A clean business

Lately, everyone's talking about "Cleantech". That term refers to clean, ecologically and economically sustainable technologies which use our (limited) resources significantly more sparingly and have the least possible environmental impact. For Empa, Cleantech is a key concern – and not just since the term became trendy.

TEXT: Michael Hagmann / PHOTO: iStock

For once, it probably wasn't the Swiss – though we can't really identify exactly who came up with the term "Cleantech". What's more, the definition of the term is somewhat vague and imprecise. Meanwhile, it's clear that many people make preposterous claims for Cleantech, some going as far as to promise it will save the world – or at least create an economic system which will harmonise environmentally friendly manufacturing technologies with sustainable growth. For quite some time now, Switzerland has also put a strong emphasis on Cleantech as illustrated by the "Cleantech Switzerland Master Plan" announced by President Doris Leuthard in November 2009.

But what's really hidden behind this magic word? Put simply, anything that leads to a reduction in the consumption of natural resources or energy and in turn reduces the impact on the environment. Some examples include technologies aimed at increasing energy efficiency such as in buildings or in the transport sector (see the article on page 12); renewable energy sources as well as innovative approaches to energy utilisation and storage (see the article on page 16); measures to protect air and water, or technologies with which pollution never even arises; plus innovative recycling or re-use systems such as to handle the growing mountain of electronic waste.

With Cleantech, however, the idea is not only to develop new technologies and adapt existing ones for sustainability. Methods must be established so it's even possible to evaluate sustainability, such as life cycle assessments (LCA). The example of biofuels dramatically shows that new products might at first glance appear to be climate friendly through lower CO_2 emissions, but when viewed over their entire life cycle they impact the environment in very serious ways (see the article on page 15).

Any and all examples falling under the heading of Cleantech are topics which Empa has to some extent been researching for many years. This Focus section introduces a few of them. Others were featured in previous issues of *EmpaNews*, at times also as a special Focus section. They include photovoltaics (*EmpaNews* 28), hydrogen as an energy source of the future (*EmpaNews* 26) and LCA as a method of assessing the environmental impact of technologies (*EmpaNews* 23). //

Engine tune-ups take on a new meaning

Cleantech covers, among other things, the improvement of established, widely used technologies to the extent that these measures can significantly reduce environmental pollution and the consumption of natural resources. Along these lines, various Empa projects illustrate that it's entirely possible to have clean internal combustion engines.

TEXT: Beatrice Huber

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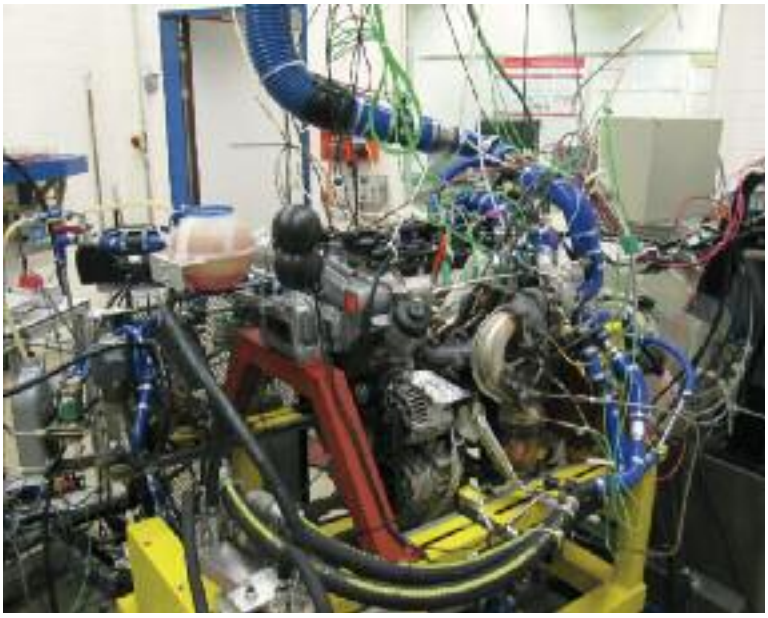
Today's mobility continues to be based on "ancient" inventions. The spark-ignition engine was patented in 1876, the diesel engine dates back to 1892, while electric motors are even older. Since then, these engines have benefited from many improvements, but they're far from reaching the limits of how much further they can be developed.

"Twenty per cent measures" for CO_2 reduction

The greenhouse gas carbon dioxide (CO_2) is a central focus in the fight against climate change. In this regard, starting in 2015, automobiles newly placed into service in the EU may emit only 130 grams of CO_2 per kilometre in a normal usage pattern (in Switzerland, a limit of 150 grams per kilometre is being discussed), and by 2020 this value should drop to 95 grams. In 2009, the value in Switzerland was 167 grams. "With the new powertrain concepts in discussion today, CO_2 emissions can be reduced by roughly 20 per cent," comments Christian Bach, head of Empa's Laboratory for Internal Combustion Engines. "Natural gas or hydrogen powertrains, renewable energy sources, hybrid or electric powertrains or even the development potential yet remaining in internal combustion engines – these measures are each individually leading to this reduction. But in order to reduce CO_2 emissions by a significant level, for instance cutting them in half, working piecemeal with any one of these measures isn't sufficient. To reach this goal, a combination of many such individual measures is necessary." That's exactly why Empa, together with ETH Zurich, is working on a new combustion process for natural gas/biogas powertrains and on developing them in conjunction with an electric hybrid concept. Industrial partners in this project are Volkswagen Research and Bosch.

Natural gas and biogas consist primarily of methane. Based on its chemical structure (four hydrogen atoms around one carbon atom), the combustion of methane results in approximately 25 per cent less CO_2 per unit of energy compared to burning petrol or diesel fuel. Methane, however, also has its drawbacks. For one, it's a potent greenhouse gas in its own right, more than 20 times more damaging to the



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Natural gas filling station in Zurich – driving with natural gas or with an admixture of biogas processed from organic waste represent just two of the many possible "20 per cent measures" to reduce CO_2 emissions. (Photo: Empa)

2
Together with partners from industry and academia, Empa is working on a clean and efficient vehicle within the scope of the CLEVER Project. It should emit only half the CO_2 of a comparable petrol vehicle. (Photo: Empa)

climate than CO_2. When organic waste, especially from agriculture and forestry, is allowed to rot without being utilised, the result is large amounts of methane which escape into the atmosphere and heat up the climate in those areas. Instead, it makes perfect sense to convert this waste into biogas and exploit its energy. Following suitable treatment, the biogas is then ready for storage in tanks. Modifications to natural gas engines or to natural gas filling stations are not necessary. In fact, the gas in Swiss natural gas filling stations today contains roughly 19 per cent biogas.

The CLEVER Project

The CLEVER Project, on which researchers from Empa, ETH Zurich as well as Volkswagen and Bosch are collaborating, intends to combine three "20 per cent measures". For this, they're studying the potential of new combustion processes especially for gas engines and optimising the thermodynamic cycles for natural gas. Empa is responsible for the experimental research and the construction of the prototype, and ETH Zurich for the underlying science. Two hearts are beating within the CLEVER prototype: first, an optimised natural gas engine (25 per cent less CO_2 compared to a standard petrol powertrain) developed just for this purpose, which will be fuelled with an admixture of 20 per cent biogas (resulting in an additional 16 per cent less CO_2); and second, an electric motor to create a hybrid configuration adding fuel savings of another 20 per cent in mixed operation. In total, CO_2 emissions can roughly be cut by half.

Natural gas hybrid vehicles ideal for mid-sized cars

Because the bulky gas tanks in the underfloor take up some amount of space, the natural gas powertrain looks promising in particular for mid-sized cars. These powertrains offer an enhancement to electric motors, which are suitable only for small cars or city/commuter cars because of their limited range and the relatively long time needed to charge the batteries. "In mid-sized cars, when we compare all available powertrain options, natural gas hybrids achieve the largest CO_2 reductions – and this all at low cost," explains Bach.

Considering the current cost structure of natural gas, biogas and petrol, it's possible, through lower fuel costs, to completely amortise the additional expense of purchasing a natural gas hybrid over the total lifetime of the vehicle. Or in other words, with a natural gas/biogas hybrid, it's possible to reduce CO_2 emissions without incurring any extra costs. According to Bach, this isn't possible with any other powertrain concept, not even with petrol hybrid powertrains. What's more, due to its lower environmental impact compared to petrol, natural gas is subject to lower taxes in Switzerland and elsewhere – at least for the time being.

In Switzerland, roughly a quarter of all new cars – more than 65,000 vehicles – are part of a corporate fleet. In this realm, there's enormous potential for natural gas hybrid vehicles because, when making a purchase, fleet managers must not only consider the acquisition cost but also operating expenses and the firm's corporate responsibility and sustainability goals.

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Hydrogen for special applications

Natural gas and biogas as fuels are paving the way for another gas, hydrogen. Its combustion results in no CO_2 at all, just water. Moreover, hydrogen fuel cells are very attractive due to their high efficiency also at part load which often occurs in the field. Hydrogen vehicles are already interesting today especially for urban buses or for special vehicles such as street sweepers, which also find use in pedestrian zones or in large indoor spaces such as exhibition halls. Because these vehicles can travel only within a limited radius and always return to a home base, a single central hydrogen filling station is sufficient. "However," adds Bach, "if this is actually to be considered Cleantech, the hydrogen must be produced in a climate-neutral manner, such as directly from solar energy." This is hardly the case today, he adds, but it is the subject of numerous R&D projects.

The "Bucher Schörling CityCat H_2" street sweeper, a joint project of Empa and the Paul Scherrer Institute (PSI) along with various industrial partners, is intended to put the hydrogen powertrain into practical use. Since autumn 2009, this street sweeper has been running in a test phase on the streets of Basel. A look at the results from the first project phase shows that the vehicle consumes on average only half as much fuel as a comparable conventional vehicle. However, there are still a few bumps in the road. Technical malfunctions have interrupted test operations several times. The vehicle's fuel-cell system is currently being completely re-engineered. From late summer of this year, the CityCat H_2, which has had a "heart transplant", will once again keep the streets of Basel clean. //

Technology Days 2010: Where is auto mobility headed?

Tage der Technik 2010
Journées de la Technique 2010

Mobility is an important pillar which supports the Swiss economy – but also a problem child on our way to a sustainable development. How can we ensure continued mobility without having a severely negative impact on people and the environment in the long run?
The opening event of the Technology Days 2010, sponsored by Swiss Engineering STV, SATW (Swiss Academy of Engineering Sciences) and Empa, is operating under the motto "Sustainable Mobility". The event examines the car as a means of transportation from various angles and is targeted at specialists in research, education, politics and economy.

Technology Days 2010:
"Sustainable Mobility – Quo vadis Automobile?"
Wednesday, 27 October 2010, from 1.15 p.m.
Empa Dübendorf, Academy
Places are limited.
Registration possible until 20 October.
www.tage-der-technik.ch

The "Bucher Schörling CityCat H_2" on the streets of Basel – in the first phase of this project, the world's first municipal vehicle with a hydrogen powertrain consumes on average only half as much fuel as a conventional vehicle. (Photo: Juri Weiss)

Driving into the green

Tomorrow's environmentally friendly vehicles for individual mobility need powertrain technologies which create as little pollution as possible. An interdisciplinary research team has investigated the sustainability of 2nd generation biofuels and determined how much petrol and diesel could be saved in Switzerland through the use of biofuels.

TEXT: Martina Peter / PHOTO: iStock

The enthusiasm for what are known as 1st generation biofuels has meanwhile evaporated into thin air. Only a small fraction of the plants is used to produce supposedly environmentally friendly fuels – for example their oil or sugar content. And because these raw materials are used inefficiently, biofuels are significantly less "eco" than originally expected, as shown in an Empa study from 2007.

A beacon of hope in the "2nd generation"

Since then, processes have been developed which allow practically all kinds of biomass to be converted into fuel. This includes green waste, manure (in both solid and liquid form), scrap wood, and plant material with a high cellulose content. However, most of these processes involve an increased expense in both technology and financial investment. As a consequence, except for biomethane, none of these 2nd generation biofuels are commercially viable. Thus government subsidies and promotion programs would be necessary, but they make sense only when these biofuels are proven beyond doubt to be sustainable and environmentally friendly.

Biofuel alone isn't enough

Empa environmental scientist Rainer Zah and his team have been conducting research on behalf of the TA-SWISS Centre for Technology Assessment. Through life cycle analyses, they're taking a close look at 2nd generation biofuels – from their production through their use and to the disposal of any waste products.

The key result of the study, presented last June: the most environmentally friendly biofuels are primarily the ones which are produced using waste products and leftover materials such as green waste, sawmill waste and wood scrap. In contrast, if plants are grown in developing countries solely for the purpose of producing (bio)fuel, the disadvantages dominate the equation. Energy crops directly compete with food crops for agricultural land and also threaten biodiversity. The study further emphasises that in Switzerland biofuels can at best provide no more than eight per cent of the fuel required for individual transport because of the limited amount of waste products that are available.

Does this mean it makes sense to abandon governmental support for biofuel development? "No," says Zah, "that would be a short-sighted reaction." The more important question is how to ensure that the most appropriate powertrain technology is used to meet differing requirements, whether for long-haul traffic, urban mobility or freight transport. Zah has worked out what that means in specific terms for 2030 assuming the most optimistic scenario. "If available biofuels were used for long-haul traffic, not just eight per cent of fossil fuels could be replaced, but thanks to more energy efficient vehicles as much as fifteen per cent. And if at the same time in cities we drove primarily electric cars whose batteries were charged through alternative energy sources such as solar power, then we can add another 25 per cent to that figure. So, in total this would allow us to replace approximately 40 per cent of today's consumption of fossil fuels."

According to Zah, the recommendation to policy makers is clear: it's doing one thing without giving up the other. "Neither electric mobility, nor improved vehicle efficiency nor support for sustainable biofuels should be given priority over the others. Far more importantly, we must find ways to promote all three approaches simultaneously and apply them to where they bring the most benefit." //

Rainer Zah has carried out a study concerning the prospects for 2nd generation biofuels on behalf of TA-SWISS. He was supported by an interdisciplinary team of ecologists from the University of Zurich and experts in the areas of materials flows and resource management from the Wuppertal Institute.

R. Zah, C. Binder, S. Bringezu, J. Reinhard, A. Schmid and H. Schütz. Future Perspectives of 2nd Generation Biofuels, edited by TA-SWISS – the Swiss Centre for Technology Assessment, published by the vdf Hochschulverlag AG of ETH Zurich, 2010. ISBN 978-3-7281-3334-2. Also available as an e-book, www.vdf.ethz.ch

New paths to industrial partnerships

Technology transfer, in other words the transfer of research findings into commercially viable products and services, is at the centre of many Empa activities. With Hexis AG, one of the leading developers of fuel cell-based electricity and heat supply systems, Empa has entered into a strategic partnership which will extend far beyond individual collaborative projects and should help this technology gain a foothold in the marketplace.

TEXT: Beatrice Huber

Fuel cells efficiently convert energy chemically bound in fuels into electricity. This makes them especially interesting for the decentralised generation and supply of electricity. If the resulting thermal waste is also used for heating purposes, the efficiency of fuel cells can be increased to 90 per cent and even higher. Rather impressive, if one considers the mere 60 per cent of energy conversion achieved with central electricity production and separate heat supply as is commonplace today. By using renewable fuels such as biogas the energy supply is not only highly efficient but also CO_2 neutral.

SOFCs, or solid oxide fuel cells, consist of a fuel electrode (anode) connected to an oxygen electrode (cathode) through a solid, gas-tight oxygen ion conductor (electrolyte). At operating temperatures from 600 to 1000 degrees Celsius, the chemical reactions on both electrodes are separated locally; the oxidation of the fuel occurs at the anode, the reduction of atmospheric oxygen at the cathode. In the process, electrons are released; they flow through an external electrical circuit, generating a current that can be used to perform work. Multiple fuel cells are arranged in a stack in order to reach the desired power rating. In contrast to other fuel cell technologies, SOFCs can use not only hydrogen but also methane. That's a key advantage because well-developed natural gas distribution networks already exist.

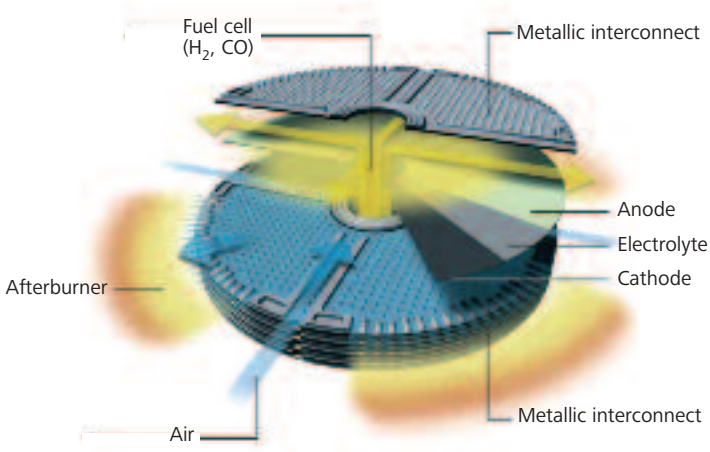
Technology transfer thanks to a strategic partnership

In order to further develop fuel cells and associated systems based on SOFC technology and establish them on the market, Empa and Hexis AG have entered into a strategic R&D agreement. A liaison office ensures the coordination of the corresponding projects, brings experts from various disciplines together and generates new ideas, for instance for EU projects. Together, researchers from Empa and Hexis want to, among other things, improve the operating lifetime of SOFCs by developing materials which better withstand the extreme chemical and thermal conditions. That's because the success of fuel cell technology for decentralised energy supplies depends heavily on the operating lifetime. Users expect that systems will function without problems for years and even decades.

Empa and Hexis complement each other

Empa has been working on the development of materials for fuel cells for quite some time and is active in the manufacture and optimisation of anodes, cathodes and electrolytic materials. In addition, its scientists are conducting research into the thermal-mechanical loads under the extreme conditions in an SOFC. Moreover, Empa has many years of experience in the field of system management for integrating such technology into buildings and evaluating its performance.

Winterthur-based Hexis AG develops fuel cell heaters which are designed to cover the entire heating and electricity requirements of single- and multi-family homes in central Europe. Prototype systems are already in use in many applications. The company has broad expertise in a large number of areas such as process technology, fuel-cell manufacture, technology integration in buildings, as well as servicing of heaters in operation. //



A fuel cell of the SOFC type can be used to generate not only electricity but also heat. For this, any fuel which hasn't been converted is post-combusted upon exiting the fuel cell stack. Such a fuel cell heater provides single- and multi-family houses with all the energy they require. (Pictures: Hexis AG)

"Fuel cells will become a part of our daily lives."

EmpaNews spoke with **Alexander Schuler**, Managing Director of Hexis AG, about the potential of fuel cells and his company's collaboration with Empa.

What do you see as the future of fuel cells?

Fuel cells will in future play a crucial role in various applications and will be available in a number of performance categories. In principle, a fuel cell is the most efficient energy converter when generating current directly from a fuel. The development status has already reached a good level; however, we're just starting to transfer this technology into commercially viable products. I'm absolutely convinced that fuel cells will become a part of our daily lives in many areas.

What are you hoping to gain through the partnership with Empa?

We assume that, together with Empa, we will be in a position to further advance the long-term aspects of SOFC development. For a small company such as Hexis it's important to have access to Swiss and EU funding bodies in order to create the sustainable scientific foundation for our technology. This is a key prerequisite for the creation of new jobs in Switzerland along with the retention of forward-looking technologies.

In your eyes, what does Empa stand for?

Empa is an excellent scientific institution with a broad profile of expertise. That's the special attraction of collaborating with Empa. The development of fuel cell technologies involves a multitude of scientific tasks – from nanotechnology in materials science through to the integration of complete systems in buildings – and Empa can provide extremely valuable contributions in many areas. To fully exploit this potential and collaborate in an interdisciplinary fashion; this is what we aim to achieve together. //

ETH-Empa professor for air pollution control

In May, the ETH Board elected Jing Wang to the position of assistant professor for industrial ecology. Wang's research focus is on, among other things, the development of instruments for the characterisation of the behaviour of nanoparticles in flowing media. Wang is an ETH-Empa professor and works as group leader in Empa's Analytical Chemistry Laboratory. Prior to his appointment to this position he was a research assistant professor at the University of Minnesota in Minneapolis, USA.

newtechClub – Centre for Sustainable Energy and Building Technologies

The newtechClub, located in Schlieren, is an independent and interdisciplinary platform for sustainable energy and building technologies. Mario Jenni, managing director of glaTec, the technology centre at Empa in Dübendorf, is a Board member. The association, founded at the end of 2009 by private companies and the public sector, wants to promote the exchange of knowledge between corporations as well as experts in the field of R&D and management which are committed to the further development and spread of innovative energy and building technologies.