

RESEARCH NEWS

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1 Eco-Computer with a natural wood look

Surfing for hours on the Internet consumes a lot of electricity and is harmful to the environment. However, a new ecological PC saves energy as it operates: It produces about 70 percent less CO₂ than conventional computers. As the first computer of its class, it obtained the "EU Ecolabel," the environmental label of the European Union.

2 Cost-effective production of infrared lenses

If visibility is poor, thermal cameras can warn drivers of people or animals on the road. Yet such devices have been very expensive – until now. An important step has been taken to manufacture them more cheaply. A new process will make the infrared lenses – a component of such cameras – up to 70 percent cheaper.

3 Minimally invasive building renovation

Renovation projects to improve the energy performance of residential buildings involve a lot of messy construction work. Researchers have come up with a new modernization concept that reduces on-site installation times. Prefabricated multifunctional window modules offer a more convenient alternative to the usual renovation methods.

4 Wind farms: A danger to ultra-light aircraft?

Airfields for ultra-light aircraft are typically constructed on level ground – and so are wind farms. However, do wind power plants generate turbulence that could endanger lightweight planes? A simulation can compute how these power plants influence aircraft at various wind speeds and wind directions.

5 Smart wireless power outlets

Many homeowners dream of being able to wash a load of laundry when the photovoltaic panels on the roof are delivering a maximum of electricity, even when they are not at home. A new Internet-enabled power outlet will soon allow users to control household appliances via their smartphone, and reduce their energy costs into the bargain.

6 Using wastewater as fertilizer

Sewage sludge, wastewater and liquid manure are valuable sources of fertilizer for food production. Fraunhofer researchers have now developed a chemical-free, eco-friendly process that enables the recovered salts to be converted directly into organic food for crop plants.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 60 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 20,000, who work with an annual research budget totaling 1,8 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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Eco-Computer with a natural wood look

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A work tool, a leisure activity resource, a personal assistant - computers are ubiquitous. Yet the environmental performance for today's computers leaves a lot to be desired: they rapidly become obsolete, typically contain toxic substances as flame retardants and have individual components that are difficult to recycle. Moreover, they consume plenty of power whose production, in turn, causes the release of CO₂ into the atmosphere.

Employees at the MicroPro Company in Ireland, working in collaboration with colleagues at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin, have engineered a wooden-frame computer with reduced environmental impacts. As the first computer of its class, the "iameco" (pronounced "I - am - eco") was awarded for the "EU Ecolabel," the European Union's environmental label. "This touch-screen PC has a very low energy consumption over the entire lifecycle of the unit - starting from production, through the use phase to its ultimate recycling," explains Alexander Schlösser, scientist at IZM. The carbon footprint is less than 360 kilograms CO₂eq over the full product life cycle, which is 70 percent less than a typical desktop PC with monitor. In addition, it can be easily recycled. Of the materials used, 98 percent can be recycled. Indeed, 20 percent of the computer can be recycled immediately - in other words, many parts and components can be reused for repairing other computers - such as parts of the wooden frame.

Heatsinks replace fans

But how is it possible to design such an environmentally-friendly PC? One example: to ensure that the processor does not overheat, a fan typically provides cooling to the PC. This kind of ventilation not only consumes energy, it also comes with an annoyingly incessant buzz. So, the fans were replaced with heatsinks, which convey the heat from the processor via copper tubes, called heat pipes. This fan-free design saves energy, and the computer is barely audible. The scientists also got creative with the display lighting. Instead of conventional lighting, LEDs illuminate the screen and improve its energy efficiency by 30 to 40 percent. The manufacturers reduced the hazardous materials to a minimum, and for the most part substituted halogenated flame retardants with chemicals that are less harmful to the environment. Over the long term, these halogenated flame retardants should disappear from all computers.

Since the eco-PC was designed with standard components, users can retrofit it anytime - for example, if more internal memory is needed. And if the computer were to crash, the users would benefit from the improved disassembly and modular design of the device. This enables the capability for easier repair and maintenance. Only those components will be replaced that are so severely damaged that they can no longer be repaired. The better maintenance option ensures a longer product life, and the easily conducted repairs ensure a high degree of environmentally sound engineering. In the

next stage, the manufacturer intends to expand the modularity of the computer so that after a few years, users can equip older computers with a new internal life. The “old” computer would then return to the latest state of the art – and would cost only half as much as a completely new PC. The employees at MicroPro and IZM want to continue collaborating in the future as well. At this time, they are jointly developing an environmentally-friendly wooden frame notebook.



The environmentally-sound touch-screen PC, iameco, is definitely out of the ordinary – indeed, it is made out of wood. (© MicroPro) | Picture in color and printing quality: www.fraunhofer.de/press

Cost-effective production of infrared lenses

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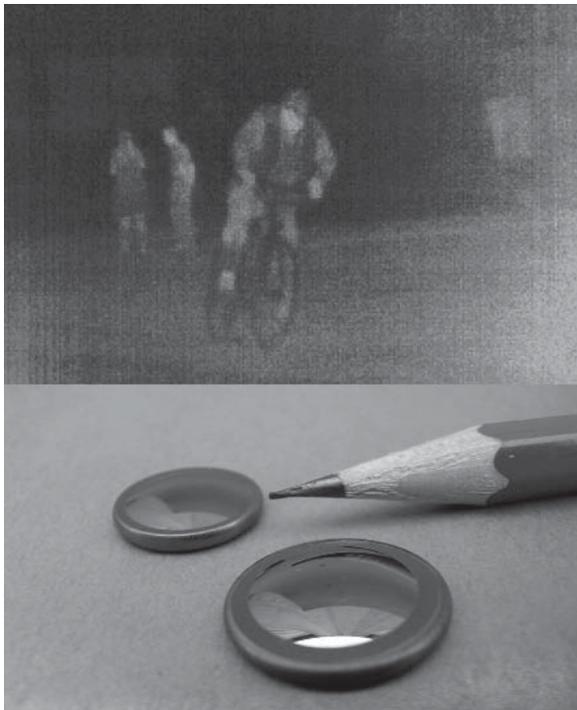
Rain pelts down on the roof of the car; it is difficult to make out anything in the pitch dark. Suddenly, a deer runs out of the forest and onto the road, but the driver cannot respond in time. When it comes to such dangerous situations, micro-bolometers constitute one way of “extending” the human eye and defusing such dangerous situations. They detect infrared rays – in other words, the heat emitted by a living creature – and in case of danger, warn the driver through an acoustic signal or a warning light. At about 2,000 euros, these devices are still quite expensive and are only being used in luxury-class vehicles.

Production costs drop by over 70 percent

Part for part, these devices should be getting more affordable. Researchers at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg are working on the infrared lenses that are in the cameras. “We have developed a production process for lenses that enables us to lower the costs of these components by more than 70 percent. Thus the prize for the micro-bolometer could be reduced,” says Dr. Helen Müller, scientist at IWM. Normally, the lenses are made out of crystalline materials like germanium, zinc selenide or zinc sulfide. The problem is that these materials are very expensive and can only be processed mechanically – it takes grinding, polishing or diamond turning to shape them into the correctly. Obviously this involves high processing costs. “Instead of crystalline materials, we use the amorphous chalcogenide glass. Its softening temperature – that is, the temperature at which it can be formed – is low. Therefore, we can form it using non-isothermic hot stamping,” says Müller. This process is similar to making waffles on a waffle iron. The researchers place the chalcogenide glass between two pressing tools which determine the form of the required lenses. Then, it is heated and formed between both pressing tools – the “waffle iron” is clamped together. After a few minutes, the glass is cooled again to below the softening temperature and removed. And thus, the lens is already perfect. In contrast to conventionally processed optics, it no longer has to be further refined. The lenses manufactured this way exhibit the same excellent optical imaging quality as those that are polished. To ensure that no glass remains attached to the tools, their surface is coated with anti-adhesive, non-stick coatings, similar to the Teflon coating on a waffle iron. The scientists now want to further refine the process towards cost-effective mass production.

The applications for micro-bolometers – and thus for cost-effective lenses – are not limited to the automotive sector. Imagine, for example, these devices assisting older people in their homes. If the senior were to fall, the bolometer registers this event and sends an alarm to relatives or neighbors through an optical or acoustic signal. In production halls, bolometers can oversee and monitor the production processes of various products, to ensure the necessary temperatures are maintained and warn employees

who are spending time in danger zones. In residential buildings, the devices could detect energy leaks, such as through unsealed windows or poorly insulated walls.



Above: Thermal image, taken with pressed lenses in a test camera. Below: Pressed lenses made of chalcogenide glass.
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Minimally invasive building renovation

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Surgeons commonly use minimally invasive techniques when operating in the abdomen. Instruments are inserted through a tiny incision in the abdominal wall, and the organs are visualized using an endoscope. This method is less stressful on the body than conventional surgery. A form of “minimally invasive intervention” could also be adopted by architects and builders, except that in this case the patients are buildings in need of upgrading to modern energy-efficiency standards. “The minimally invasive approach can be applied to the renovation of buildings, enabling their energy efficiency to be improved with a minimum of messy construction work,” says Michael Krause, a scientist at the Fraunhofer Institute for Building Physics IBP in Kassel. He and his research team have developed a system of multifunctional window modules that could be used as an alternative to the usual renovation methods that cause so much inconvenience to the building’s inhabitants. The “Prefab” project is funded by the German Federal Ministry of Economics and Technology (BMWi).

Normally, building improvement work to reduce energy consumption and CO₂ emissions is carried out by separate specialized contractors, including insulation and window installers, heating engineers, electricians, and plumbers. But these different tasks are often not coordinated, a situation that can result in construction defects and prolong the duration of the renovation project. “Meanwhile, the inhabitants of the building have to put up with all the noise and mess, especially if a new air-conditioning or heating system is being installed at the same time. Sometimes it is even necessary to wait for the apartments to be vacated before the renovation work can be started,” comments Krause. “Our multifunctional window modules enable on-site installation times to be shortened, considerably reducing the stress experienced by the tenants.”

Prefabricated building components

In addition to the actual window and window frame, the modules are equipped with a technical systems box and a surrounding insulation panel, consisting for example of a polystyrene-based composite system. The self-supporting units are inserted in the existing window opening from the exterior, and provide additional external insulation around it. An alternative version permits architects to use a solution consisting of a timber frame in combination with a mineral insulating material such as fiberglass or rock wool. The removable technical systems box is located under the window sill. It provides room for installing components such as heat exchangers, decentralized micro-pumps for heating-system control, air filters, and even power sockets, ventilation channels, or Internet cabling. Electrical wiring and water pipes are installed on the outside wall underneath the insulation panel and routed into the building through cutouts in the technical systems box. Numerous additional activities such as installing cable conduits and plumbing systems thus become superfluous. The entire unit, including the box, is delivered fully assembled by the window manufacturer, significantly reducing

the on-site installation time. Another advantage of installing all these components in an easily accessible box underneath the windowsill is that it simplifies maintenance. If repairs are necessary, any component can be retrofitted or replaced immediately. "By integrating heat exchangers and air circulation units in the renovation system, we can limit heat loss through the building envelope and ventilation. And by ensuring a high quality of workmanship, we can guarantee a perfectly airtight seal and avoid thermal bridges, in other words, no warm air can escape. All in all, the new system reduces energy consumption," says its designer, who adds: "Because the insulation panels are constructed as self-supporting units, they are strong enough to envisage equipping them with solar collectors or photovoltaic cells."

A demonstration version of the prefabricated, multifunctional window module is already available. It was manufactured by the institute's industrial partner Walter Fenster + Türen in Kassel. As the next stage, Krause and his colleagues at the IBP intend to test the window modules in situ, in the renovation of a real building: "In principle, they can be installed in many different types of building stock; we have decided to focus on multi-family residential housing dating from the 1950s."



The window module with its surrounding insulation is simply inserted in the existing window opening.

(© Fraunhofer IBP) | Picture in color and printing quality: www.fraunhofer.de/press

Wind farms: A danger to ultra-light aircraft?

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For a motorized hanglider or a one-seater weighing 300 kilograms: the business of flying by ultra-light aircraft is booming. That is also why numerous airfields are applying for the license to host these lightweight gliders. Most of these airfields are located on flat land, which is also the preferred terrain for wind power plant. However, these facilities could turn out to be a risk factor for aviators, especially when it comes to take-off and landing: On the one hand, the power plants “pilfer” the winds from the planes, because wind speeds aft of such facilities are considerably lower. If the aircraft fly in the region behind the rotor, then they will suddenly find themselves contending with an entirely new aerodynamic situation. On the other hand, rotors produce turbulence in the air that could equally interfere with the aircraft.

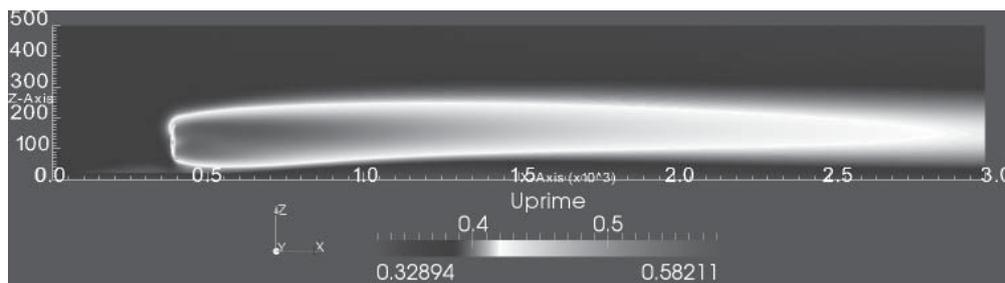
Simulation calculates turbulence

The extent to which wind turbines impact ultra-light aircraft is an especially pertinent question now at the Linnich-Boslar ULV Airfield, where a major wind farm is slated for construction in close proximity. The operator, BMR Windenergie, wants to be sure – prior to construction – that no risk imperils the aviators. On behalf of this company, researchers at the Fraunhofer Institute for Wind Energy and Energy System Technology IWES in Oldenburg developed a simulation that enables them to calculate what turbulence these facilities generate, how they alter wind speed and what influence these factors have on airplanes. “We conducted these simulations under a variety of scenarios,” says Dr. Bernhard Stoevesandt, head of department at IWES. “We simulated various wind directions, two different wind speeds and five different flight trajectories in which the plane is under the rotor’s sphere of influence for various lengths of time.”

Complex grid model

For the simulations, the researchers initially created a computer model of the ground and a wind profile of the surrounding area where the wind farm is to be built. A grid was placed over the model. The computer calculates how the power plants alter wind conditions and turbulence at various points on the grid. “The true skill is in the creation of the grid: Because the points on the grid where the computer makes the individual calculations must lie at exactly the right places,” explains Stoevesandt. The complexity of the simulation is enormous – the software must calculate the prevailing currents within several million grid cells that mutually influence each other. Other challenges consist in properly depicting the trail – that is, the turbulence and the change in wind speed behind the rotor – and determining how it affects the airplane. “To validate the simulations, the trail from actual wind energy plants was measured at various individual points behind the rotor, and the measurements compared with the simulations,” affirms Stoevesandt. “Each of the data matched well.”

Altogether, the scientists examined the effects of wind farms within an approximately 1500 meter perimeter and an altitude of up to 500 meters. By comparison, the hub of the rotor is 123 meters in height. The finding: At the Linnich-Boslar landing field, the turbulence generated by the wind turbines is lower than the ordinary turbulence of the surrounding environment. Still, this finding can only be applied to other airports to a limited extent, because the surrounding terrain has a tremendous impact on the trail; unlike flat terrain, the trail is different where the landscape is forested or hilly. "The simulations would have to be commensurately adjusted for those kinds of airfields," says Stoevesandt.



The simulation reveals the turbulence generated by wind turbines. The red beam indicates heavy turbulence – which is particularly common behind the wind power plant. (© Fraunhofer IWES) | Picture in color and printing quality: www.fraunhofer.de/press

Smart wireless power outlets

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Soon there will be no need for special timers to switch lighting on and off or operate household appliances when the homeowner is absent. In future, all this can be done by means of a smartphone or PC, thanks to Internet-enabled wireless power outlets that support the new IPv6 Internet protocol. The smart socket was developed by researchers at the Fraunhofer Institute for Communication Systems ESK in Munich in collaboration with the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern and the industrial partner embedded brains GmbH. "We have been able to connect the power outlets wirelessly using the IPv6 protocol," says ESK research engineer Günter Hildebrandt. "All household appliances plugged in one of the sockets can be switched on and off remotely using an IPv6-compatible device such as a smartphone or laptop PC – from anywhere."

The wireless power outlets are a component of the HexaBus home automation system that was developed by the ITWM as part of the mySmartGrid project (www.mysmart-grid.de). "The HexaBus components make the smart home of the future a reality. They enable household appliances to be controlled intelligently, thus optimizing or reducing electricity consumption. For example, the householder can start the washing machine during cheap-rate off-peak hours, or run the dishwasher when the photovoltaic panels on the roof are generating sufficient power," says industrial engineer Mathias Dalheimer of the ITWM, who leads the SmartGrid project and is its chief programmer.

Intelligent control and measurement of power consumption

In addition to the wireless power outlets, the HexaBus system employs a specially designed USB stick that plugs into any compatible, off-the-shelf router. The user enters the command to switch on an appliance via a standard web browser or an Android-compatible smartphone app. The router and stick then forward the data to the power outlet. This two-way communication function also allows the wireless power outlet to send data to the smartphone, informing the user how much power various appliances are consuming at any given time. Thus, the user can optimize their power consumption. "The combination of parallel control and measurement functions is an entirely novel feature that no other wireless power outlet has offered before," says Hildebrandt.

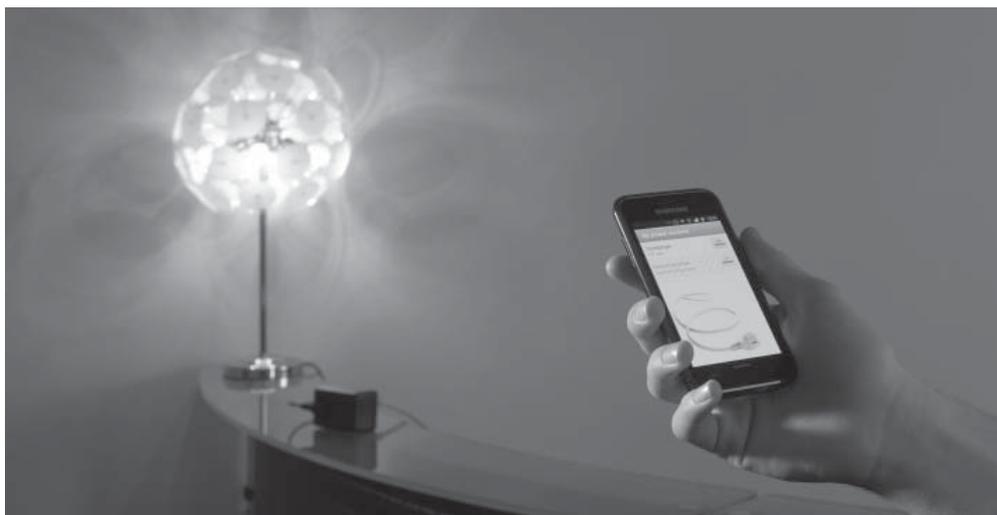
Because the HexaBus system is based on the IPv6 data communication protocol, a separate IP address is assigned to each power outlet, and thereby to each connected appliance, enabling them to be accessed directly. But how did the researchers go about integrating Internet functionality in the wireless power outlets and USB sticks? To do so, Hildebrandt and his team developed special protocol software and an extension to the Contiki operating system that enables it to handle the 6LoWpan (IPv6 over Low power Wireless Personal Area Network) communication protocol. Contiki is an open-source operating system for networked embedded devices such as the microcontrollers

incorporated in wireless power outlets and USB sticks. A linked web browser protocol enables users to assign a separate name to each power outlet – such as “washingmachine.basement”.

Guaranteed data security

Users have no need to worry about the security of their data – all information is transmitted in encrypted form. To make this possible, the experts modified Contiki to enable it to operate with the AES-128 advanced encryption standard. Wireless control signals are transmitted in the 868-MHz frequency band. “This permits users to remotely control a widely distributed network of appliances. The distance between the power outlet and the router can be as high as 30 meters,” explains Hildebrandt.

The HexaBus power outlets are ready for commercial application. Their manufacture has been entrusted to embedded brains GmbH, the industrial partner that was also responsible for the hardware development of the power outlets and USB sticks. Meanwhile, the researchers have a new idea up their sleeves: they want to enhance their system with multihop networking capability. By linking together a series of power outlets, the router will be able to pass messages from one to another, thus extending the range of the communication system – a solution that could be of interest to businesses for their office buildings and industrial sites.



The table lamp can be switched on and off by means of a smartphone app – thanks to the HexaBus wireless power outlet. (© Fraunhofer ESK) | Picture in color and printing quality: www.fraunhofer.de/press

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Using wastewater as fertilizer

Phosphorus is a vital element not only for plants but also for all living organisms. In recent times, however, farmers have been faced with a growing shortage of this essential mineral, and the price of phosphate-based fertilizers has been steadily increasing. It is therefore high time to start looking for alternatives. This is not an easy task, because phosphorus cannot be replaced by any other substance. But researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart have found a solution that makes use of locally available resources which, as unlikely as it might seem, are to be found in plentiful supply in the wastewater from sewage treatment plants and in the fermentation residues from biogas plants: a perfect example of the old saying "from muck to riches". The new process was developed by a team of scientists led by Jennifer Bilbao, who manages the nutrient management research group at the IGB. "Our process precipitates out the nutrients in a form that enables them to be directly applied as fertilizer," she explains.

Mobile pilot plant for field tests

The main feature of the patented process, which is currently being tested in a mobile pilot plant, is an electrochemical process that precipitates magnesium-ammonium phosphate – also known as struvite – by means of electrolysis from a solution containing nitrogen and phosphorus. Struvite is precipitated from the process water in the form of tiny crystals that can be used directly as fertilizer, without any further processing. The innovative aspect of this method is that, unlike conventional processes, it does not require the addition of synthetic salts or bases. Bilbao: "It is an entirely chemical-free process."

The 2-meter-high electrolytic cell that forms the centerpiece of the test installation and through which the wastewater is directed contains a sacrificial magnesium anode and a metallic cathode. The electrolytic process splits the water molecules into negatively charged hydroxyl ions at the cathode. At the anode an oxidation takes place: the magnesium ions migrate through the water and react with the phosphate and ammonium molecules in the solution to form struvite.

Energy-saving, chemical-free process

Because the magnesium ions in the process water are highly reactive, this method requires very little energy. The electrochemical process therefore consumes less electricity than conventional methods. For all types of wastewater tested so far, the necessary power never exceeded the extremely low value of 70 watt-hours per cubic meter. Moreover, long-duration tests conducted by the IGB researchers demonstrated that the concentration of phosphorus in the pilot plant's reactor was reduced by 99.7 percent to less than 2 milligrams per liter. This is lower than the maximum concentration permit-

ted by the German Waste Water Ordinance (AbwV) for treatment plants serving communities of up to 100,000 inhabitants. "This means that operators of such plants could generate additional revenue from the production of fertilizer as a sideline to the treatment of wastewater," says Bilbao, citing this as a decisive advantage. Struvite is an attractive product for farmers, because it is valued as a high-quality, slow-release fertilizer. Experiments conducted by the Fraunhofer researchers have confirmed its effectiveness in this respect: crop yields and the uptake of nutrients by the growing plants were up to four times higher with struvite than with commercially available mineral fertilizers.

The scientists intend to spend the next few months testing the mobile pilot plant at a variety of wastewater treatment plants before starting to commercialize the process in collaboration with industrial partners early next year. "Our process is also suitable for wastewaters from the food-industry and from the production of biogas from agricultural wastes," adds Bilbao. The only prerequisite is that the process water should be rich in ammonium and phosphates.



Struvite fertilizer recovered from wastewater is a high-quality product that slowly releases nutrients into the soil. (© Fraunhofer IGB) | Picture in color and printing quality: www.fraunhofer.de/press