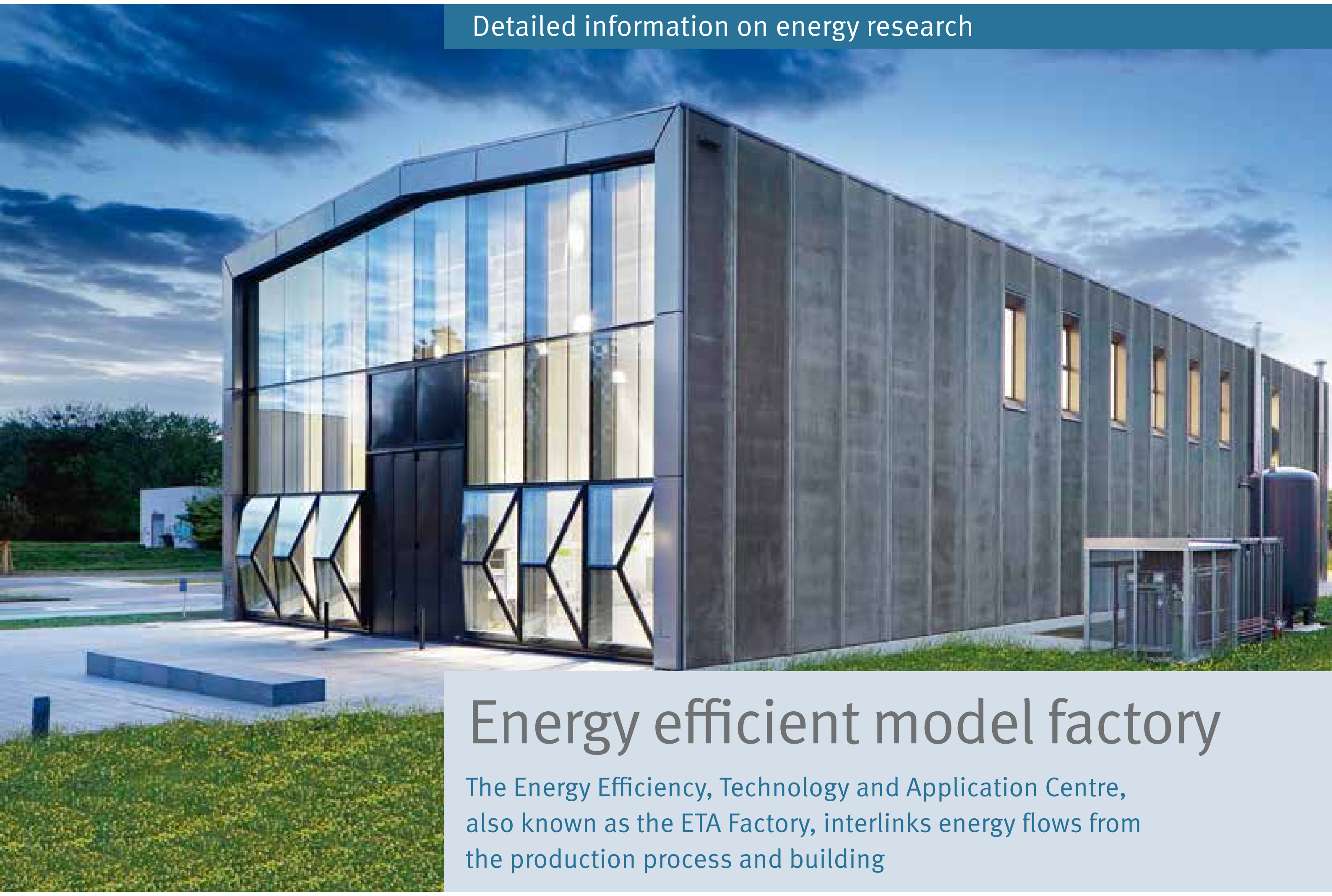
Projektinfo **03**/2018

Detailed information on energy research



Energy efficient model factory

The Energy Efficiency, Technology and Application Centre, also known as the ETA Factory, interlinks energy flows from the production process and building

BINE Information Service

A multi-functional, multi-networked factory in every respect: The ETA Factory on the campus of the Technische Universität Darmstadt is a research project, large-scale demonstrator and place of learning. It networks the building envelope and industrial process chain across technologies and disciplines in individual and integrated solutions, thus increasing the energy efficiency of the overall system. Shifting the system boundaries between machines and the building creates economically realisable energy savings of up to 40 per cent relative to conventional factories.

36 project partners from science and industry are working to optimally network the energy and material flows in the factory of the future. The Institute for Production Management, Technology and Machine Tools (PTW) at TU Darmstadt is coordinating this interdisciplinary team from the mechanical and civil engineering, architecture, electrical and communication technology as well as supply engineering fields. Industrial working groups are supporting the implementation of the research results into operational, production engineering-based practice. ETA stands for Energy Efficiency, Technology and Application Centre. In engineering sciences the Greek letter „eta“ refers to efficiency, a key indicator of energy efficiency.

Unlike previous factory halls, the building for the ETA Factory is not just a shell for the production facilities: the machines and building are energy efficiently interlinked while the energy flows are optimally harmonised in the production processes and building as well as in the supply and building technology. The researchers are using a production process chain from metal processing to

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demonstrate how a factory can work in a holistically energy-efficient manner. In addition to researching tomorrow's energy- and resource-optimised industrial production, the multifunctional research factory serves to network and exchange knowledge between researchers and users. It is a learning environment for industry and teaching that supports the transfer of knowledge into practice.

Understanding and optimally using the energy system

The factory's design was aimed at reducing the energy consumption and at the same time increasing the load flexibility. For the researchers, the challenge was to use the right form of energy in the required quantity at the right time and in the right place. At the same time it is important to prevent excess capacities in the infrastructure, production, distribution, storage and conversion. In the ETA Factory they show which savings can be achieved if the factory's energy system is understood holistically. Savings were achieved by optimising the:

- production machines and cross-sectional technologies in mechanical engineering
- technical building services equipment and supply technology
- building envelope, facades and structure
- monitoring, energy data management and mining through adopting „Industry 4.0" approaches
- load flexibility and control optimisation
- simulation approaches for planning and operating production facilities

The savings successes are evident for each of the fields of action, such as the processing and cleaning of the workpieces as well as the use of the building and the system control management.

Energy-efficient machining

The machine tools used in the factory (machining centre, vertical turning machine, vertical grinding machine) are a fifth more energy efficient than reference machines. This was achieved by measures for all peripheral loads, including variable-speed hydraulic power units and a needs-led supply of cooling lubricant, whereby the machining parameters defined by the process were retained.

In addition, the cooling system and the use of inevitable waste heat have been improved. For example, the motor spindle for a lathe converts about one fifth of the electrical energy supplied into heat. Decentralised cooling enabled more than 40 % of the waste heat to be dissipated and used for other processes (Fig. 2).

When cooling the grinding machine, the decentralised compression chiller was replaced by a newly developed heat exchange module that is integrated into the factory's central cooling network. The fluid-bound heat dissipation also reduces the heat input into the production hall, which in turn reduces the energy required for air conditioning.

Waste heat utilisation in cleaning machines

Before the next processing step, the workpieces are cleaned. The cleaning systems are also integrated into the central heat supply systems. These use waste heat from the machine tools by heating the cleaning bath in conjunction with heat pumps. The researchers insulated the cleaning machine according to the „thermos flask principle". This reduces the heat required for bath heating during the cleaning process by up to 29 %. The potential for optimisation amounts to 15 % based on the total energy requirement of the machine. This also reduces the cooling requirement of the production facility and the sound power level drops by around 9 % compared with non-insulated systems.

Fig. 1 *In the ETA Factory, the production machines and building are networked energy efficiently and unavoidable waste heat continues to be used in the system.*

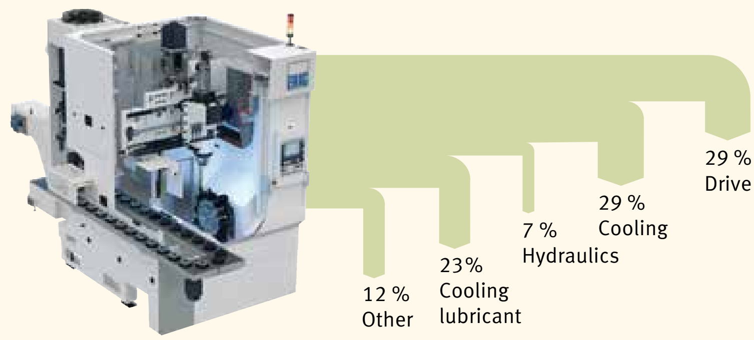
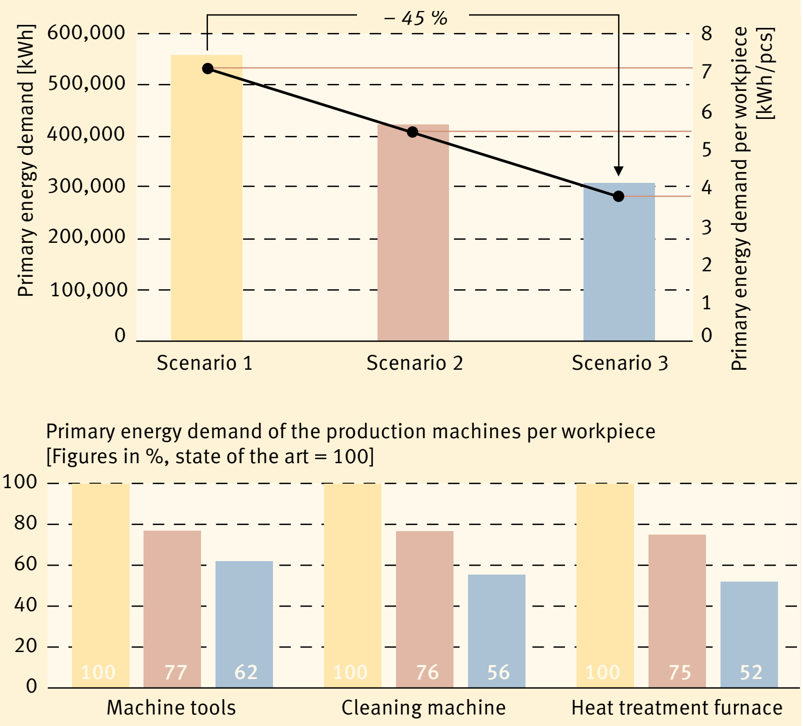


Fig. 2 *Where the deployed energy flows: Active power requirement of a lathe.*

Recording and optimally regulating energy flows in the factory

The energy-based networking of the subsystems in the ETA Factory requires an intelligent control system that serves the various energy converters and accumulators as well as numerous pumps and valves. To optimise this the researchers developed tailor-made design tools for the factory planning. With simulation experiments, they can plan optimal operating strategies and determine the effects on the total electrical and thermal energy consumption of the factory.

In addition to optimising energy flows in production, energy costs can be reduced very effectively. The ETA Factory with its information technology-networked infrastructure represents a versatile test field for Industry 4.0



The three scenarios are based on the following assumptions
- *17 production shifts per week / 8 h production*
- *Utilisation of production facilities: Machine tools 70 %, Cleaning machine 40 %, Heat treatment furnace 80 %*
- *Primary energy factors: Electricity 1.8; Natural gas 1.1*

Scenario 1 – State of the art
- *Standard machines*
- *Cooling using compression refrigeration*
- *Heat generation from electrical energy*

Scenario 2 – Energy efficient machines
- *Individual measures implemented at the machine level*
- *Heating of heat treatment system by natural gas recuperation burner*

Scenario 3 – Energy efficient machines in networked production
- *Thermal networking of the furnace and cleaning machine*
- *Cooling of the furnace and machine tools through the building envelope*

Fig. 3 *Above: Primary energy demand of the ETA factory and per workpiece; Below: Comparison of the primary energy demand of the individual production machines per workpiece, comparison of the state of the art and two efficiency scenarios*

applications: innovative control and optimisation procedures can be tested here at the component, plant and system level. Follow-up projects will develop solutions to optimise the costs in real time. These include a model-based predictive control system that is constantly improving with the help of artificial intelligence.

The energy-optimised building envelope in the process chain

The building envelope consists of precast concrete elements that are traversed with plastic capillary-like piping and thereby thermally activated. A new, ultralight foam concrete is used for thermal insulation. The building structure is almost completely recyclable. The hollow, pre-stressed concrete floorboards for the prefabricated floor slabs also act as an air duct network through which temperature-controlled supply air is fed. This eliminates the complex installation of ventilation ducts that would otherwise be required. The networking of buildings and production enables the utilisation of excess thermal energy from the air conditioning machine processes: the thermally activated inner and outer surfaces of the building envelope act as large heating and cooling surfaces.

Kinetic energy storage device

In the ETA Factory, a new type of flywheel has been installed which, as a kinetic energy storage device, compensates for fast, powerful load fluctuations in the milliseconds-to-seconds range. Kinetic energy storage devices provide load-smoothing and enable the factory's connected load to be reduced – both of which help to reduce system perturbations caused by the factory and to increase efficiency at the power grid level. If the functionality is taken into account when planning the factory's in-house microgrid, grid connection transformers, for example, can be made smaller and their efficiency increased by more constant utilisation. In addition, the kinetic energy storage device increases the network quality of the factory's microgrid.

Louvres integrated in the insulating glazing in the south facade deflect the incident sunlight far into the building: the daylight is optimally used, controlled as required and supported by dimmable LED lighting in the hall.

Achievable energy savings in the factory

The holistic approach adopted by the ETA Factory enables additional 15 to 20 % energy savings in addition to optimising individual components. The researchers compared the energy consumption of conventional factories with two other scenarios (Fig: 3). In factories with energy-efficient machines in networked production, the primary energy consumption is up to 45 % lower than in conventional factories.
By way of example, some of the data on the achieved consumption reductions are listed here:
- In machining, more efficient machine technologies, such as for hydraulic pumps and refrigeration, can achieve more than 50 % energy savings. Further savings can be achieved by recovering waste heat from the cooling of machines and cooling lubricant.
- When heat-treating workpieces, significant savings on nitriding gas and fuel gas are possible through changed process sequences and the recovery of waste heat. In the ETA project, more than 20 % of the natural gas needed for the hardening process was successfully saved without additional consumption elsewhere.
- New processes and additives also enabled workpieces to be cleaned considerably more economically before subsequent processing steps, with savings ranging between 25 and more than 65 % depending on the measure.

The thermal exchange between the building, building technology and process chain enabled, by means of an electric heat pump, vacuum-superisolated stratified storage tanks and optimisation of thermal networks, considerable savings of around 27 % to be achieved compared with individual measures.

Energy-efficient and grid-supportive factory

As a model factory of the future, the ETA Factory works flexibly and energy efficiently links machines and the building. Researchers at TU Darmstadt are continuing to develop this concept of energy- and resource-efficient production in the PHI Factory project: here they are investigating how they will need to adapt components and equipment as well as the factory's overall energy system in order to operate production flexibly, both in an energy-efficient and dynamic energy market. They are also developing and testing concepts on how the industrial sector can help stabilise the power grid in future. The joint project, which was launched at the end of 2016, involves three institutes from TU Darmstadt as well as two smaller and four large companies. Through flexible production and flexible management of the electrical factory network, the intention is to control the energy use in such a way that it is possible to increase the energy efficiency across systems and smooth out fluctuations between the electricity supply and demand.

The researchers are activating previously unused potential for increasing the energy flexibility in production plants and industrial processes and are supplementing this with different storage solutions. They are upgrading the corresponding production processes and systems in order to provide system-relevant network services cost-effectively. In addition to goods production, the factory can therefore support the local distribution network by smoothing peak loads, dynamic reactive power compensation, increased self-consumption and the provision of control power. The researchers are also providing the PHI Factory with standalone capability – it will then be able to run for up to one hour in emergency mode, whereby important tasks will be prioritised. The new technology and management systems will enable energy to be deployed in a targeted and precisely timed manner – an important step on the route to achieving an "Industry 4.0" industrial revolution that is compatible with Germany's energy transition.

Project participants

- **Management of the joint ETA Factory project:** Technische Universität Darmstadt, Department of Mechanical Engineering, Institute for Production Management, Technology and Machine Tools (PTW), Prof. Dr. Ing. Eberhard Abele, info(at)ptw.tu-darmstadt.de
- **Energy controlling and control of energy flows:** Bosch Rexroth Aktiengesellschaft – DC/PJ-GoGreen, Lohr
- **Energy-efficient machining processes:** EMAG Maschinenfabrik GmbH, Salach
- **Energy- and media-efficient heat treatment:** IVA Schmetz GmbH, Werk Dortmund
- **Energy-efficient workpiece cleaning:** MAFAC – Ernst Schwarz GmbH & Co. KG, Alpirsbach
- **Thermal interaction of the factory building, building technology, process chain:** Bayerisches Zentrum für Angewandte Energieforschung, e. V. – Bereich Energiespeicherung, Garching b. München
- **Dissemination of research results for the ETA Factory:** Technische Universität Darmstadt

Links and literature (in German)

- TU Darmstadt. PTW (Hrsg.): ETA – die Modell-Fabrik, Vernetzte Energieeffizienz im System, Darmstadt, 2018
- ETA-Fabrik | www.eta-fabrik.de
- PHI-Factory | www.phi-factory.de
- Energieeffizienz-Netzwerk ETA-Plus | www.netzwerk-eta-plus.de
- Forschungsnetzwerk Energie in Industrie und Gewerbe, Forschungsfeld Fertigungstechnik www.forschungsnetzwerke-energie.de/industrie-und-gewerbe/forschungsfelder/fertigungstechnik

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