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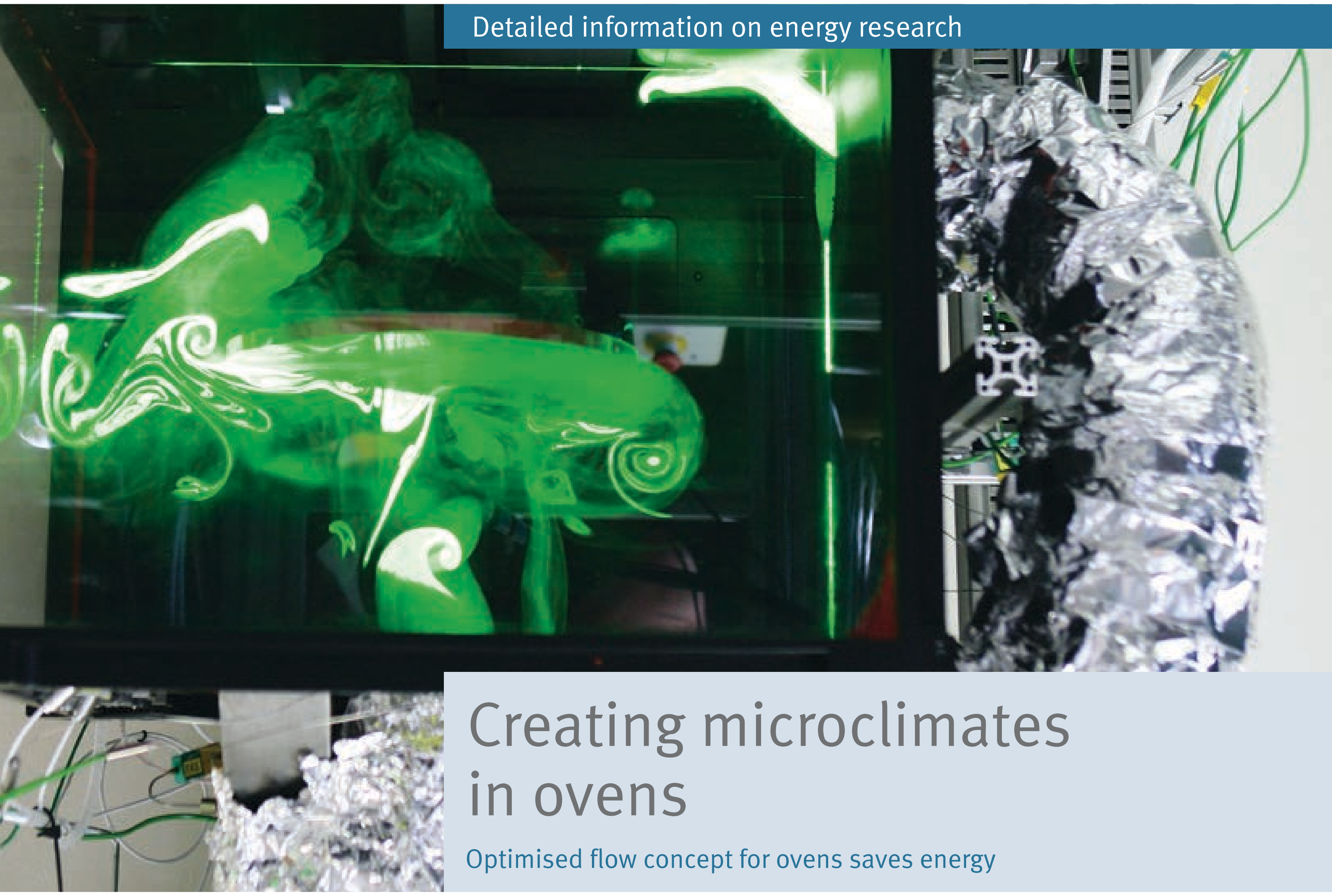
Detailed information on energy research



Creating microclimates in ovens

Optimised flow concept for ovens saves energy

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Fan-forced or convection ovens can be found today in many households. They work very efficiently if they are used for longer baking or roasting processes and are fully loaded. However, the devices are not optimised for preparing snacks or small dishes with a short cooking time. In the "ecoBack" project, researchers are investigating how a microclimate adapted to the food can reduce the energy requirement.

In modern ovens, heated air circulates evenly throughout the oven space. It ensures that roasts brown on all sides without burning on one side. Cakes can even be successfully baked when several levels are used. However, the consistent heating causes unnecessarily high energy costs when preparing small quantities of food – particularly if the food is no longer being cooked but only needs to be heated up. For example, it costs more than half a kilowatt-hour of electricity to "just" heat up a frozen pizza. With the increasing number of single households, a greater demand for convenience and fewer family meals being held together, ovens are increasingly being used in such ways.

In collaboration with the Institute of Mechanical Process Engineering at Stuttgart University, researchers at the E.G.O.-Group – which is one of the world's leading suppliers to home appliance manufacturers – are pursuing the idea of no longer warming up the entire oven space for snacks. Instead a sophisticated hot air flow creates a microclimate around the food that enables the heat energy to be specifically targeted at the food. The concept enables systems to be developed that heat, dry, defrost, keep warm or bake food more energy efficiently and quickly. In addition, the researchers are confident that such a technique can also be used to solve other heat treatment tasks such as drying coated parts or thermal surface treatment.

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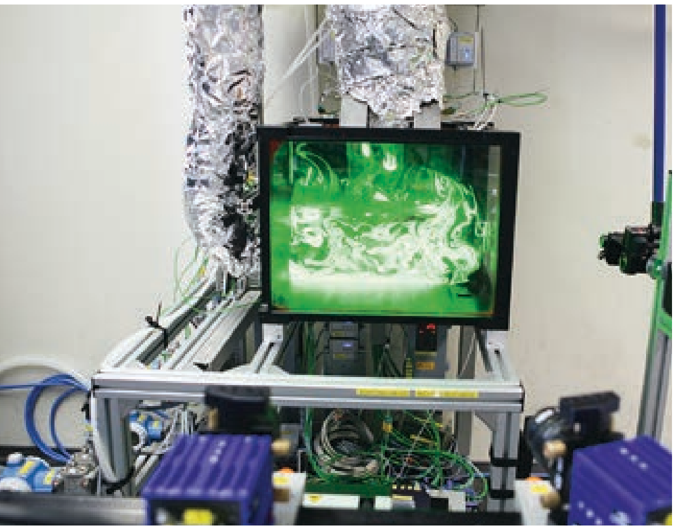

Fig. 1 *Flow concepts are tested in the laboratory oven*

Baking pizza in the computational model

The preparation of a frozen pizza provided the researchers with a reference task for numerous computer-based simulations and practical experiments. Since there are a variety of ways to feed hot air around such a body, several versions were investigated as shown in Fig. 3. The scientists compared the various flow concepts in comprehensive simulations. For this purpose they used a steady-state CFD simulation model that depicts the actual heat transfer. Based on analytical solutions and empirical data, a model was developed for relevant flow and heat transfer phenomena such as convection, conduction and radiation. A steady-state simulation yielded significantly faster results than an unsteady simulation and without any perceptible loss of accuracy. This enabled configurations to be calculated in only around three days instead of two weeks.
In each case a sample was simulated with the geometry of a frozen pizza. To simplify the boundary conditions, the temperature of the sample was fixed at a constant 0 °C. The inflow temperature of the air was 190 °C. For a direct comparison, the researchers also simulated the flow form for conventional ovens. This therefore enabled them to compare their results with the heating technology that currently has the highest energy efficiency available on the market.

Pizza in a hot air bell

A flow concept where an impact jet hits the food from above, and the air in the lower oven space flows in laterally, proved particularly promising (Fig. 2). This corresponds to a combination of the flow concepts 1, 2 and 5 from Fig. 3. The air is drawn out again at the oven ceiling. The inflow rate of the lateral air jet must constantly adapt to the changing conditions during the heating of the oven so that the lower air jet, under the influence of the natural uplift, precisely hits the food. With this flow concept, the pizza is enveloped in a kind of bell of flowing hot air. The hot air is kept as far away as possible from the oven walls, which is why the external losses are low. Especially the lower half of the oven remains relatively cold. This and two other flow concepts were modelled experimentally in a laboratory oven.

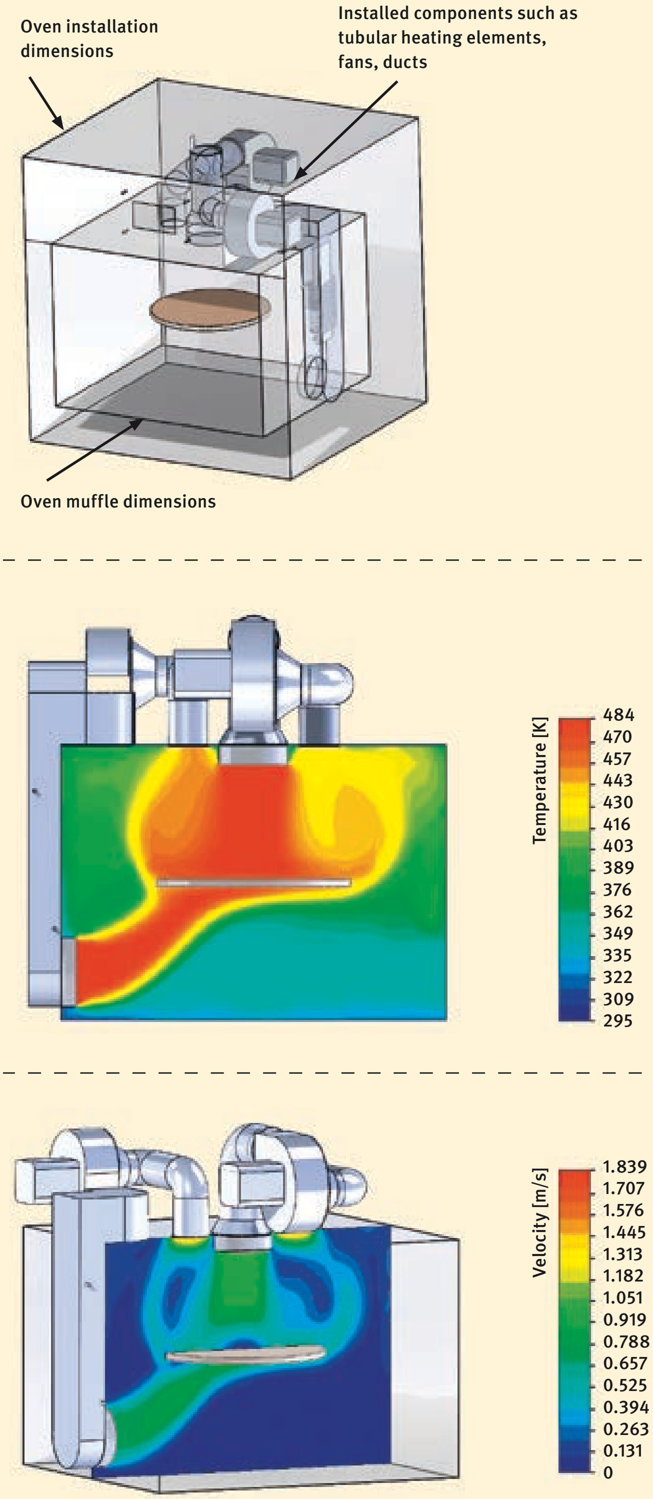

Fig. 2 *Simulation results for the temperature and flow distribution in the demonstrator*

Experiments using a laboratory oven

For the practical testing, the researchers built a laboratory oven with measuring and regulation technology as well as a sophisticated control system. This made it possible to regulate the temperature and volume flow at the air intakes not only in terms of fixed values but also as a function of process variables such as the interior temperature or the temperature of the sample. This enabled micro-climatic conditions to be automatically created around

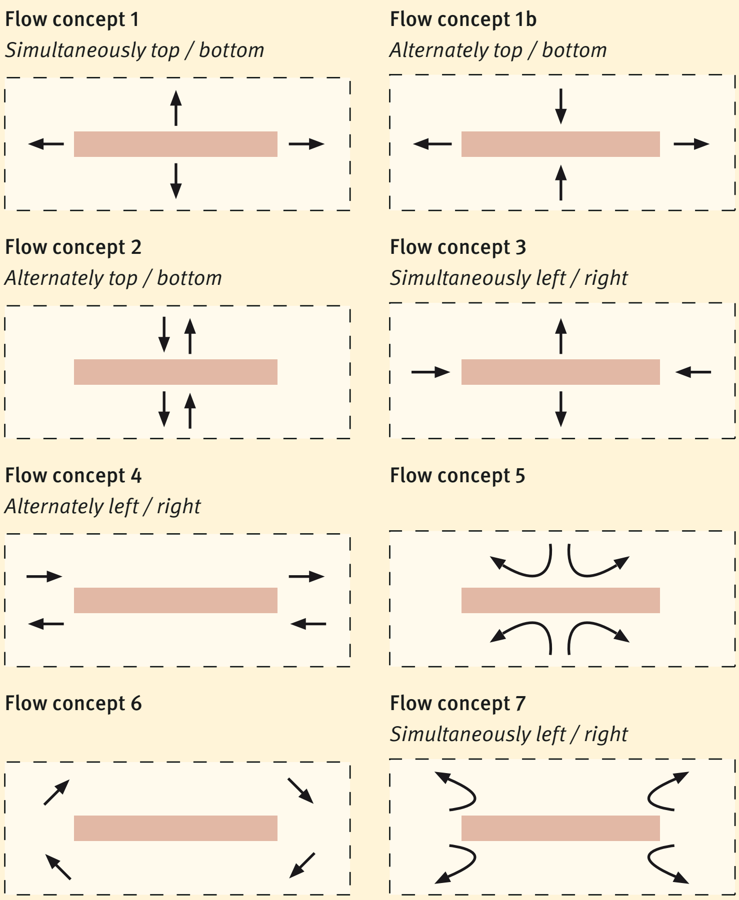

Fig. 3 *Flow concepts to generate a microclimate*

Fig. 4 *The demonstrator already has the standard dimensions of a commercial built-in oven.*

the sample. An automatic function also enabled fixed, time-controlled processes to be run. This ensured that the experiments could be reproduced.

A PIV (Particle Image Velocimetry) measurement system determined the flow velocities in the measuring chamber, which were resolved both spatially and temporally. With this non-contact measurement method, so-called tracer particles are added to the airflow. High-speed cameras capture the movement of these particles in a laser sectional plane. Based on the data, the flow field is then calculated using software.
The results from the experimental tests closely matched the simulations. This enabled the respective flow concepts to be validated in the laboratory. In a next step, the research results were then transferred to a demonstrator whose dimensions are based on a real oven.

Demonstrator shows savings potential

At the beginning of 2013 the research team completed the demonstrator with standardised oven dimensions (Fig. 4). They measured and optimised the flow concepts using similar criteria as in the laboratory oven. In the final tests the demonstrator proved that snacks and small dishes can be prepared much more energy efficiently than before.
The demonstrator was specially optimised for frozen pizza and cooking products with a similar geometry. For example, it required around 40% less energy to cook a frozen pizza than a standard state-of-the-art oven.

From research to the product

Dr Michael Riffel, the head of the project, sees good opportunities for further developing the new concept for use in commercial ovens: “In the next step we will be adjusting the flow and heating concept to other cooking products.” The researchers then want to carry out an energy label test according to the EN 60350-1 standard. “It would be possible to combine intelligent ovens of the future with this energy-efficient heating concept,” says Riffel and adds: “Sensors in the oven space would then gather the necessary information that can be used to select the respectively suitable automatic program.”
However, the scientist’s long-term vision goes even further: “I could also imagine the development of a completely housing-free oven. The food is placed on a support ‘in’ the oven space and is then directly impacted with hot air using jets or similar devices. This could save both raw materials in the manufacturing process as well as energy in operation.”
The technology can also be used for all thermal processes where targeted heat is only required at certain points. These include, for example, industrial drying or surface processes.

Lowering power consumption in households

Private households are responsible for about a quarter of German electricity consumption, although this figure has slightly reduced since 2006. A study by the German Association of Energy and Water Industries (BDEW) and the HEA – Fachgemeinschaft für effiziente Energieanwendung e. V. has analysed the consumption patterns and potential savings.
The growing number of small households is tending to increase the total electricity requirement. Persons living alone consume an average of 2,050 kilowatt-hours of electricity per year. The per capita consumption in a 4-person household is 42 per cent lower. Noteworthy is the increase in consumption for consumer electronics and office equipment. This now accounts for a quarter of the private electricity consumption. In contrast, devices that are more energy efficient have considerably reduced the electricity consumption for cooling and freezing in the last 15 years. Less energy is also required for lighting.
Large electrical appliances have become much more energy efficient since the introduction of the Energy Label in the 1990s. In accordance with the European Union's Ecodesign Directive, refrigerators, freezers, washing machines and dishwashers rated in what was once the highest energy efficiency class, energy class A, can no longer be sold in the EU. The study comes to the conclusion that every household could save an average of 614 kWh per year if only large household appliances with the best energy efficiency class were used.

High efficiency gains through research

The efficiency of electrical appliances has significantly increased over the years through continual detailed improvements to all components. There have often been gains in efficiency when conventional technology has been supplemented or replaced with innovations.
A classic example is the heat pump dryer that first became available to private households in 1997. Approximately one in two dryers sold today works with a highly efficient heat pump.
Conventional dishwashers need electrical energy twice: for heating and drying. New devices with adsorption storage systems eliminate the heating process for drying dishes. This saves more than 20 per cent of the electrical energy.
New circulation pumps with particularly efficient, electrically commutated motors provide considerable potential for energy savings in basement boiler rooms. Replacing an old, unregulated heating pump can reduce the electricity bill by 200 euros a year.
LED lamps are increasingly replacing conventional and energy saving light bulbs.
With refrigerators with predefined installation dimensions, improved thermal insulation adversely impacts on the size of the interior space – unless highly efficient insulating materials are used. Vacuum insulation, for example, creates more space in the refrigerator.

Project participants

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Literature (in German)

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