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RESEARCH NEWS

12 | 2015 ||

1 Offshore wind farms – measuring buoy reduces costs

Building and operating offshore wind farms is an expensive business. To be able to estimate the profitability of the plants, first the wind potential must be determined. Fraunhofer researchers have now created a wind measurement buoy with sophisticated, precise measurement technology that supplies the necessary data.

2 Growing stem cells faster on seaweed

Alginate forms a kind of supporting skeleton in the cell walls of certain kinds of algae. Fraunhofer scientists use the gel-like mass from Chilean seaweed as the substrate for stem cells. They can flexibly adjust the pore size and elasticity of the alginate, and it transports active ingredients and has better optical characteristics than plastic materials.

3 Meat and Bone Meal as a Source of Phosphorus

Slaughterhouse waste is processed into meat and bone meal and subsequently fed to livestock or incinerated. This meal could be put to better use, though. It contains phosphorus, a scarce mineral used as fertilizer. A new system burns meal, producing ash that could be used as the raw material for phosphorus fertilizer.

4 Electric cars: batteries with brains

The battery is the heart of the electric car. Fraunhofer researchers have developed an energy storage device which is significantly more cost-effective over the entire life cycle in comparison with previous models. If one of the more than one hundred battery cells is defective, it can be replaced easily. Until now, the entire battery had to be replaced.

5 Door manufacturers benefit from simulation tools

Building burglary-resistent doors with thermal insulation is a challenge for manufacturers. Their complex structure provides holes for the flow of air. With scientific simulation methods, Fraunhofer researchers have designed an insulating construction on the computer – without expensive prototypes having to be built.

6 The Self-Catering Houseboat

A life away from traffic noise and exhaust fumes – more and more people are drawn to water. Energy self-sufficient floating homes not only fulfill the criterion for this new lifestyle, they can also boost economy. Medium-sized companies, manufacturers, universities as well as two Fraunhofer Institutes work hand-in-hand on the autartec® project.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 66 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 24,000, who work with an annual research budget totaling 2 billion euros. About 70 percent of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the Americas and Asia serve to promote international cooperation.

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Offshore wind farms – measuring buoy reduces costs

Planners of offshore wind farms need to know which way the wind is blowing, as their profitability depends on wind speeds. "Constant high wind speeds at sea can offset the huge investment costs for building the farms and connecting them to the grid. The profitability of wind farms comes from the difference between feed-in compensation and the costs for construction and maintenance," says Claudia Rudolph, scientist at the Fraunhofer Institute for Wind Energy and Energy System Technology IWES in Bremerhaven. Using a special wind measurement buoy, the meteorologist and her team want to calculate the wind potential and therefore the energy yields that can be expected, thus providing valuable support to wind farm planners. For this endeavor, the researchers rely on LiDAR (Light Detection and Ranging) technology.

An alternative to wind met masts

The design of the Fraunhofer IWES LiDAR buoy is based on the light buoys that have been used in the North Sea for over thirty years, which the scientists have adapted to measure wind potential. It is over eight meters in length, has a diameter of 2.55 meters and weights 4.9 tons. The buoy carries a LiDAR measuring device that measures wind speeds at heights of between 40 and 200 meters. "LiDAR systems send pulsed laser beams into the atmosphere, which reflect off of aerosol particles in the air. From the frequency shift of the backscattered signal, the wind speed and direction are calculated at the corresponding measurement heights," explains Rudolph.

Although the technology is already used on land, it was previously considered unsuitable for measurements on buoys and floating platforms because it was too imprecise. The buoy's own movement, which distorts the measured values, prevented the reliable use of a LiDAR device. To allow these measurements to be carried out on moving structures, the IWES researchers developed a correction algorithm that subtracts the buoy's own movement from the measurement values.

The new floating LiDAR system guarantees high measuring accuracy, comparable to the results obtained by fixed offshore wind met masts. This was the conclusion of validation measurements carried out in the North Sea, where the buoy was installed at a location with a water depth of 30 meters at the Alpha Ventus offshore farm 45 kilometers off the coast of the island of Borkum, near the FINO 1 wind met mast. There was a 99.7 percent correlation between the values from the met mast and those from the buoy.

"Out in deep water, the LiDAR buoy is a genuine alternative to wind met masts, which measure wind speeds only at a height of 100 meters," says Rudolph. Another advantage of the system is that the flexible buoy can be used anywhere at sea and is quick to install, making the costs five to ten times lower. The buoys are also much easier and

cheaper to maintain than wind met masts. Depending on individual requirements, the system can also measure additional parameters such as waves, currents and temperatures at the same time.

Another of the buoy's noteworthy features is the aluminum housing that encapsulates the LiDAR measuring device and protects it against salt water and the extreme environmental conditions at sea. The housing contains special glass through which the laser beam passes unhindered and unbroken into the atmosphere. An autonomous power supply system completes the package: three small 400-watt wind generators and three 70-watt solar panels generate the electricity, while three gel batteries store it. This ensures that reserve energy is available for a week without wind and sun. Inside the floating platform there is a computer for data communication. Status and measurement data are transmitted to the recipient via WLAN or satellite.

Projects in the North Sea

A LiDAR buoy is currently being used in a research project off the coast of Denmark, while a further buoy will be used for demonstration measurements in the North Sea. Through this project, the scientists aim to present their development to the Offshore Wind Accelerator (OWA) consortium brought together by the Carbon Trust, a nonprofit organization whose mission is to promote the transition to a climate-friendly economy. "If you fulfill the OWA's criteria, you are awarded pre-commercial status, which sends an important signal to our potential customers. It shows that our system is fully operational, and enables us to approach wind farm planners and operators with various offers such as long-term measurements for yield forecasting and online wind measurements during installation," says Rudolph.

In the North Sea, wind measurement buoy with sophisticated, precise measurement technology situated in front of the FINO 1 wind met mast. (© Fraunhofer IWES) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Wind Energy and Energy System Technology IWES | Appelstrasse 9a | 30167 Hannover | www.iwes.fraunhofer.de
Press: Britta Rollert | Phone +49 511 762-14186 | britta.rollert@iwes.fraunhofer.de

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Growing stem cells faster on seaweed

For the drug tests of the future, the pharma industry needs large quantities of pluripotent stem cells. These stem cells have the potential to transform themselves into any kind of somatic cell, such as the cells of inner organs. Many thousands of stem cell lines from a huge variety of patients are currently being built up in biobanks, where doctors can access perfect models of the genetic illnesses of these patients. Using these stem cells, doctors and pharmaceutical companies can test new drugs better and more quickly than before.

Scientists at the Fraunhofer Institute for Biomedical Engineering IBMT in Sulzbach have identified seaweed from Chile as a particularly efficient source of nutrients for the expansion of pluripotent stem cells. Over the past few years, they have developed a controlled and documented production process for alginate, the seaweed's supporting structure. The process encompasses everything from harvesting the seaweed on Chilean beaches and in the seas off Chile, to importing the granulated and dried seaweed, to manufacturing the alginate and using it in cell culture to grow pluripotent stem cells at the institute in Saarland. British pharma companies are currently validating the process in their laboratories. "The first concrete trials with partners from the European Federation of Pharmaceutical Industries and Associations (EFPIA) are planned for next year," says Prof. Heiko Zimmermann, Managing Head of Fraunhofer IBMT. "The goal is to demonstrate that we can use the process to produce stable pluripotent stem cells. At the institute, we've already managed to do just that for many individual stem cell lines." The Fraunhofer scientists at Sulzbach developed the production process and the technology platform jointly with their colleagues in Chile and the United Kingdom.

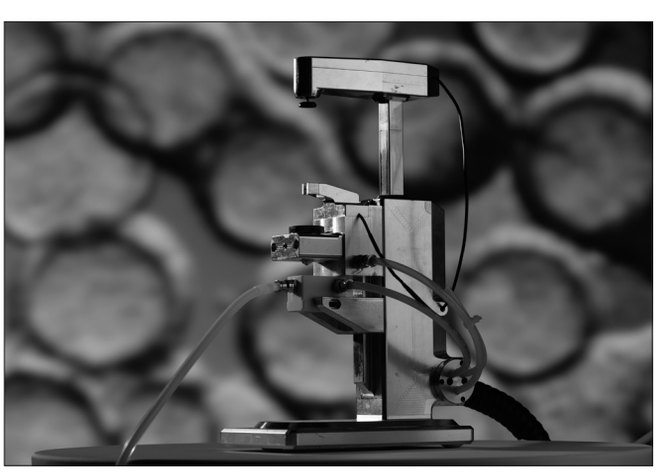
Alginate from two Chilean seaweed types particularly suitable

Two seaweed species that grow on the coast of Chile form the source material: Lessonia trabeculata and Lessonia nigrescens. Supporting structures in the cell walls of the seaweed are made of alginate, which is particularly suitable for stem cell cultivation: it consists of a highly aqueous gel that is more viscous than honey. When cross-linked with calcium or barium, it is both stable and flexible – like the jello you find in your dessert bowl – and also permeable for nutrients and important factors. "Cells feel especially at home in elastic 3D environments such as are found inside the body. It's precisely this environment that can be simulated perfectly using alginate," explains Prof. Zimmermann. This is an ideal environment particularly for heart muscle cells, which contract regularly. The scientists flexibly set the elasticity through the mixture of seaweed species and produce the alginate in beads of any size. "After all, different cells need different culture conditions," says Prof. Zimmermann. "We also introduce active ingredients into the alginate and release them in a controlled manner." Examples of such ingredients are substances that transform pluripotent stem cells into certain

somatic cells. "In the future," continues Prof. Zimmermann, "the alginate will not only act as a passive substrate, but will also actively influence the growth of the stem cells." The absence of autofluorescence in the elastic biomass is a further advantage and is important for optical analysis techniques. "The stem cells grow better on our alginate – and particularly well in automated bioreactors. They differentiate better into the desired somatic cells than on the plastic substrates generally used today," says Prof. Zimmermann.

Harvesting the seaweed is subject to rigorous controls: there are special licenses for Chilean fishers, who harvest only the seaweed that is suitable for manufacturing the alginate, and only as much as permits sustainable resource management on the Chilean coast. In a laboratory operated by IBMT and Fraunhofer Chile at UCN University in Coquimbo, the seaweed is individually peeled, shredded, and completely dried. This is all done within 24 hours to prevent the material from becoming contaminated. The seaweed granulate is then exported to Germany, where IBMT scientists separate out the alginate in the institute's cleanroom. After this process, it is available in liquid form and can be shaped into beads using a strong jet of air. "The beads are rendered more stable in a barium bath, as barium tends to remain in the seaweed mass. The trick is to make the material stable, but not too hard," says Prof. Zimmermann.

The researchers place the protein-coated alginate into a bioreactor, which provides the optimum temperature and CO_2 environment and continuously stirs the nutrients and cells. Measuring around 200 micrometers, each individual alginate bead performs the role of a Petri dish. The stem cells grow over the alginate in the containers in three to seven days, propagating as they do so. "Because the alginate volumes in the reactors can be increased slightly, we can grow pluripotent stem cells in greater quantities and in smaller spaces," says Prof. Zimmermann.



Twin-jet system for manufacturing alginate beads. (© Fraunhofer IBMT) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Biomedical Engineering IBMT | Joseph-von-Fraunhofer-Weg 1 | 66280 Sulzbach | www.ibmt.fraunhofer.de
Press: Dipl.-Phys. Annette Maurer | Phone +49 6897 9071-102 | annette.maurer@ibmt.fraunhofer.de

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Meat and Bone Meal as a Source of Phosphorus

Liverwurst, salami, steak – Germans eat a lot of meat. Not all parts of cattle and swine land on plates, though. Their teeth, hooves, bones and eyes, for instance, are left over and processed into meat and bone meal – over 200 000 tons in Germany alone every year. The ground scraps are fed in part to livestock. The rest, consisting of parts like eyes and brains that might carry the BSE pathogen, is incinerated in waste incineration plants together with other waste.

Agricultural Fertilizer

Researchers at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg are proposing a new method: "We burn meat and bone meal in a special way that enables us to recover an important mineral from it," explains Patric Heidecke, research manager at the Fraunhofer IFF. After all, approximately three to four percent of the raw material is phosphorus, a mineral that is not abundant and is expensive. It is primarily used as agricultural fertilizer. As much as sixteen percent of the ash is phosphorus. That is as high as in natural deposits located primarily in China, Morocco and the USA. "Just like the phosphoric material extracted from those deposits, the ash could be processed into fertilizer," says Heidecke. "In purely mathematical terms, this could cover around five percent of annual demand for phosphate fertilizer in Germany."

Separating Heavy Metals from Ash

Although the meat and bone meal is already being incinerated in part even now, it is mixed with other fuels to do so. On the one hand, this dilutes the phosphorus in the ash produced and, on the other hand, undesired substances also end up in the ash through other substances. Another problem is that the byproduct contains heavy metals such as mercury and lead, which are not allowed to land in a field later, too. The ash from waste incineration plants contains these contaminants, either, however.
The researchers have factored all of this into their research. The principle entails loading meat and bone meal in a fluidized bed unit heated to 850 degrees Celsius. Air flows continuously from below into a combustion chamber and mixes the meal with hot quartz sand. The mass ignites and the organic particles burn completely. The heat is drawn off and can either be used directly or is converted into electricity. The combustion gas produced, which also contains a large part of the ash because of the vortex, is conducted into a cyclone separator, which separates the "good", clean ash from the "bad", which contains the toxic heavy metals. The researchers slow the stream of air to do this. The ash descends to the floor, while the heavy metals and ash particles, which are smaller than one tenth of a millimeter, remain airborne. They are trapped and disposed of later.

What parameters have to be set for combustion to produce a maximum of heat, on the one hand, and to prevent the formation of undesired contaminants such as nitrogen oxides, on the other hand? The researchers studied this in a wide-ranging series of tests. The researchers used a fluidized bed unit that is approximately four meters high and produces 150 kilowatts of power. "A unit with ten megawatts of power could also be built without any difficulty, however," says Heidecke. They now intend to build the first commercial unit at a field partner's facilities. "This concept will have established itself in ten years," the expert is certain, "since it is not only suitable for meat and bone meal as fuel but also for sewage sludge." Although the fertilization of fields with sewage sludge is still permitted at this time, the sludge contains heavy metals as well as nitrate, which can eutrophy bodies of water.

All over the world, phosphorus is a scarce raw material, which is used as fertilizer, for instance. Meat and bone meal contains phosphorus. A new process utilizes this resource significantly more efficiently. (© Fraunhofer IFF) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Factory Operation and Automation IFF | Sandtorstraße 22 | 39106 Magdeburg | www.iff.fraunhofer.de
Press: Anna-Kristina Mahler | Phone +49 391 4090-446 | presse@iff.fraunhofer.de

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Electric cars: batteries with brains

The core of electric cars are their batteries. So far, these have been monolithic blocks in which the individual battery cells as well as the necessary technology have been housed. All individual cells should theoretically be able to save the same amount of energy. In practice, though, this is somewhat different: due to production reasons, their capacities vary. This is problematic, since the cells are connected in series. The entire battery is therefore only as strong as its weakest cell. If this cell is "empty", the remaining energy in the other battery cells does not help – the car has to be recharged. For that reason, manufacturers presort and install cells of a similar capacity into a battery. Since some cells are sorted out as a result of this process, and this pushes the price of the batteries up. Another shortcoming is that when a cell is defective, the vehicle stops functioning. That means that the entire energy storage device has to be replaced.

Independent battery cells communicate with each other

Researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart have now created an alternative. "Our modular battery system solves these problems," says Dr. Kai Pfeiffer, Group Manager at the IPA. The trick: each battery cell has its own built-in microcontroller that records relevant physical parameters, such as the temperature and the state of charge of the cell. As a result, each cell knows what condition it is in. The cells "talk" to each other via the existing power wiring between battery cells. This is known as power-line communication. They can also communicate with other devices, such as the on-board computer, which uses the data from the cells to calculate how much remaining energy the entire battery still has, the so called state of charge.

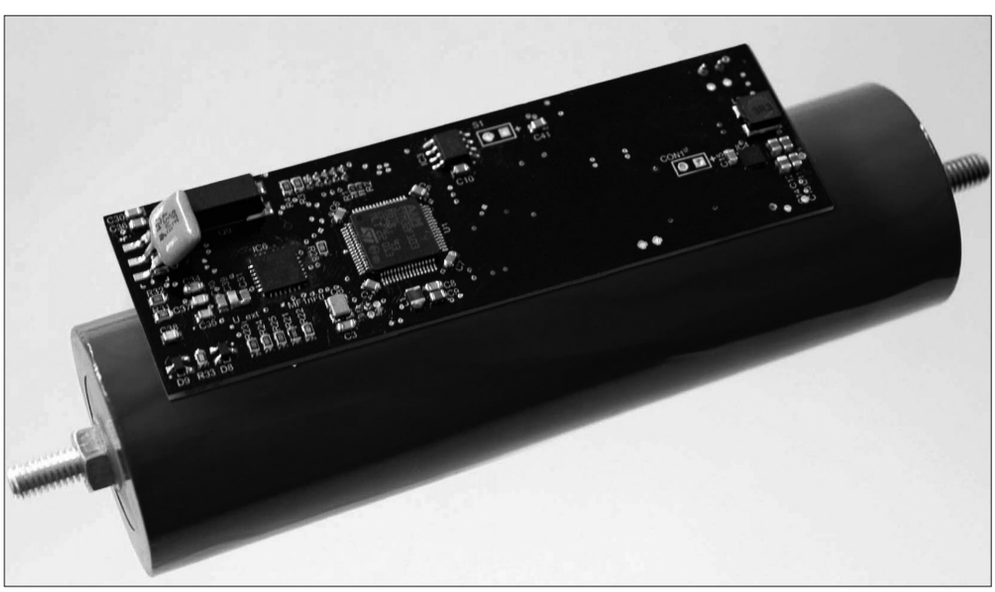
Greater range

If a cell is empty, but the others still have energy stored, the car does not have to stop, like it did before. Rather, the empty battery cell simply decouples from the cluster, acting like a current by-pass. The others continue to deliver energy. "Depending on the cell quality, we can therefore increase the range by at least four percent," explains Pfeiffer." Over time, this effect is amplified: in the case of an old battery, and if the empty cells are replaced, it is conceivable that a range up to ten percent higher can be achieved".

Since one cell with lower capacity hardly affects the overall range of a car, the manufacturers no longer need to pre-sort it. This should significantly reduce costs. In addition, the capacities of the cells adapt to each other over time. This is because the ones that can store less energy are switched off earlier. The cells therefore run longer and, as a result, faster: their capacity decreases. And if a battery cell malfunctions, it is not necessary to bring the vehicle to the workshop. Since the car has more than one

hundred cells, it does not depend on any individual one. And if the driver decides in favor of a repair, it is sufficient to merely replace the single cell instead of the entire battery.

The researchers have already developed a prototype of the battery cell. The challenge is now to miniaturize the electronics and embed them into cells. "We want it to cost less than a euro," Pfeiffer says. Part of the development process is being conducted in the EU project "3Ccar".



Intelligent cell of the Fraunhofer IPA: A microcontroller records physical parameters such as temperature and state of charge. If a cell is empty, it switches itself off automatically. (© Fraunhofer IPA) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Manufacturing Engineering and Automation IPA | Nobelstraße 12 l 70569 Stuttgart | www.ipa.fraunhofer.de
Press: Jörg-Dieter Walz | Phone +49 711 970-1667 | presse@ipa.fraunhofer.de

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Door manufacturers benefit from simulation tools

Small and mid-sized companies usually do not have a research department. The expertise of scientists can also create added value for them, though. This is shown by the example of a manufacturer of burglary-resistent house doors from Rhineland-Palatinate in Germany: simulation methods and software tools of the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern have been helping to construct these burglary-resistent doors such that they are now eligible for a grant from the Kreditanstalt für Wiederaufbau (KfW- Credit Institute for Rebuilding). The new frame construction provides the entire door with an heat transfer coefficient (HTC) of 0.49 W/m²K. In the process, its burglary-resistent properties remain unchanged.

"This is a very low value for burglary-resistent doors, considering their complex structure," says Dr. Matthias Kabel from the Department Flow and Material Simulation at ITWM. "Previously, the frame constructions had a value of 2.84 W/m²K. Now, the HTC of the models from the company catalog are less than 1.3 W/m²K. All doors are therefore eligible for funding," says Dr. Kabel. The HTC is a measure of the thermal transmittance of a gas through a solid body. It is expressed in watts per square meter and Kelvin (W/m²K). "We have demonstrated through the project that with the help of complex simulation methods and software tools, we can optimize even our everyday objects – with direct added value for the customer," says Dr. Kabel.

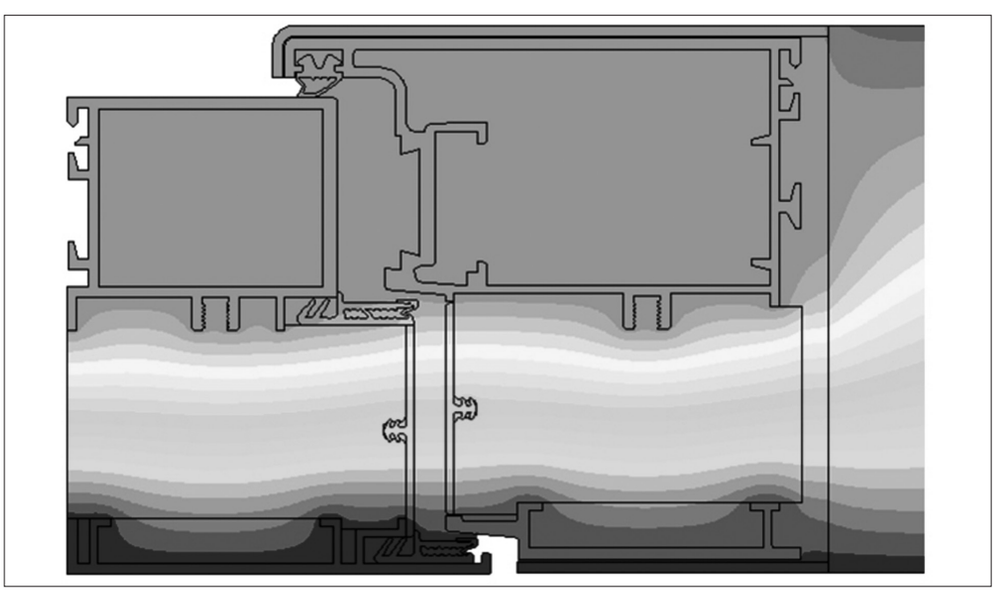
No expensive prototypes are needed

The company manufactures burglary-resistent doors and door frames made of aluminum. The problem: aluminum is particularly good at conducting heat. Cold penetrates into the house and interior heat escapes to the outside. "Not an ideal situation for the energy efficiency of the house," says Dr. Kabel. The ITWM researchers compared and tested the design proposals by predicting all the essential functional properties using precise numerical calculation methods. "With the help of computer simulations, we have been able to look at a large number of possible variants and to design the various materials in the area of the door leaf and the frame profile to the exact millimeter," says Dr. Kabel. The manufacturer did not have to build its own prototypes for the individual variants. As a result, it saved time and costs. "With our tools, we were able to quickly pair up information about the door structure and heat transfer with the requirements of the DIN standard for thermal insulation of windows, doors and shutters. This resulted in proposals for optimal design plans of various door models for the company," says Dr. Kabel.

In the first step, the scientists showed that they can simulate the real measurements of heat transfer on the computer precisely. "This helped the customer to become more confident in the process. The company does not have a research department and worked intensively with us on product development," says Dr. Kabel. "Without the

simulation, the manufacturer would only have had the mean value of the heat loss of the frame. With the help of the computer-assisted illustration, it was possible to determine exactly which part of the frame was responsible for which portion of the heat loss. We made specific proposals about how the design of the frame could be thermotechnically optimised." The researchers adapted their simulation software to the requirements of the problem regarding the doors: among other things, this included selecting the right material parameters, digitally and accurately portraying the physical effects of heat transport in doors, as well as considering the corresponding DIN norm in the simulation software.

The thermal insulation of houses is a key component of energy transmission and is promoted in Germany. The federal government of Germany wants to greatly reduce energy consumption in residential buildings by the year 2050. Through the KfW, it is also promoting the installation of thermally-insulated interior and exterior doors. However, only if an HTC of less than 1.3 W/m²K can be verified.



Cross-section of burglary-resistent external doors: Using scientific simulation methods, Fraunhofer researchers have identified the exact points where heat escapes through the aluminum frame (dark color). (© Fraunhofer ITWM) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Industrial Mathematics ITWM | Fraunhofer-Platz 1 | 67663 Kaiserslautern | www.itwm.fraunhofer.de
Press: Ilka Blauth | Phone +49 631 31600-4674 | ilka.blauth@itwm.fraunhofer.de

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The Self-Catering Houseboat

Floating homes are becoming increasingly popular in Germany – not only as holiday homes, but also as permanent residences. The Lusatian Lake District (Lausitzer Seenland) is particularly suitable for such a lifestyle: with its 23 lakes and a surface area of over 32 000 acres, it is the largest artificial lake district in Europe. Over decades, the region, which is located between the German states Saxony and Brandenburg, had been characterized by open-cast lignite coal mining. In the coming years, this way of life of living on water will help enhance the region's attractiveness and boost its economy.

This is also the objective of the Lusatian autartec® project, which the two Fraunhofer Institutes based in Dresden, the Fraunhofer Institute for Transportation and Infrastructure Systems (IVI) and the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS), are involved in, as well as other partners from the region such as medium-size companies, manufacturers, the Technical University of Dresden (TUD) and the Technical University of Brandenburg (BTU). They will all work hand in hand to build a floating home on Lake Geierswalde, to the northwest of the city of Hoyerswerda, by 2017. This floating home will not only look elegant, it will also be able to provide for its own water, electricity and heat. "These kinds of energy self-sufficient floating homes do not exist yet," says autartec® project coordinator Professor Matthias Klingner of IVI. Many lakes in the Lusatian Lake District are cut off from infrastructure such as water and energy supply. "We want to find a solution for this kind of environment," says Klingner.

Living energy independent on water

Standing on a 13 by 13 meter steel pontoon, the house extends over two levels and offers 75 square meters of living space on the ground floor, and another 34 square meters on the first floor. A 15 square meter terrace overlooks the entire lake. The house combines modern architecture and structural engineering with state-of-the-art equipment and building facilities. For example, solar cells are integrated in the building envelope and lithium polymer batteries store the collected energy. In order to save space, the battey systems developed at IVI are integrated into the textile concrete walls or into the stair elements.

Researchers at IVI are also working on the efficient provision of heating and cooling systems. A salt hydrate fireplace provides heat on cold winter days: above the fireplace there is a tub filled with water and salt hydrates. "When the fireplace is on, the salt hydrates liquefy and begin to absorb heat," Dr. Burkhard Fassauer of IKTS explains. When the salt hydrates are completely liquefied, the thermal energy can be stored almost indefinitely. In order to release the heat when required, radio-based technology is used to induce crystallization. The principle is known from pocket warmers: to induce

crystallization, a metal disc inside is clicked so that the pocket warmer solidifies and gives off heat. When heated in water, the crystals liquefy and the heat is stored until the next click. However, a fireplace is not enough to heat the house during the winter. This is where a zeolith thermal storage unit in the pontoon can help: the zeolith minerals are dried during the summer – a purely physical process in which heat is stored. "In winter, the moist air is enough for the storage unit to give off heat," Fassauer explains. An adiabatic cooling system provides for cool air in the summer. Unlike conventional air conditioning systems, it does not require electricity but uses the principle of evaporative humidification to cool. A surface on the side of the house is landscaped and moistened and the process of evaporation then cools the building envelope.

The experts at IKTS are responsible for the water supply in the houseboat. "We are currently developing and experimenting with a closed loop system for drinking and service water," Fassauer explains. To accomplish this, the scientists rely on a combination of ceramic membranes and various electrochemical and photocatalytic processes. Ashore, wastewater is usually treated using biological processes. This is not possible in a floating house. "We must rely on physical and chemical methods. Thus, ceramics provide very efficient ways to bring together processes like photocatalysis, electrochemistry and filtration in a confined space," says Fassauer. Other materials such as steel and plastic would fail in such aggressive processes. The equipment for the circulatory system will be accommodated in the pontoon.

Building design of a floating house that provides its own heat and water.
(© Fraunhofer IVI) | Picture in color and printing quality: www.fraunhofer.de/press

Fraunhofer Institute for Transportation and Infrastructure Systems IVI | Zeunerstraße 38 | 01069 Dresden | www.ivi.fraunhofer.de
Press: Elke Sähn | Phone +49 351 4640-612 | elke.saehn@ivi.fraunhofer.de
Fraunhofer Institute for Ceramic Technologies and Systems IKTS | Winterbergstraße 28 | 01277 Dresden | www.ikts.fraunhofer.de
Press: Katrin Schwarz | Phone +49 351 2553-7720 | katrin.schwarz@ikts.fraunhofer.de