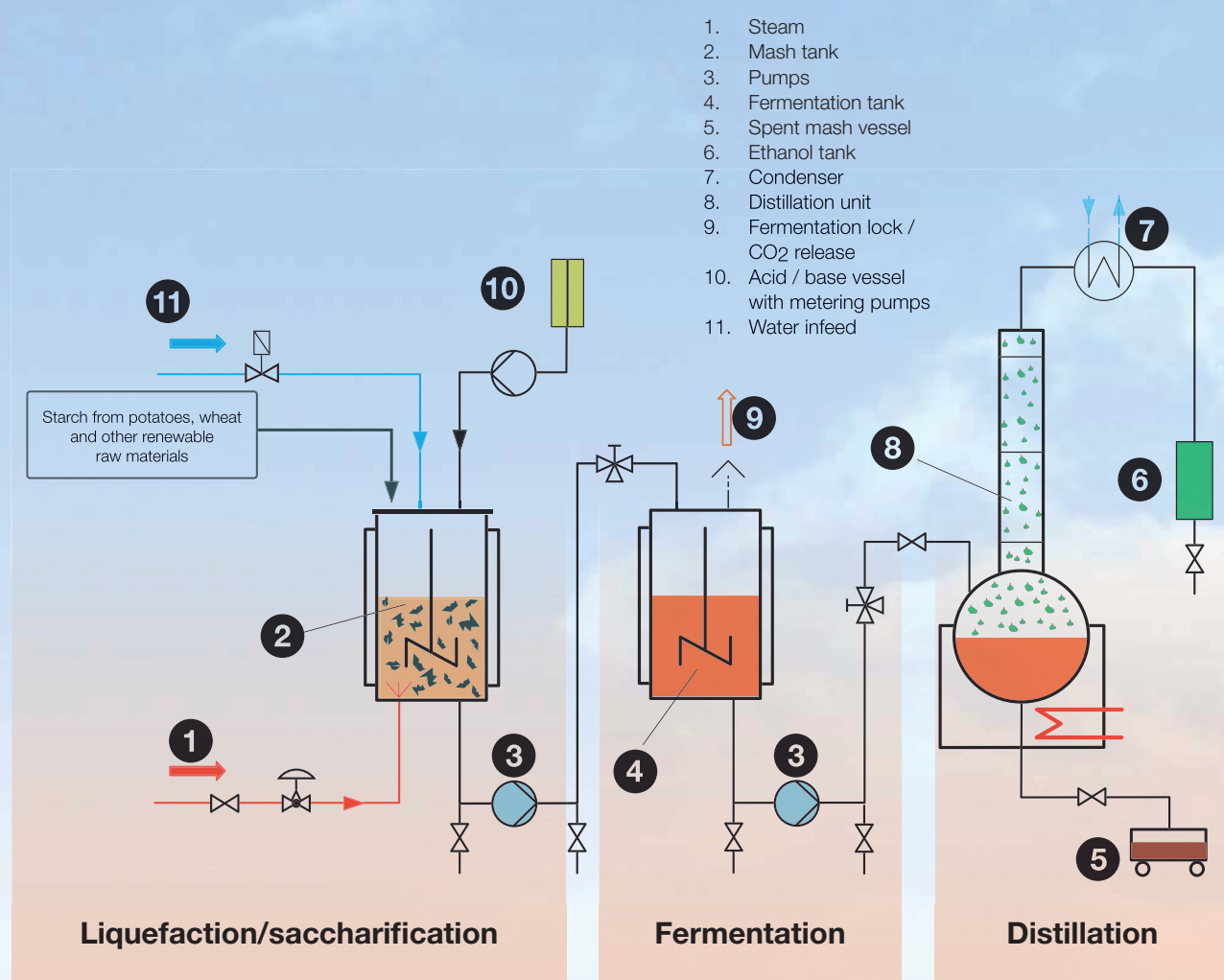
2E TEACHING EQUIPMENT FOR THE TOPIC OF ENERGY FROM BIOMASS

CE 640 Biotechnical Production of Ethanol

Principle of operation

Renewable raw materials are used for the biotechnical production of ethanol. The experimental plant CE 640 can be used to perform all the steps required in the production process. This includes the liquefaction and saccharification of the raw materials, the conversion of sugar into ethanol and the final distillation process. CE 640 provides for the controlled introduction of steam and hot water in order to enable precise control of the temperature in the individual process steps.

During the liquefaction and saccharification processes, different enzymes are used one after the other. To ensure the most favourable conditions for these processes, suitable pH values can be preselected. The metering of the required amounts of acid or base is then controlled by PLC. Double-chamber diaphragm pumps are used for inter-tank transfers. Specific process optimization methods can be tried by controlling individual system components. The amount of ethanol produced can be used to determine the total yield of the respective fermentation process.



Learning Objectives/ Experiments

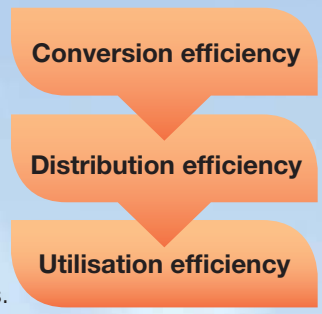
- Liquefaction and saccharification by use of enzymes
- Anaerobic fermentation by yeast cultures
- Distillation with a professional bubble tray column
- Process control via PLC

More details, including an informative film, are available in the special brochure "CE 640 Biotechnical Production of Ethanol"

Sustainability through optimised systems

Energy efficient systems

Nowadays, measures for increasing energy efficiency are gaining in importance in almost all areas of everyday life. A key approach to achieving sustainable optimisation is to view the individual stages from generation, via transport through to the use of energy as a complete system.



The 2E training equipment looks in detail at this approach in a variety of ways.

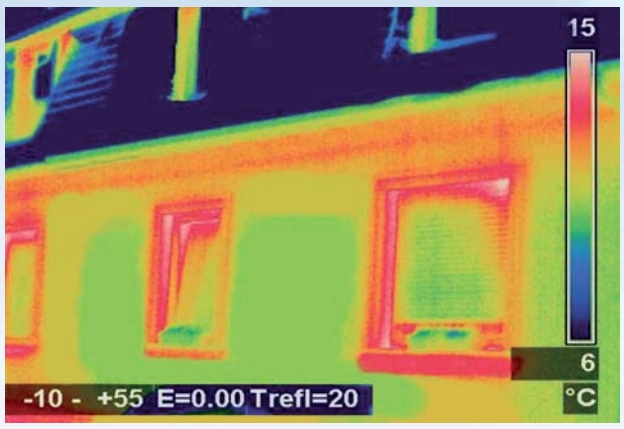
Higher conversion efficiency for solar thermal absorbers

In addition to the measures for increasing energy efficiency through improved and more economical use, the direct conversion process between different forms of energy is also being continuously optimised. For example, during the conversion of radiant energy into heat, higher efficiency is achieved by the use of selective absorber layers. This effect can be examined with our experiment ET 202 Principles of thermal solar energy.

Higher utilisation efficiency through insulation and heating optimisation

Optimising the heating of buildings

Sometimes implementing simple measures and being more aware about energy is enough to achieve substantial savings. When it comes to heating buildings, the required energy can in some cases be reduced by more than 80% by a combination of measures. This includes improved insulating materials, an optimised hydronic balance of the heating circuits and the use of modern controlled circulating pumps.



Detecting heat leakage

Poor insulation in old buildings can result in heat leakage. Such problem areas can be detected using sensitive infrared cameras by measuring heat radiation. It is not only the thermal conductivity of the materials, but also their application, which determines the overall efficiency of the insulation.

Higher utilisation efficiency through controlled consumption

Consumption based on demand

In many systems improved control of energy consumption alone can lead to substantial savings. An example of this is presented in our trainer for heating technology HL 630. The power consumption of a modern differential pressure controlled circulating pump is up to 50% less compared to a continually running pump.

According to this principle substantial savings are also possible in industry. In many areas in which fluid-flow machines are used to transport process media (gases, liquids), a more intelligent method of operation can often result in significant savings. Typical negative examples also include systems with uncontrolled pumps where the required flow rate can only be adjusted by choke valves.

Consumption based on supply

Since the provision of reserve capacities in energy supply networks involves considerable effort and expense, savings can be achieved by better coordinating the time of energy demand to the available energy supply. This adjustment can improve utilisation efficiency. Typical examples are electrical household appliances which are only operated outside of periods of peak demand.

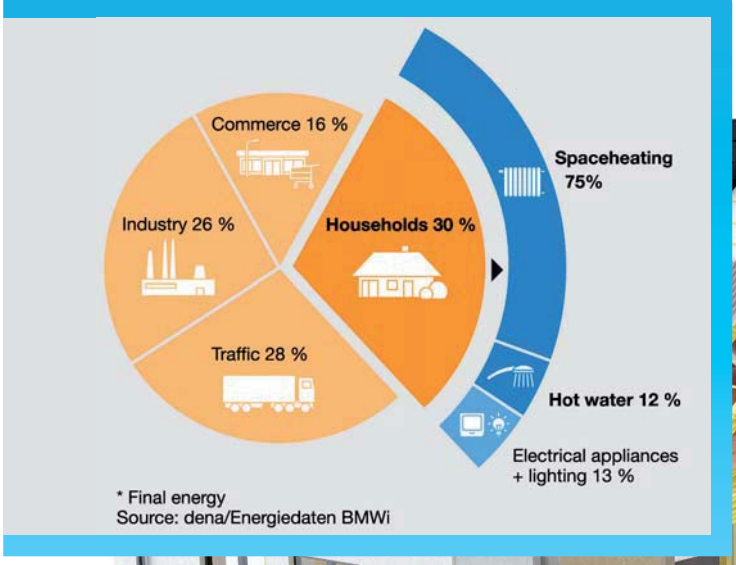
Higher total efficiency through cogeneration

Combined utilisation concepts in decentralised systems such as in modern cogeneration systems ideally combine the requirements of an efficient system. Cogeneration involves the simultaneous production of electric and thermal energy, with the waste heat being used for heating purposes. Using e.g. CO_2 neutral biogas as the fuel in such systems also increases the contribution to climate protection.

Wasting energy

Conventional large-scale power plants only utilise a fraction of the energy source used. Typical older generation coal-burning power plants only convert roughly a third of the energy into electricity, the rest is lost as heat.

The main energy consumers in Germany



2E TEACHING EQUIPMENT FOR ENERGY EFFICIENCY

HL 630 Efficiency in Heating Technology

If all the outdated heating systems in Germany were to be equipped with controlled pumps, this could result in potential energy savings of up to 2GW during periods of peak demand in winter. This is roughly equivalent to the capacity of two modern large power plants.

Principle of operation

The trainer contains a complete heating circuit with circulating pump, electrical heater, convector for dissipating heat, various pipe sections, fittings and safety devices.

The losses of the most important fittings can be determined using seven differential pressure sensors. Control response and energy flux can be plotted using four temperature sensors, a flow rate sensor and an effective power sensor.

The most important part of the experiments allows a series of comparative measurements to be made between a conventional circulating pump and a differential pressure controlled circulating pump.

The measured values are transmitted directly to a PC via USB for processing with the software supplied. Both circulating pumps, the heater and the convector fan can be controlled via PC.

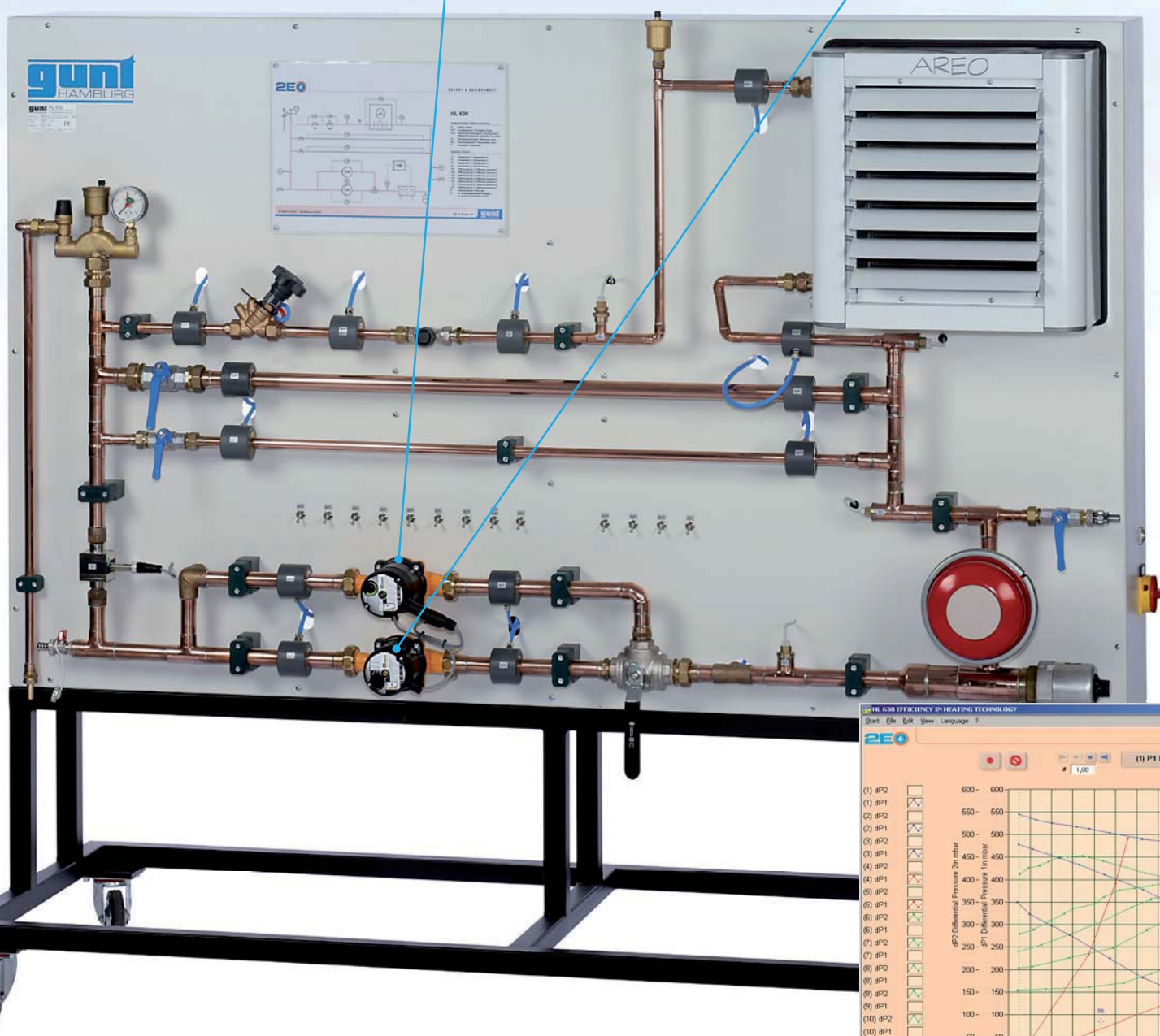
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

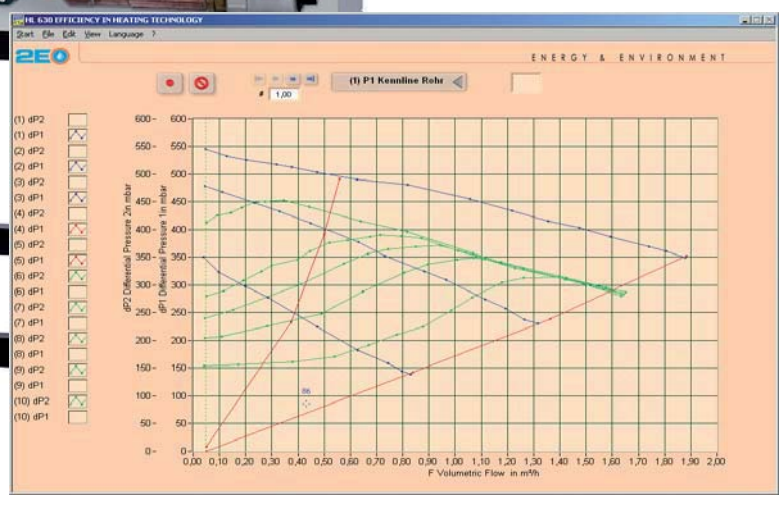
Learning Objectives/ Experiments

- Comparison of pressure losses in various pipe sections and fittings
- Representation of system and pump characteristics
- Control of energy efficient circulating pumps

Energy efficient circulating pumps with adjustable differential pressure control

Uncontrolled circulating pump with selectable speed





The operating behaviour of a heating system is characterised by the relationship of pressure and volume flow. By plotting both values as an axis in a diagram against each other it is possible to read the respective operating point from the intersection point between the pump characteristic and the system characteristic.
Characteristics and operating points can be immediately represented using the software.

2E product series energy efficiency

ET 420 Ice Stores in Refrigeration Technology

HL 305 Hydronic Balancing of Radiators

HL 630 Efficiency in Heating Technology

WL 376 Thermal Conductivity of Building Materials

More details and technical data can be found under www.gunt2e.de

2E a division of gunt HAMBURG

No life without water

2E places special emphasis on water because of its fundamental importance to life.

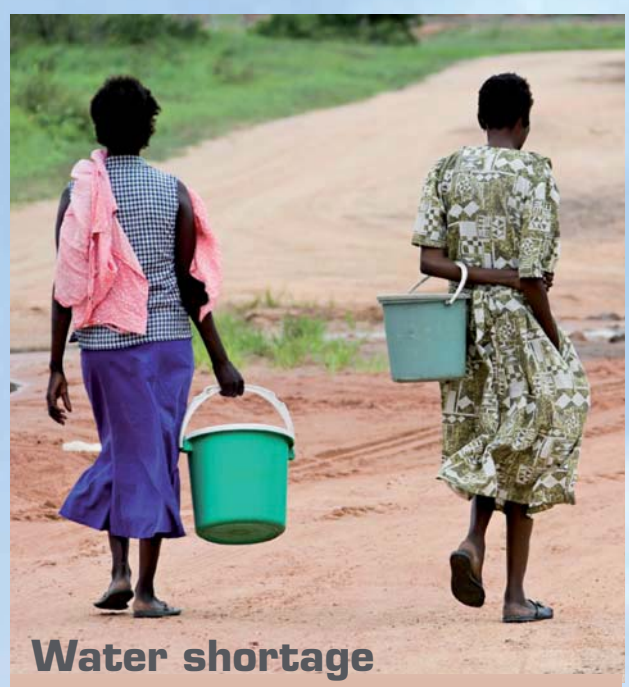
A complete systematic program dealing with the basic methods of water treatment has been created.

Water is a limited natural resource and fundamental for life and health. In 2000, the World Health Organization estimated that of the world's 6 billion people, at least 1.1 billion lack access to safe drinking water and 2.4 billion persons live without access to sanitation systems. An estimated 14 to 30 thousand people, mostly young and elderly, die every day from avoidable water-related diseases (e.g. diarrhoeal diseases). The lives of these people who are among the poorest on our planet are often devastated by this deprivation, which impedes the enjoyment of health and other human rights.

World Water Council: "Why a right to water is necessary"

What is meant by water treatment?

The properties of water are changed by private or industrial use. Used water (waste water) cannot be directly discharged into a watercourse. Waste water first needs to be treated so that it no longer poses a threat to the environment. If the waste water released into the watercourse contains e.g. large amounts of organic substances, they will be degraded by micro-organisms with a high consumption of oxygen. This leads to oxygen deficiency in the open water and can cause fish to die. Water treatment can also serve to make water suitable for a specific purpose. Examples include the production of drinking water or the production of process water for industrial purposes.



Water shortage

An increasing number of regions in the world are affected by water shortage due to climate changes, inadequate possibilities for treating water and the lack of methods for keeping water clean.

Basic methods of water treatment

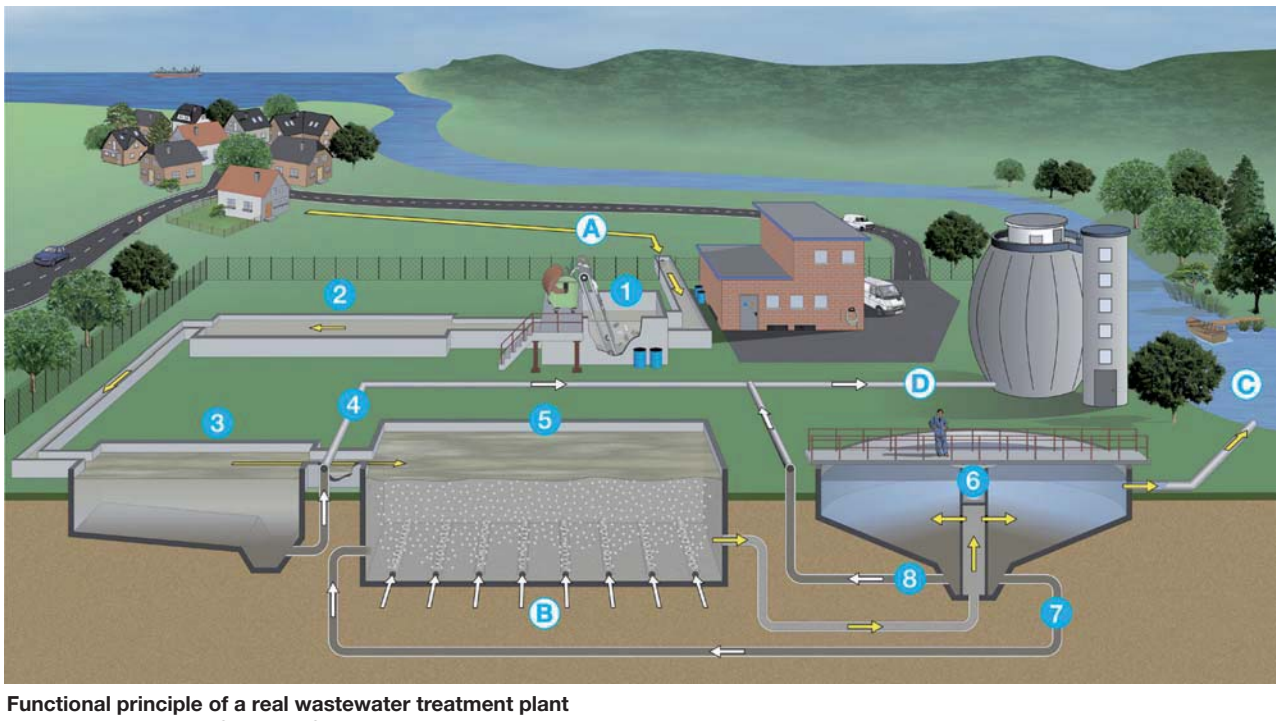
Undissolved Substances (Solids)	Dissolved Substances		
	Organic Substances		Inorganic Substances
Organic Inorganic	Biodegradable	Non-Biodegradable	
Mechanical Processes	Biological Processes	Physical/Chemical Processes	
• Flotation • Sedimentation • Filtration	• Aerobic processes • Anaerobic processes	• Adsorption • Membrane Separation Process • Ion Exchange • Precipitation/Flocculation • Chemical Oxidation	

The removal of undissolved substances (solids) takes place with mechanical processes. Dissolved substances can either be removed with biological processes or with physical/chemical processes.

The aim of biological processes is to remove organic, biodegradable substances. Microorganisms use these substances as a food source and thus degrade them. If this process occurs with dissolved oxygen present, this is called an aerobic process. This includes the activated sludge and biofilm processes. They are mainly used in the cleaning of communal waste water in wastewater treatment plants.

In contrast, anaerobic processes occur without oxygen present. Anaerobic processes are primarily used for highly organically polluted waste water. This type of waste water is found e.g. in the food and paper industries.

Organic, non-biodegradable and inorganic substances can be removed by physical/chemical processes. An example of this is water softening by ion exchange or adsorption of chlorinated hydrocarbons in activated carbon.



Functional principle of a real wastewater treatment plant
Mechanical cleaning: 1 Screen, 2 Sand trap, 3 Primary sedimentation tank, 4 Primary sludge
Biological cleaning: 5 Aeration tank, 6 Secondary clarifier, 7 Return sludge, 8 Surplus sludge
A Waste water, B Compressed air, C Recipient, D Sewage sludge

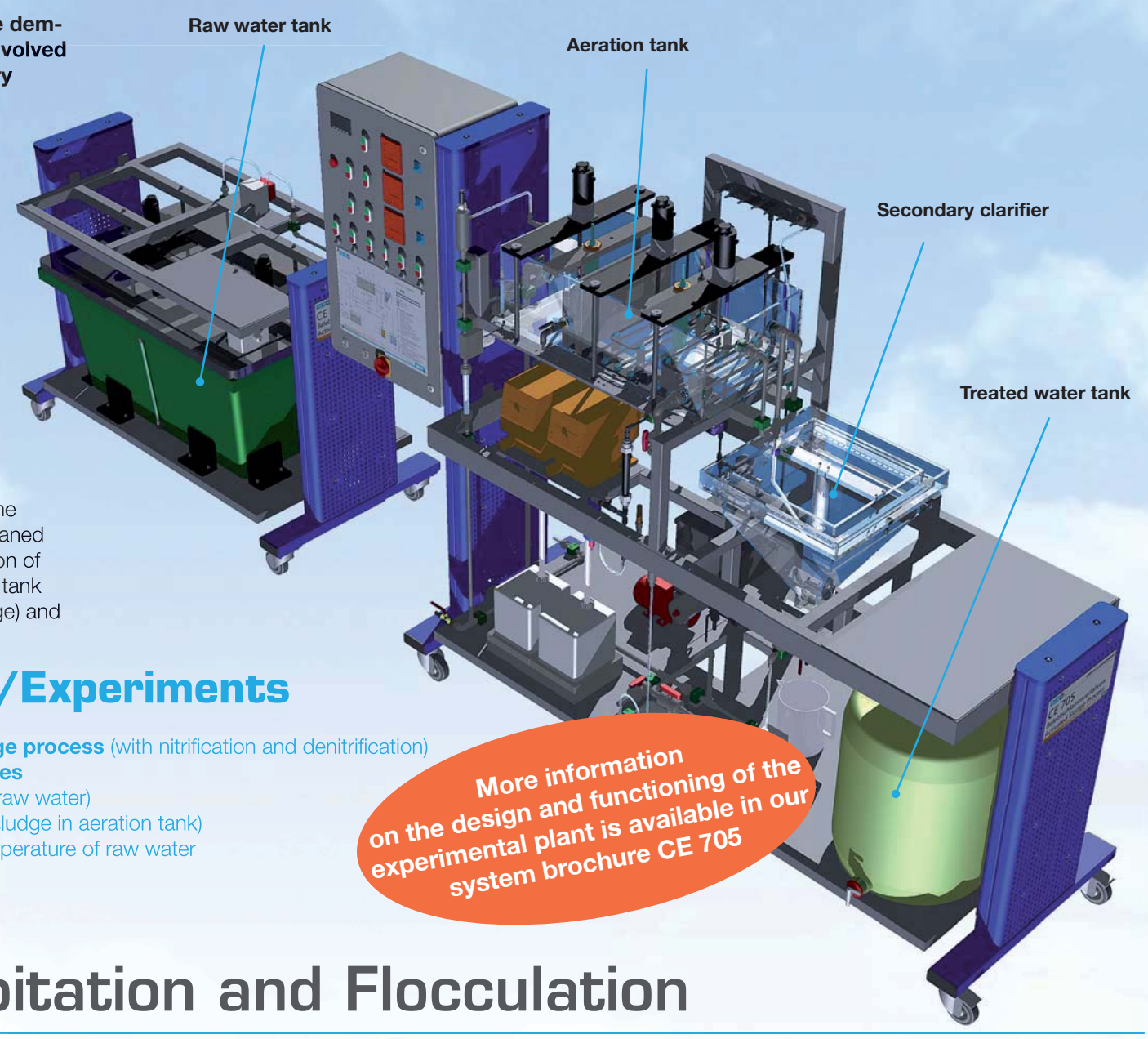
2E product series for the basic methods of water treatment

CE 300 Ion Exchange
CE 530 Reverse Osmosis
CE 579 Depth Filtration
CE 581 Water Treatment Plant 1
CE 582 Water Treatment Plant 2
CE 583 Adsorption
CE 584 Advanced Oxidation
CE 586 Precipitation and Flocculation
CE 587 Dissolved Air Flotation
CE 701 Biofilm Process
CE 702 Anaerobic Water Treatment
CE 705 Activated Sludge Process
HM 142 Separation in Sedimentation Tanks

2E TEACHING AND RESEARCH EQUIPMENT FOR WATER TREATMENT

CE 705 Activated Sludge Process

The experimental plant CE 705 enables the demonstration of all the basic process steps involved in biological water purification in laboratory scale, including how they are carried out in a real wastewater treatment plant.



Principle of operation

The raw water polluted with dissolved organic substances is pumped into the aeration tank. The aerobic microorganisms in the raw water degrade the organic substances. For this process to take place they need oxygen which is added to the aeration tank. The microorganisms multiply and are termed as activated sludge. In the secondary clarifier the activated sludge is then separated from the cleaned water (treated water) by sedimentation. A portion of the activated sludge is returned to the aeration tank (return sludge). The other portion (surplus sludge) and the treated water are collected in tanks.

Learning Objectives/Experiments

- **Familiarisation with the activated sludge process** (with nitrification and denitrification)
- **Meaning of important system key figures**
  – Reflux ratio (flow rate of return sludge to raw water)
  – Sludge age (residence time of activated sludge in aeration tank)
  – Oxygen concentration, pH value and temperature of raw water

More information on the design and functioning of the experimental plant is available in our system brochure CE 705

CE 586 Precipitation and Flocculation

The experimental plant CE 586 demonstrates the removal of dissolved non-biodegradable substances by precipitation and flocculation with subsequent sedimentation. This method is especially used for drinking water treatment and for the clean-up of contaminated sites.

Principle of operation

A pump transports the contaminated raw water to the precipitation tank. Due to the reaction of the dissolved metal ions with the precipitant, insoluble metal hydroxides (solids) form. From here the water flows into a flocculation tank which is divided into three chambers. The purpose of flocculation is to improve the sedimentation properties by adding a coagulant. The solid particles combine into flocs (coagulation). To generate larger flocs, a flocculant is then added (flocculation). In the third chamber low flow speeds are present to prevent any turbulence. The now well sedimentable flocs are then separated from the treated water in a lamella separator. The treated water and the sedimented flocs (sludge) are collected in two tanks.

Learning Objectives/Experiments

- Familiarisation with the methods for precipitation and flocculation
- Effect of the pH value on precipitation
- Creation of a stable operating state
- Determination of the required metering quantities (precipitant, coagulant, flocculant)
- Functional principle of a lamella separator

Comprehensive information on all programme areas is available at www.gunt2e.de and in our catalogue 5d

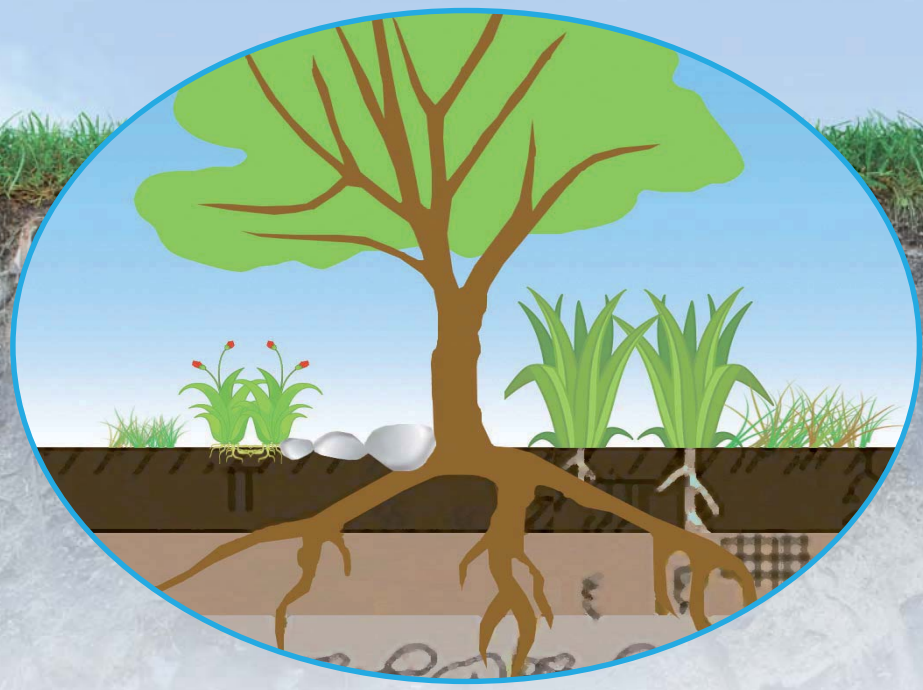
Soil – the Earth's sensitive skin

The field of soils examines topics relating to physical processes in the layer known as the pedosphere. By definition the object of research is soil science, i.e. the outer layer on the surface of the earth.

2E is particularly interested in the processes that take place in the soil which serve to preserve and restore our natural foundation of life.

The main topics of soil

- Infiltration of rainwater
- Ground water flows
- Transportation of ground water
- Clean-up of contaminated sites



Soil functions as a ...

Living habitat	Source of food
Pollutant filter	Usable area
Water reservoir	Raw material source
Climate regulator	Natural archive
Nature	Use

As the main part of natural ecosystems, soil fulfils many important functions for man and the environment. Closer inspection reveals how valuable soil - a mixture of minerals, plant residues, water and air - is to us!

Infiltration of rainwater

To enable soil to act as a pollutant filter e.g. for contaminated rainwater, water must be able to pass through the layers of soil unhindered if possible. The objective of sustainable housing development must therefore be to keep soil surface sealing to a minimum and to provide for sufficient infiltration possibilities. This is the only way to preserve natural regeneration processes in order to ensure that man can continue to enjoy the benefits from clean ground water sourced from wells.

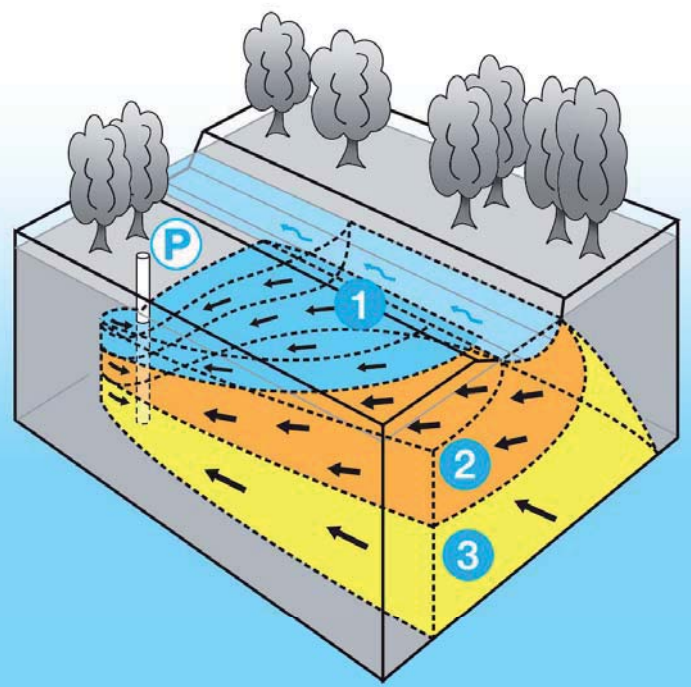
2E has developed a series of units to introduce the important influencing factors for preserving and supporting these soil processes.

Understanding infiltration processes, ground water flows and filtration properties is especially essential for environmental technology students.

Contaminated soil

Typical problems relating to contaminated sites are mostly indicative of decades of careless industrial production practices and their legacies. A further cause is the use of unsuitable substances in agriculture. Pollutants can enter the soil through rain, waste water, landfill leakage or industrial accidents.

The most important objective in cleaning up contaminated sites is to eliminate any possibility of future danger to man and the environment.



Ground water close to a river flows in tiers

Ground water types in a pumping station close to a river.

1 Young river infiltrate from a local source
2 Older river infiltrate from further upstream
3 "Real" ground water from the infiltration of rainwater
P Ground water pumping station or piezometer

The relative proportions of the three ground water types in P vary with time because of variable water levels in the river.

Source: Eawag: Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland

Decontamination methods for cleaning up contaminated soil

- Biological processes
- Thermal processes
- Soil washing processes
- Soil air suction processes

2E TEACHING EQUIPMENT FOR THE TOPIC OF SOIL

HM 145 Measurement of Ground Water Profiles

Principle of operation

The experimental unit HM 145 facilitates basic measurements in the area of infiltration action on rainfall and ground water flows.

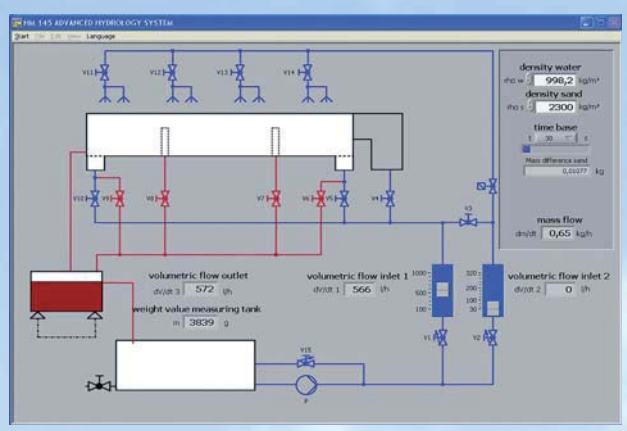
The experiments are performed in a stainless steel tank filled with sand, which is equipped with a sprinkler system so that rain can be simulated. The tank contains two wells for carrying out experiments for lowering the ground water. There are a total of 19 measuring points, whose measured values can be read on a tube manometer.

The experimental unit also provides for the investigation of rivers and surface water with transport and deposit of sediment in connection with flow obstacles.

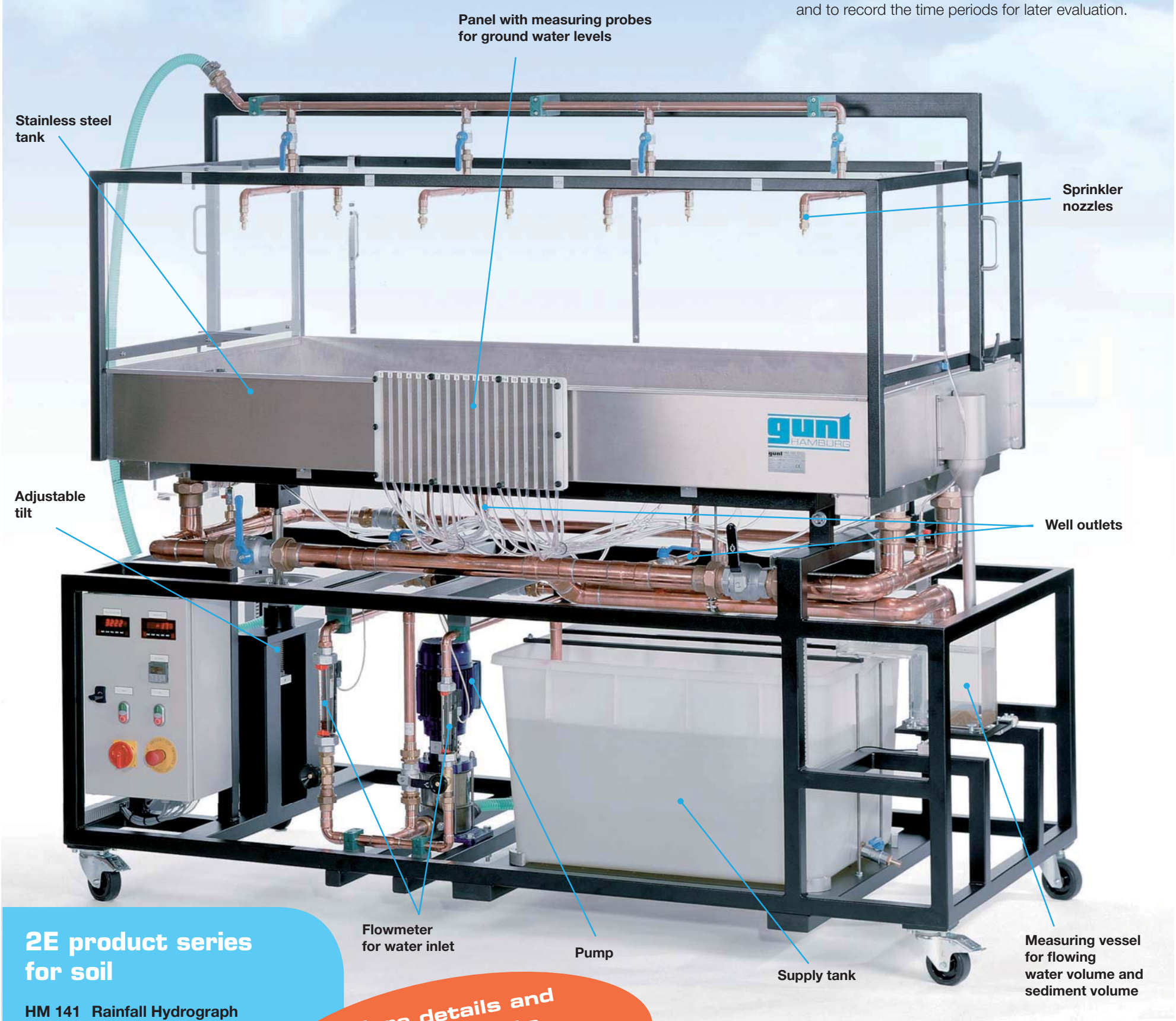
Learning Objectives/ Experiments

- Effect of the permeability and storage capacity of soil
- Water infiltration
- Natural draining via wells or drainage
- Flow behaviour and sediment transport in rivers

Measured data collection



The inlet and outlet volume flows and the amount of sediment can be continuously measured. The software can be used to represent this data in a system diagram and to record the time periods for later evaluation.



2E product series for soil

HM 141 Rainfall Hydrograph

HM 145 Measurement of Ground Water Profiles

HM 165 Permeabilty and Storage Capacity of Soils

HM 167 Ground Water Flow

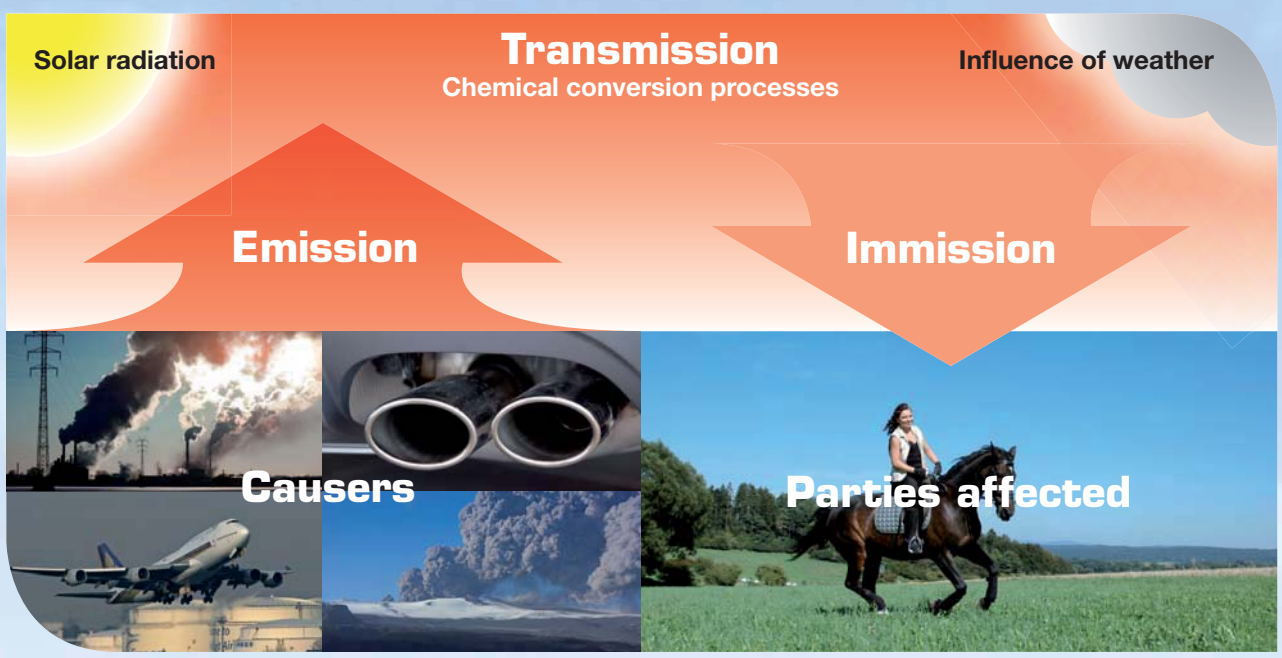
HM 169 Flow in Permeable Media

More details and technical data can be found under www.gunt2e.de

2E a division of gunt HAMBURG

Immission protection

Protecting man and nature



Because of its fundamental importance to life for man and nature, the 2E learning structure contains a separate series of units relating to the topic of air.

Air pollutants are created e.g. by combustion processes for heating and transport, but also by industrial processes. Emission is understood to be the discharge of pollutants. Before these pollutants affect man and the environment (immission), solar radiation and other weather effects in the atmosphere may change the properties of the substances.
Such pollutants can be present in our breathing air either in the form of gases or particles.

The effect, concentration and duration of exposure to the pollutants can cause varying adverse health effects.

Components of the air we breathe

Air is a mixture of different gases. The main components are nitrogen (78%) and oxygen (21%). Air also contains low concentrations of noble gases, carbon dioxide and natural source gases. Pollutant-free air at the right temperature and humidity, and also sufficient oxygen, is essential for the respiration and health of man, animals and plants.

Air pollutants and permitted limit values

(in conformity with the Ordinance on Immission Values - 22nd Federal Immission Protection Ordinance)

Benzene	**5 µg/m³**
Lead	**0.5 µg/m³**
Particulate matter	**40 µg/m³**
Carbon monoxide	**10 mg/m³**
Ozone	**180 µg/m³**
Sulphur dioxide	**125 µg/m³**
Nitrogen oxides	**40 µg/m³**

Basic methods of air pollution control

The ideal scenario would be to avoid the release, that is the emission, of air pollutants. Often the work and costs required for implementing special separation processes can be significantly reduced by optimising the processes responsible for pollution.

Effect of air pollutants

Air pollutants are dispersed in the atmosphere and enter the ecosystems in various ways. They affect flora and fauna differently and thus have an effect on biodiversity.

Deposition of sulphur and nitrogen compounds in soil causes acidification. As a result, there are changes in the amount and composition of the available nutrients. Plants and plant communities which are reliant on neutral soil conditions have no chance of survival in the long-term given the current level of emissions. Whole ecosystems are lost, reducing the variety of ecosystems.

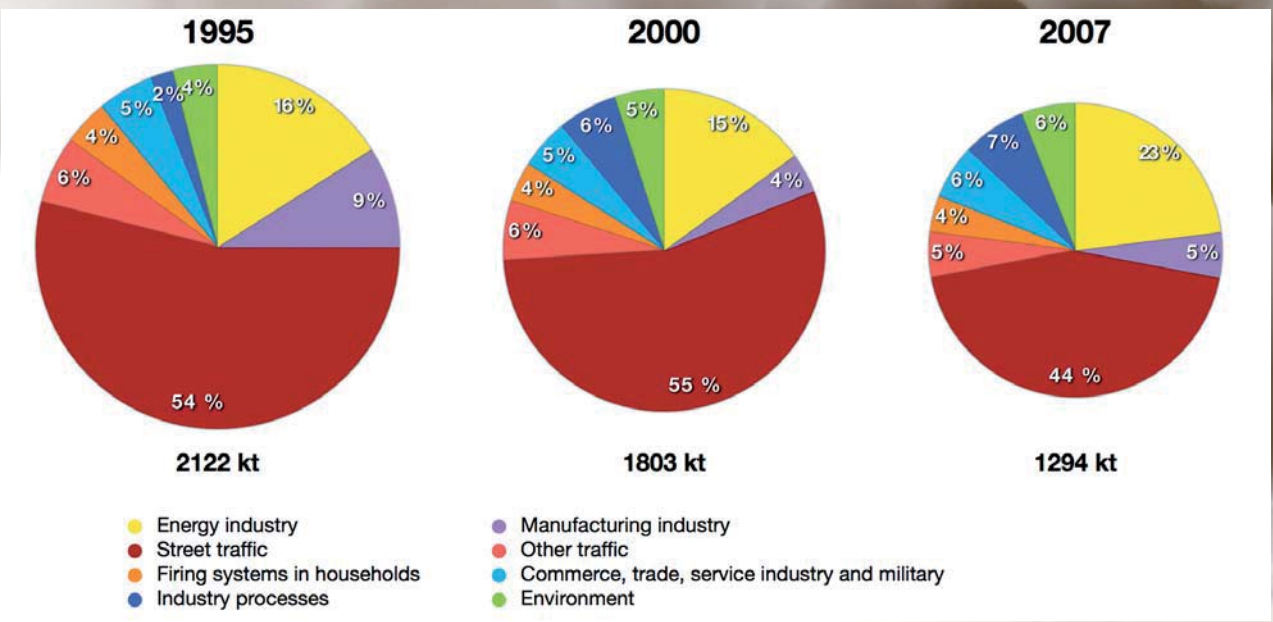
In Germany there has been a significant drop in the level of air pollutants in the past 20 years. Today, significantly fewer pollutants are released into the air thanks to the introduction of filter and flue gas cleaning systems in power stations and industrial plants, the use of lower-emission fuels and, modern catalysts and fuels. Moreover, European-wide limit values for sulphur dioxide, carbon monoxide, benzene and lead are now no longer exceeded in Germany.

Separation processes for gases

- **Condensation**
- **Adsorption**
- **Absorption**
- **Extraction**
- **Rectification**

Separation processes for dust and aerosols

- **Use of centrifugal forces (cyclone)**
- **Separation by particle density (washing tower, rotary atomiser)**
- **Separation by particle size (cloth filter)**
- **Separation by electrostatic attraction**



Decline of nitrogen oxides emissions in Germany in kilotonnes

2E TEACHING EQUIPMENT FOR AIR POLLUTION CONTROL

CE 400 Gas Absorption

Principle of operation

Gas absorption or gas washing can be used for applications in which a gas component is to be removed from a gas mixture.

The trainer CE 400 demonstrates this process by the separation of CO_2 from an air mixture. Gas separation takes place in a packed column in the countercurrent. Water is used as the solvent. The water charged with CO_2 is guided in a closed circuit and regenerated again in the desorption column for re-use.

Learning Objectives/ Experiments

- Investigation of the absorption process when separating gas mixtures in a packed column
- Representation of the absorption process in an operating diagram
- Investigation of the variables influencing the effectiveness of absorption

More details and technical data can be found under www.gunt2e.de

CE 235 Gas Cyclone

Gas cyclones are used for the separation of particles from a gas flow. One area of application is the prefiltration from exhaust gases from power stations and waste incinerating plants.

Principle of operation

The air flow is artificially loaded with solid particles and fed tangentially into the cyclone at the top. In the cyclone, the air flow moves downwards as a rotating primary vortex.

The main separation process takes place in the primary vortex. Owing to the centrifugal forces and the difference in density between the air and the solid, the coarse solid particles move towards the wall. They slide down the wall and are collected. At the bottom of the cyclone the vortex is reversed. In the middle of the cyclone it moves as a secondary vortex back up towards the immersion tube.

The fine particles which are smaller than the separation size are ideally discharged from the immersion tube at the top with the secondary vortex. This fine material is separated out of the air flow by a filter. The separation size defines the theoretical boundary between the fine and coarse material.

Learning Objectives/ Experiments

- Influence of solid content and the air flow rate on
  - pressure loss at the cyclone
  - degree of separation
  - separation function and separation size

Switching to a recycling economy

It must be assumed that the waste to be treated contains diverse material combinations and processing states. The answer to the question of recycling or landfill must of course consider economic and ecological aspects.

In principle, to achieve sustainability the aim must be to use materials and processing methods which allow for closed material cycles with minimum energy consumption during production.

In Germany dumping untreated substances has been forbidden since June 2005.

Depending on the composition or causes of waste, different mechanical, chemical and biological processes are used for treatment.

The physical-mechanical separation processes used are based on the following material properties:

- Form
- Density
- Surface properties
- Magnetic and electric properties
- Colour and reflection or infrared spectrum

Methods of mechanical waste treatment

- **Crushing**
- **Classification**
  (separation by particle size)
- **Sorting**
  (separation by material properties)
- **Compression / agglomeration**
  (volume reduction)

Climate protection through recycling

Germany is the world's leader in recycling waste materials. This especially applies to reusable materials, which are relevant from a climate point of view. The highest amount of CO_2 is saved by recycling paper, cardboard and cartons and waste wood. Similar savings are achieved by recycling light-weight packaging materials and by generating energy from residual waste in waste incinerating plants.

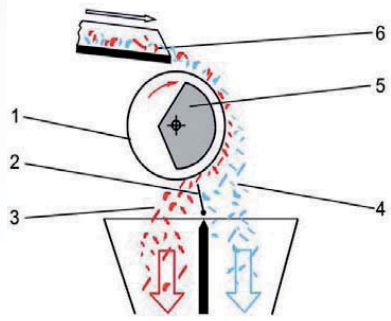
Since in Germany most of the waste streams are controlled with regard to their recycling characteristics, an effective way of reducing greenhouse gas emissions is to improve the related technical processes.

CE 280 Magnetic Separation

Magnetic separation is a method of sorting which utilises the magnetisability of components of a solid compound to separate ferromagnetic particles.

Principle of operation

The solid compound to be separated is fed into the feed hopper. A vibrating trough conveys the compound onto a rotating, non-magnetic drum.
Inside one area of the drum there is a fixed permanent magnet. Non-magnetisable components drop into a collector tank due to gravity. Magnetisable components adhere to the drum in the area of the magnet, are carried along and drop into a different tank as soon as they are beyond the magnetic zone.



Fundamental principle of drum-type magnetic separators

1. Rotating drum (non-magnetic)
2. Adjustable separating panel
3. Magnetisable components
4. Non-magnetisable components
5. Permanent magnet
6. Feed material

Learning Objectives/ Experiments

- **Learning the fundamental principle and the method of operation of a drum-type magnetic separator**
- **Efficiency of separation process dependent on**
  – mass flow of feed material
  – mixing ratio of feed material
  – type of feed material
  – drum rotation speed
  – position of permanent magnet
  – position of separating panel

2E TEACHING EQUIPMENT APPLICATIONS

Effective in use

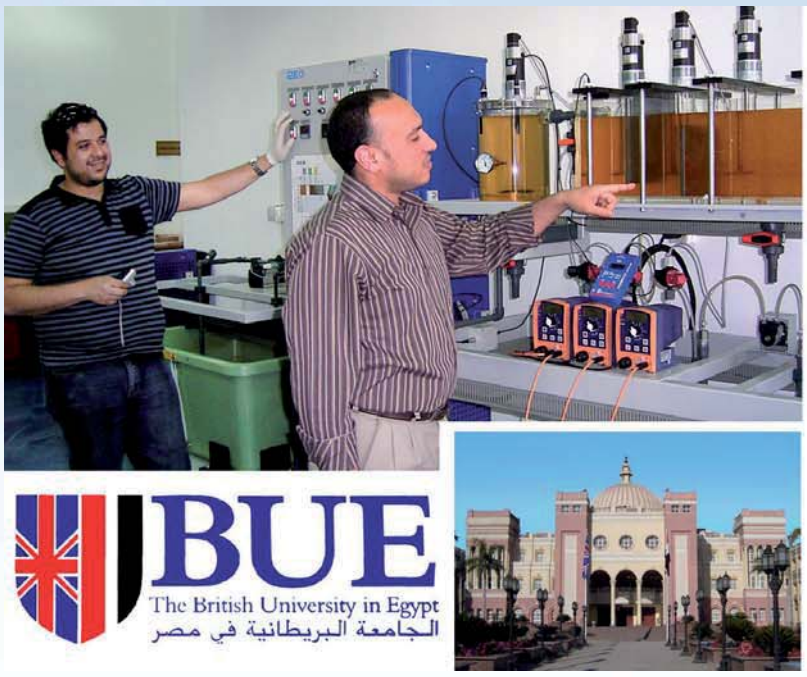
Fachhochschule Münster University of Applied Sciences

At the Münster University of Applied Sciences, units from the 2E product range are used in several courses of studies. In the Department of Chemical Engineering, CE 640 "Biotechnical Production of Ethanol" is used in a two-day internship for future industrial engineers.

In the Department of EGU, complete training is offered in the fields of future-oriented and resource-conserving energy, building and environmental technologies. Different 2E units are used in the lab practicals. These include

- **ET 102 Heat Pump Trainer**
- **CE 579 Depth Filtration**
- **CE 583 Adsorption**
- **CE 587 Dissolved Air Flotation**
- **CE 702 Anaerobic Water Treatment**

Training at the British University in Cairo



A member of staff at the British University in Egypt (Cairo) explains the operation of CE 586 Precipitation and Flocculation.

Training with 2E units

We are happy to offer you competent training for all units in the field of Energy & Environment. Please contact us to discuss details regarding content, scope and dates.

The instructional material

For many of our 2E units we offer a comprehensive range of instructional material to help you with getting started and preparing teaching and lab exercises.

The detailed instructions contain:

- **Explanation of the basics**
- **Description of the unit(s)**
- **Reference experiments conducted**
- **If applicable, the manufacturer instructions for integrated components**

The materials are delivered in printed paper form in a folder and also as PDF files on a CD.

Sustainable Engineering in the 2E Team

We are continually working to improve our existing products and to complete the range of products.

For example, a biogas plant is in preparation for the field of biomass. For the topic of energy efficiency the development of a cogeneration unit in lab format is planned. The use of a fuel cell is intended.

Our main source of suggestions comes from our exchange with customers and also by continuously reviewing the latest curricula and technological developments.

The main course contents are based on the concepts of **Sustainable Engineering**, that is, taking into account sustainability in all energy and material flows under review.

The focus on 2E main topics enables us to ensure that the learning contents of individual units are optimally coordinated with one another.

In the development of new 2E units years of didactic experience in the preparation of technical course contents is of key importance.

Visit our website
www.gunt2e.de

Imprint

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10.2010