Pictures of the Future

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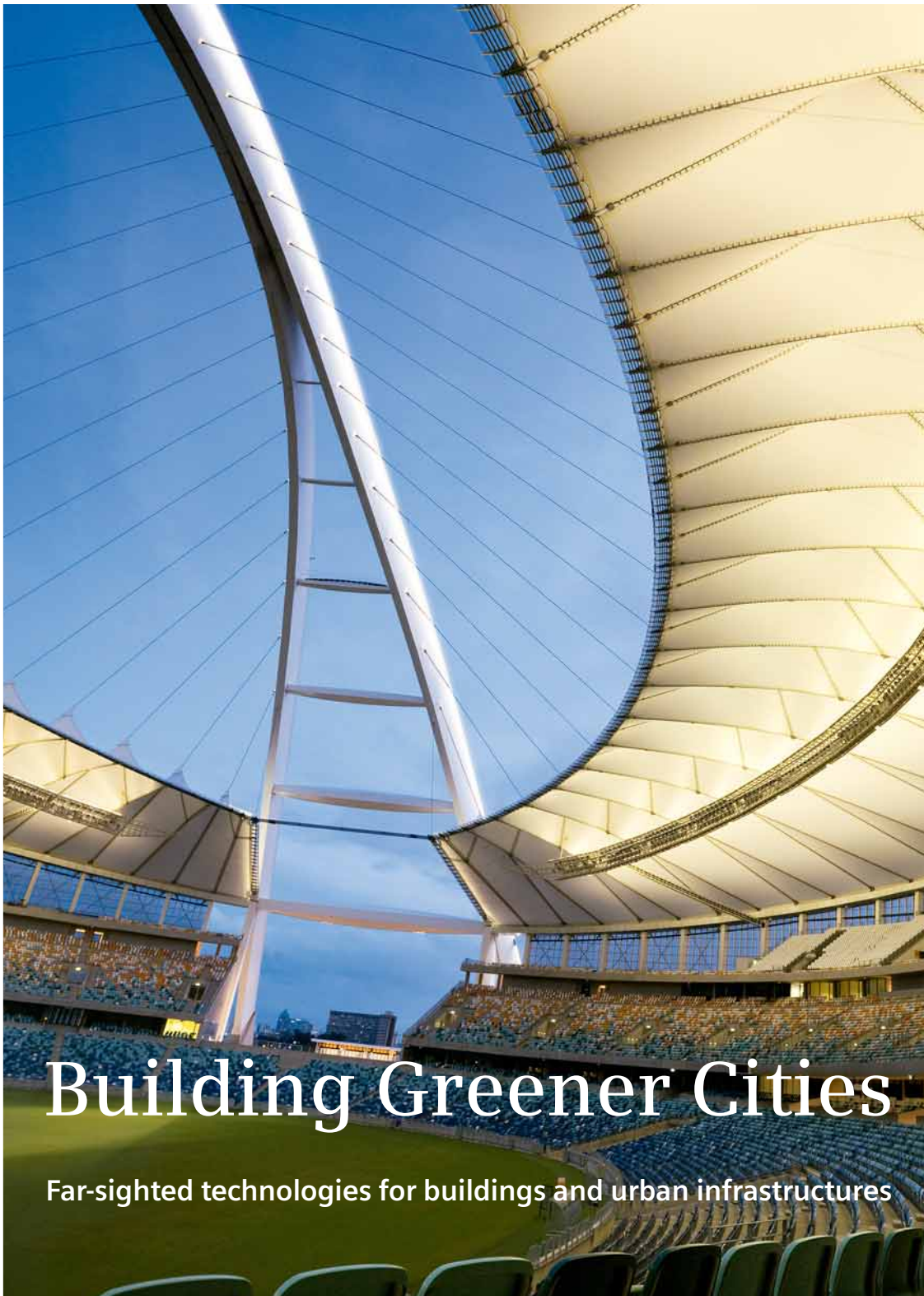
Molecular Detectives

Targeting pathogens and pollutants with new technologies

Open Innovation

Cost-effective, collaborative roads to knowledge



Building Greener Cities

Far-sighted technologies for buildings and urban infrastructures

A Hallmark of Sustainability

Dr. Heinrich Hiesinger is CEO of the Industry Sector and a member of the Managing Board of Siemens AG.

Anna Kajumulo Tibaijuka, Executive Director of the United Nations Human Settlements Programme (UN-HABITAT), summed up a crucial trend of our time when she said, "2007 was the year in which *Homo sapiens* became *Homo urbanus*." That year marked the first time in history that the number of city dwellers surpassed the number of people living in rural regions — and the urbanization process is far from over. In Asia alone, the population of major cities is expected to grow by 80 percent by 2030, from 1.6 billion today to almost 2.7 billion. China already has 175 cities with over a million inhabitants, and every year settlements accommodating an additional 13 million are literally shooting out of the ground.

The slogan of the EXPO 2010 world fair in Shanghai — "Better City, Better Life" — is thus very appropriate. Only sustainable urban development can ensure that tomorrow's cities will remain decent places to live. From May to October 2010, 240 countries, cities, and international organizations will demonstrate energy-efficient and environmentally friendly urban solutions to EXPO's expected 70 million visitors. No other company can offer as broad a spectrum of such solutions as Siemens.

Siemens has received orders worth over €1 billion in connection with EXPO 2010. Around 90 percent of this sum is based on environmental technology. The orders include 50,000 energy-saving light-emitting diodes (LEDs) on the EXPO grounds, new metro lines and parking guidance systems, plus intelligent building technology for buildings inside and outside the exhibition grounds. Siemens also helped to build the Waigaoqiao power plant, which covers almost one third of Shanghai's electricity requirements and is one of the world's most efficient power plants (p. 38).

This issue of *Pictures of the Future* documents how ultramodern solutions for sustainable urban development are being implemented all over the world (pp. 12-55). For example, in conjunction with Tongji University in Shanghai, Siemens develops "eco-city models" (p. 104) that will enable urban growth and environmental protection to go hand in hand in China. In Europe, the company has created the European Green City Index (p. 17), which compares environmental friendliness and associated measures in the continent's 30 most important cities. The Scandinavian cities of Copenhagen (p. 20), Stockholm, and Oslo (p. 22) top the list, while the eastern European city of Vilnius (p. 31) got very good marks for its air quality and buildings.

But conurbations outside Europe and China are also doing pioneering work to create sustainable cities for their citizens — in many cases with help from Siemens. For example, for many years we have been supporting the city-state of Singapore's efforts to become a world-class "green" city (p. 44). Our input includes help with a center of expertise for urban development and efficient solutions for treating wastewater and drinking water. Here, we also plan to inaugurate a pilot plant that uses electrical fields to desalinate saltwater in a highly efficient process — and consumes less than half the energy required by the best conventional methods.

In South Africa, Siemens is playing a key role in modernizing the infrastructure in time for the soccer World Cup (p. 28). The projects in which we are participating include communication technology for traffic and safety systems, turbines for the power supply, and thousands of LEDs for the 350-meter-long arch that rises high above the Moses Mabhida Stadium in Durban. The latter example demonstrates that "enhanced energy efficiency does not conflict with a beautiful form of architecture," as star architect Daniel Libeskind reminds us (p. 36).

His claim is also supported by many of the outstanding pavilions at EXPO 2010 in Shanghai. The Theme Pavilion, the EXPO Center, the Culture Center, as well as the gigantic China Pavilion, all have one thing in common: Thanks to ultramodern building technology from Siemens, they consume up to 25 percent less energy than conventional buildings, while their operating costs are cut by up to 50 percent. After the world fair is over, these buildings will remain a hallmark of sustainability that will symbolize the significance of Shanghai and China.

Cover: Swinging into tomorrow's world — an arch as tall as a 30-story building stretches over the Moses Mabhida Stadium in Durban. Shining brightly, thanks to 15,000 LEDs from Osram, it symbolizes the new South Africa and demonstrates the multifaceted possibilities associated with energy-efficient urban design.

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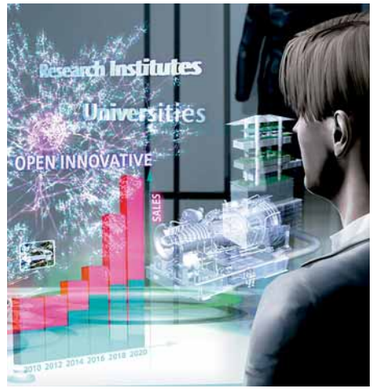

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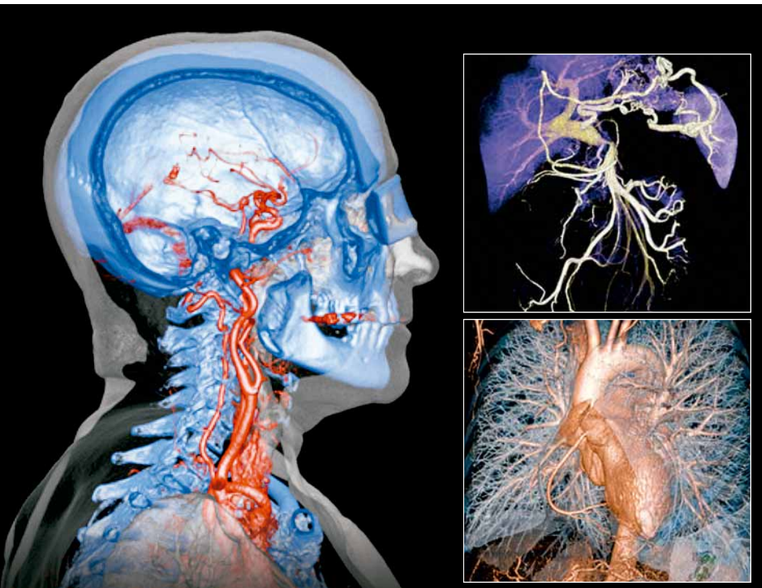


Winning images from a contest illustrate that superb anatomical detail can be achieved with minimal X-ray exposure in angiography (left), pancreatic (top right), and thoracic imaging.

Minimal Exposure

Computer tomography (CT) makes it possible to view millimeter-sized structures inside the body, such as coronary vessels and tiny arteries in the lungs. Because it is essential to minimize patient exposure to X-rays, Siemens Healthcare initiated an International CT Image Contest in October 2009. The competition called on physicians, medical institutes, and hospitals that use the Somaton Definition computer tomography system from Siemens to achieve the best possible image quality at the lowest possible X-ray dosage. Some 300 images from more than 30 countries were submitted for consideration. The names of the winners were announced in March 2010. Successful entries came from Belgium, China, Japan, Canada, Portugal, and Sweden. A jury made up of internationally renowned medical specialists concluded that the winning images were not only of good quality but also demonstrated that a very high level of diagnostic significance — and clear depiction of even the finest details — can be achieved with extremely low radiation dosages. The public was able to join in the discussion on Facebook, where more than 1,400 people commented on the submitted images. "The competition is intended to inform the public about the topic of X-ray dosages and increase their awareness of the responsibility felt by equipment manufacturers and radiologists," says Dr. Sami Atiya, CEO for Computer Tomography at Siemens Healthcare. The Somatom Definition CT, which was developed by Siemens scientists in 2005, is the world's first dual-source computer tomography unit. The device is equipped with two X-ray sources and two detectors that rotate synchronously and simultaneously record data in half the time it takes for conventional technology to do the same. The CT unit can thus record images of the heart within 83 milliseconds — an extremely short exposure time. It is thus possible to produce a very good image even when patients have a high heart rate. The Somatom Definition Flash, which was developed in 2008, is also a dual-source CT. Compared to its predecessor, it reduces image recording time and radiation dosages even further and needs only around 0.25 seconds to X-ray a heart. The dosage required here is less than one millisievert (mSv), as opposed to eight to 30 mSv for conventional devices. *hs*

Turning with the Tides

Siemens has acquired an approximately ten-percent interest in the Marine Current Turbines company. The British firm is a pioneer when it comes to planning and developing tidal power plants that operate underneath the ocean surface. Such facilities utilize currents such as the ebb and flood of the tides to produce electrical energy. The plant turbine is mounted onto a mast firmly anchored into the ocean floor. In a manner similar to a wind turbine, two-bladed rotors rotate with the movements of the tidal flow and

Rotors turn with the tide and produce electricity in a process developed by Marine Current Turbines.

can be turned through 180 degrees on their axis in order to optimally adjust to the direction and speed of the current. Marine turbines produce electricity much more efficiently than their land-based counterparts because the energy density of water is 800 times higher than that of wind. A further advantage is provided by the fact that the regular tidal cycles make electricity production more predictable, which simplifies system planning. Marine Current Turbines has already put its first commercial underwater electricity production facility into operation at the Strait of Strangford in Northern Ireland, where two rotors with a total output of 1.2 megawatts have been feeding power into the grid since November 2008. The facility provides some 1,500 households with electricity, which makes it the most powerful tidal power plant in the world at the moment. The technology offers particularly significant potential in coastal regions with strong tidal currents such as those of France, Canada, the UK, and parts of eastern Asia. *fm*

Dresden secures its treasures with radio frequency IDs.

State of the Art

The State Art Collections in Dresden, Germany, are using sophisticated technology to protect their works of art — RFID chips that Siemens and several partners developed especially for the city's art treasures. The small and inconspicuous radio sensors can be easily affixed to any work of art and do not contain any unsightly wires or other components that could disturb an observer's view. The sensors detect even the slightest movements and use special algorithms to distinguish between unintentional contact and actual emergencies. They then pass the information they collect to a security center in real time. *sw*

Shining Record

Light is creating new opportunities in areas as diverse as mini-projectors and data transmission. Osram has developed the world's smallest blue laser diode in what marks the first step toward the production of tiny projectors that can be installed in cell phones and digital cameras. It may thus soon be possible for mobile terminals to not only show pictures and videos but also project them onto walls. Such projectors create their images line by line from a moving point of light, much like a tube television. In contrast, a new mini video projector generates images like a slide projector — using a powerful light-emitting diode (LED) from Osram, instead of a light bulb. The cell phone-sized pocket projectors can achieve a screen size of up to 127 centimeters. Modulated white LED light can also be used to transmit data wirelessly — without any visible brightness differences. Researchers from Siemens and Fraunhofer's Heinrich Hertz Institute have set a data-transmission world record of 500 megabits per second with their new technique. *hs*

Light emitting diodes can transmit data and project images onto walls (left to right).

Pleasant light and colors help patients feel relaxed during diagnostic exams.

Feel-Good Scanning

Undergoing a CT or MR scan often provokes feelings alternating between fear and hope. Siemens therefore worked with doctors and patients to develop Healthcare Lighting, a lighting design concept for medical facilities. Patients can now choose the lighting mood and colors they would like to have in the examination room. One theme film, for example, displays blue skies or a mountain landscape, depending on the patient's wishes, while also playing the patient's favorite music in the background. Many patients feel more comfortable and relaxed in such an atmosphere. *ak*

Individualized Graffiti

Digital Graffiti — a revolutionary information system developed by researchers at Siemens Corporate Technology and Johannes Kepler University in Linz — has won Austria's "ebiz egovernment award." The technology can be used to leave virtual messages at specific locations for certain people, or just for anyone. Whenever a designated recipient enters such a location, data is transmitted to his or her cell phone and the graffiti can be read onscreen. Plans at the University in Linz call for the system to be used to provide information on subjects of interest, personal appointments, and lecture locations to students and staff. *fm*

Digital graffiti automatically provides location-based information.

Although Lovins' house is high in the Rocky Mountains, intelligent energy-efficiency measures in conjunction with solar cells and rooftop collectors make it self-sufficient.

Inverting the Electric Supply Pyramid

Over 100,000 people have toured the low-energy house Amory Lovins co-designed and built in the 1980s. However, the bespectacled 62-year-old energy expert exudes enthusiasm as he explains the benefits of his recently modernized domicile to visitors with the pride of a man who has turned his ideas into reality — at least in his own home.

The house is located 2,200 meters above sea level in the Rocky Mountains, not too far from Aspen, Colorado, where winter temperatures used to reach minus 44 degrees Celsius. The windows' double glazing encloses two invisible plastic films with heat-reflecting coatings on both sides, and insulating xenon gas fills the spaces in between. Superwindows, superinsulation and ventilation heat recovery — a package that helped inspire the German "Passivhaus" movement — cut the building's heating requirements by about 99 percent. This helped pay for saving nearly all water-heating and electricity too. The total net extra capital cost was repaid by energy savings in ten months. The equipment monitoring the house's data streams may use more energy than the appliances and LED lights.

During the day, Lovins uses rooftop solar cells to generate electricity. Thanks to his efficient household appliances and lamps, he can often feed some of this power into the grid. At night, electricity is provided by wind power from the public grid. The roof also houses a solar-thermal unit that provides hot water and heats the floors. It has thus been over a year since Lovins has had to use the two wood stoves that he installed as a backup. His house is so warm that banana trees have been thriving in its winter garden for more than 20 years. A tour of the house confirms Amory Lovins' key hypothesis that the biggest energy source is it's very productive use.

Lovins, who was awarded an Alternative Nobel Prize in 1983, studied at Harvard and Oxford. At the latter he wasn't allowed to pursue a doctorate in energy. But he was obsessed with the issue, and in 1976 he went public with his message in an essay published in the prestigious journal *Foreign Affairs*. In 1982, he and his then wife, Hunter Lovins, established Rocky Mountain Institute (RMI) in Old Snowmass, Colorado, which today has over 90 employees and partly funds itself through consulting contracts with major companies. Customers include energy groups, automotive companies, the Pentagon, and retail-sector giants such as Wal-Mart. Lovins now serves as the Institute's Chairman and Chief Scientist.

You've been a pioneer in the field of energy efficiency since the 1970s. How does it feel to see the things you've been talking about become part of the public discourse?
Lovins: It's definitely better to see ideas you've promoted gain acceptance after a long time than never to see them accepted. Still, that doesn't mean RMI and I can simply sit back and relax. On the contrary, we've just launched our most ambitious project ever, which we call "Reinventing Fire." This new project coherently brings together into one synthesis all the knowledge we've gained over the past three decades. We're developing a comprehensive roadmap for a profitable transition from coal and oil to efficiency and renewable energy. We also continue to work closely with major companies to develop and spread models of best practice.

Oil is an issue you addressed back in 2004, when you published *Winning the Oil Endgame*...
Lovins: Yes — and we've moved further toward independence from oil today than we could have hoped for six years ago. Gasoline consumption in the U.S. has been declining since 2007, mainly due to more fuel-efficient vehicles and the use of biofuel additives. The U.S. could become independent of imported oil by 2040 and of all oil by 2050. Deutsche Bank is even forecasting that global oil use will start decreasing around 2016.

Eliminating coal is going to be much more difficult, however. The International Energy Agency (IEA) believes that population growth and increasing prosperity will cause global electricity consumption to rise by 76 percent between now and 2030. Experts predict that coal-fired power plants will still be covering more than one third of electricity requirements even in 2030.
Lovins: This scenario will not come about if smart decisions are made. I agree it may be more difficult to stop using coal than oil. But we need to get away from coal, both for climate protection and to make the electricity system more secure and affordable. RMI found that energy efficiency, plus distributed and renewable energy sources in the U.S. can produce 22 times as much electricity each year as US coal does now.

What's the most effective way to decouple electricity production from coal?
Lovins: With negawatts.

Negawatts?
Lovins: That's a typographic error I popularized to mean "saved electricity." Our biggest energy resource is using energy far more productively. The potential here is huge. For example, if the whole country used electricity as efficiently as did the top ten states in 2005, we could replace around 62 percent of the electricity generated with coal in the U.S. With costs of around one cent per kilowatt-hour saved, such measures are much cheaper than generating electricity.

Can you give us an example?
Lovins: Take for example an old office building. We helped the owners of the Empire State Building in New York City to see how a modernization package could reduce the skyscraper's energy consumption by 38 percent with a three-year payback. The design integrates heat insulation, efficient lighting, and remade windows that reduce heating and cooling costs. We've also provided lots of support to industrial companies. For example, RMI helped Texas Instruments to not only cut the construction costs of a chip factory by 30 percent, but also make substantial savings in energy and water at the same time.

Let's talk about electricity producers. Doesn't it make sense in the medium term to build more efficient and environmentally friendly coal-fired plants?
Lovins: Of course, new coal-fired plants should use the best technologies. However, they still have no good business case. Distributed power networks and renewable energy are generally cheaper, cleaner, more robust, and less risky in financial terms. Here in the U.S., wind capacity increased more in 2007 than coal capacity did during the previous five years. And globally we're seeing similar developments. In 2008 the world invested more in renewable energy sources than in fossil fuels.

China is still building a lot of coal and nuclear plants...
Lovins: In 2009, China added only half as many net coal power plants as in 2006. By 2020, the country plans to obtain 120 gigawatts from wind power. The original target of 30 gigawatts by 2020 will already be reached in 2010. China is now the number one maker or user of photovoltaics, wind power and other renewables.

So renewable energy is the answer?
Lovins: Ultimately, there is no unique correct answer. However, renewables are a key part of the solution. Picture the electricity supply system as a pyramid whose base today consists of coal and nuclear power. The middle is natural gas, and the top is renewable energy and efficiency. We should invert this pyramid so that the base is far more efficient electricity consumption. Renewable energy sources and some combined heat and power make up the middle. This part is linked with real-time pricing, demand response, and smart charging and discharging of electrified cars to help balance supply with demand. At the top of the pyramid, the remaining fossil fuels and nuclear power will gradually be phased out, in much the same way that we phased out steam locomotives.

What about the classic problem with renewable energy sources — the base load?
Lovins: That's a widespread fallacy. Individual coal and nuclear plants do not by any means supply power constantly. Thermal power plants are generally shut down ten to 12 percent of the time. Sometimes they unexpectedly fail. On the other hand, some renewable energy sources generate power constantly. Examples include small hydropower plants, biomass and geothermal facilities, and solar-thermal plants with adequate heat storage.

However, wind…
Lovins: …and photovoltaics depend on the weather. It's the same dilemma that the electricity industry has faced since Edison's day: No source of electricity generates power as consistently as some consumers want. That's why we have electricity grids that link all the power plants so that together they can meet demand.

Business leaders are paying more attention to you. Are we now headed in the right direction?
Lovins: None of today's energy supply facilities will still be in operation in 2050. The choices we make today, will determine the energy system we have in 40 years. The spectrum of possibilities is broad, varied, and changing fast. Companies that rise to the challenge will be successful, and we don't need to worry about the others because they won't be around any more.

It seems that these challenges were forgotten at the Climate Conference in Copenhagen.
Lovins: The delegates argued there about how much climate protection costs, who's going to pay for it, and whether it's worth the effort. That's the wrong debate, since investment in climate protection doesn't cost money, it brings in money. That's because it's simply cheaper to conserve energy than it is to generate it. Once politicians and the public begin to understand that, resistance against the necessary measures will melt faster than the glaciers are melting today.

You're really not much of a pessimist…
Lovins: At the RMI, we do solutions, not problems. We're practitioners, not theorists. We do transformation, not incrementalism. And we're neither optimistic nor pessimistic. Both treat the future as fate, not choice, and don't allow us to take responsibility for creating the future we want.

■ *Interview conducted by Hubertus Breuer.*

Solar thermal power plants with parabolic mirrors that track the sun are an established technology for the production of electricity. Below: Siemens' Lebrija 1 pant near Seville.

Focus on the Sun

Engineers have been striving to generate power from solar thermal energy for a century. Now, the technology is finally about to come of age. With the acquisition of Solel, Siemens has become a market leader at the cutting edge of several key solar-thermal technologies: parabolic mirrors, receiver tubes and steam turbines.

There is nothing more powerful, the saying goes, than an idea whose time has come. Solar thermal technology — the generation of energy from the heat of the sun — has tried to get off the ground three times already. In 1912, the American Frank Shuman built a parabolic reflector system in Egypt that was expected to produce 55 kilowatts (kW) of power. "Twenty thousand square miles of collectors in the Sahara," he wrote, "could permanently supply the world with the 270 million horsepower it needs." But the world did not wait; it needed more and more horsepower and increasingly drew its power from oil and other fossil fuels. Solar thermal energy seemed to become a footnote in the history of power generation. It was only the huge increase in the price of oil in the 1970s that aroused new interest in the technology. Sixty years after Shuman's first attempt, the Israeli company Luz developed new parabolic trough power plants. Nine plants from this period are still generating energy today in California's Mojave Desert. But as the price of oil began to fall again, interest in solar thermal systems also waned. Power station projects were postponed or canceled, and Luz went bankrupt.

Now, almost 100 years after Shuman's first project, the day finally seems to have come for solar thermal technology. Avi Brenmiller is one of the authors of this success. He remembers well the disappointments of the past decades: "In the 1980s, I was working on special coatings for the receiver tubes in which thermal oil is heated with concentrated solar energy. Our vision at the time was to master the whole chain — in other words, everything from the capture of solar energy and the steam cycle generation of electrical power. It was depressing to see how a promising technology suddenly lost support," he says.

But Brenmiller was persistent. In the course of a buyout, Luz became Solel, one of the leading suppliers of components for power generation systems using concentrated solar power (CSP) — and Brenmiller became CEO. In the first six months of 2009, Solel posted sales of almost $90 million. Then, in late 2009, Siemens purchased the company. With its staff of more than 500, Solel subsequently became Siemens Concentrated Solar Power Ltd. Brenmiller's dream has come true.

Now, thanks to the acquisition, the key components, systems and solutions for solar thermal power stations covering the entire conversion chain can be supplied from a single source. Siemens Renewable Energy Division offers everything from parabolic mirrors to steam turbines.

"This vertical integration is essential," says Brenmiller. "Concentrated solar power systems are highly complex; which means that the most important driver for maximizing efficiency is the perfect interaction of all components."

A Vision Becomes Reality. A power plant to consist mainly of Siemens components is now being built in Lebrija, Andalusia. The plant illustrates what a visionary project called Desertec might one day look like (see *Pictures of the Future,* Fall 2009, p. 19). The vision of the Desertec Industrial Initiative (DII) is ambitious. It calls for a network of solar thermal power plants and wind farms in the Mediterranean region, the Middle East, and North Africa to not only meet local demand, but to generate 15 percent of Europe's electricity requirements. The industry consortium driving DII, which began its work in 2009, is currently developing economically viable strategies for the construction of a network of plants.

Construction work on the Lebrija 1 CSP plant in southern Spain began in 2008. The majority of its most important components are shipped from Israel and arrive at Cádiz harbor. The contents of the sea-freight containers destined for Lebrija, however, have to be treated as sensitively as if they were raw eggs. Up to 7,000 mirrors arrive each week. Almost 170,000 are needed to fit out what will soon be a 50-megawatt (MW) power plant. All in all, the mirrors account for approximately six percent of the plant's total cost of almost €300 million. Receiver tubes — pipes that receive solar radiation from the mirrors and transfer it to a fluid — are another major expense.

The components are assembled on-site in Lebrija in a specially-built hall. "When we arrived, we found a cotton plantation at the site," says Siemens Concentrated Solar Power Vice President Moshe Shtamper, who is responsible for the construction of the thermal solar facility at Lebrija 1. His project team first had to remove the cotton and then have drains laid in the marshy delta of the Guadalquivir River. Now there are concrete pillars extending down as far as 40 meters into the ground, and the 6,048 parabolic troughs are mounted on top of these. Each trough consists of 28 individual mirrors that focus light onto the receivers. The parts are now being put together in the assembly hall by workers from the area some of whom used to earn their living by picking cotton. Using hydraulic hoisting cranes, they are combining individual mirrors to create parabolic troughs, which are then transported to the solar field by a tractor and trailer. There, cranes hoist the two-ton troughs into position. The plant could go online before the end of the year and, with the help of a steam turbine from Siemens, is expected to supply over 50,000 Spanish households with electricity. (see p.10).

"The most important objective for the coming years is to further reduce the cost of electricity produced at CSP plants," says Eli Lipman, Vice President of Research and Development at

Why Receiver Tubes Are Hot Stuff

The basic principle of solar-thermal power generation is simple. Energy from the sun heats water, either directly or indirectly through a heat transfer medium. The water turns to steam, and the steam drives a turbine at high pressure (see *Pictures of the Future,* Fall 2009, p. 23). Parabolic mirrors focus the needed sunlight onto a small surface in order to achieve sufficiently high temperatures. A receiver tube is fixed in the focal line of a row of concave mirrors. A liquid flows through these tubes as a heat transfer medium — synthetic oil and molten salt are the most commonly used substances today. The heat transfer medium is heated to approximately 400 degrees Celsius — molten salts allow temperatures of up to 550 degrees and are therefore more efficient — and in a second step releases the heat via a heat exchanger to water, which turns to steam and ultimately drives a turbine.

The receivers have a considerable influence on the overall efficiency of the plant. Siemens is therefore pursuing intensive research on further improvements to these high-tech tubes (photograph above). The highest priority is absorbing as much solar radiation as possible while simultaneously preventing emission of the heat stored in the transfer medium. The structure of the receivers is complex. "The coating is crucial: multiple layers of various materials, including a ceramic-metal mixture, reduce the re-radiation losses," says Vice President of Research and Development at Siemens Concentrated Solar Power, Eli Lipman. The heat transfer medium flows through a stainless steel tube. This is enclosed in a glass cylinder, and in the space in between there is a vacuum.

A receiver tube is therefore similar in principle to a greenhouse. The maximum amount of sunlight must get inside, but the heat produced there should not get outside. The better this is accomplished, the more efficient and profitable the solar installation becomes. But great heat also poses significant challenges. As temperature increases, the various materials used for the receiver expand at different rates. A sort of bellows connecting the metal tube with the outer glass pipe flexibly compensates for the resulting stresses.

The latest Siemens receiver tubes are currently the most efficient ones on the market. In a 50 MW plant, the use of this model instead of conventional receivers would mean yield an extra 6,500 MWh per year, or enough power for an additional 1,500 households. That represents a five-percent increase in the efficiency of the plant as a whole — just from improvements to the receiver.

Siemens Concentrated Solar Power. "The real breakthrough for solar thermal technology will come as soon as it allows power generation at competitive prices — in other words, when it can do without subsidies."

The influence of the receiver tubes on the overall efficiency of a solar thermal plant is greater than that of any other individual component. One priority is therefore to make this link in the chain even more efficient. At the end of 2009, Siemens Concentrated Solar Power introduced what is currently the most efficient receiver on the market. Its efficiency derives from a combination of high solar absorption and reduced thermal loss. The latter is dependent on the extent to which absorbed solar energy is re-radiated. The improvement is partly due to special thin film coatings, explains Lipman: "We can now capitalize on synergies in research and development with Siemens Corporate Technology. This will help us to further enhance the technology. We expect to be able to achieve not only an efficiency of more than 25 percent at peak load but also an average overall yearly efficiency of more than 16 percent."

Other components influence the economic efficiency of solar thermal power plants as well. By using larger parabolic mirrors, for instance, fixed costs per square meter can be driven down. Additional mirror-related improvements will help to reduce the final cost of energy based on initial investment, operations and maintenance, and the cost of capital. "By combining our strengths and optimizing the solar field and power block subsystems we are using an additional lever to raise the efficiency of CSP facilities," says René Umlauft, CEO of the Siemens Renewable Energy Division. "We have a clear target of producing electricity at a competitive price in the mid term."

Perfect Curves. The individual mirrors that make up parabolic troughs are manufactured near the town of Nazareth in the north of Israel. Siemens project manager Ehud Epstein puts on safety goggles that protect his eyes from flying shards and opens a second button on his shirt. The closer he gets to the oven, the hotter it gets. At approximately 1,500 degrees Celsius, the special-purpose silicate in the oven melts into glass. "At other times, glass for armored vehicles is made here. We do a separate shift for parabolic mirrors," says Epstein. "In this case, we use glass with a low iron content. This ensures that they absorb only a minimal amount of solar energy and therefore reflect most of it." The hot liquid glass flows out of the oven over steel rollers in a river of molten light. Sheets measuring 1.6 by 1.7 meters in diameter are broken out, ground down at the edges and then heated again. The glass sheets are placed on stainless steel mats and then passed through another oven that was specially built for this purpose. Here, in the course of about 1.5 hours, they slowly take on the desired curved shape needed for perfectly focusing solar radiation. "During this stage, it's important that there be no stresses left in the material that could later lead to fractures. After all, we guarantee a service life of 25 years."

With parabolic mirrors, getting just the right curve is essential to maximizing efficiency. Meticulous quality control takes place in a plant in Israel, helping to ensure at least 25 years of operation.

A single parabolic trough consists of 28 individual mirrors. Since the trough must be able to reflect sunlight in such a way as to perfectly focus it on a nearby receiver tube, each mirror must have a curvature of a fraction of a degree in order to minimize scattering losses. What's more, the mirrors themselves must absorb as little solar radiation as possible. As is the case with receiver tubes, coatings play a key role in terms of maximizing desirable characteristics and minimizing undesirable ones. Thus, Epstein's team ensures that a silver solution, as well as a coating of copper and several layers of corrosion-inhibiting paint are sprayed on the back of each mirror

Epstein walks past a long line of finished mirrors. Depending on how they are standing, he seems to become either widened to comical proportions or extended vertically into a skinny giant with thin limbs. "This is my hall of carnival mirrors," he jokes. "After a long day, you just have to stand in front of the right one, and suddenly you've gotten rid of all those extra pounds for a few seconds. That puts you in better spirits."

Competitive Production. While some solar thermal power plants have entered service in Spain and the U.S. state of Arizona, plans are only now being made for the first facilities in Israel. "The irradiance data for Israel are perfect. The whole Negev Desert is an ideal area for CSP plants," says Brenmiller. "And if the plants were also equipped with gas turbines, you could generate power competitively right now in Israel, even without any subsidies." The downstream steam turbine in such gas-solar hybrid power plants can be powered by solar heat, and by the waste heat produced by the gas turbine. This means that the power plant can also generate electricity during the hours of darkness.

At least for a transitional period, solar energy and fossil fuels will coexist to maximize each other's strengths. However, the energy mix as a whole will increasingly shift toward renewable energies, Brenmiller believes. If for no other reason, this development will definitely take place simply because of dwindling oil reserves.

In retrospect, then, it almost seems an irony of history that solar thermal technology should have made one of its grand entrances right at the start of the oil age, approximately 100 years ago. After all, it is now making another, just as that particular age appears to be nearing its twilight.

■ *Andreas Kleinschmidt*

Siemens' Lebrija 1 plant in southern Spain is designed to generate electricity for at least 25 years.

Israel: Perfect Place for PV

Israel is an ideal location for harvesting the sun's energy — not only in the form of solar thermal power plants, but also with photovoltaic systems that promise big yields. Siemens has taken a 40-percent stake in Arava Power, Israel's leading developer of photovoltaic systems. Siemens is also the general contractor on a project to build the first PV power plants in the desert — including one at Kibbutz Ketrua in the south of Israel. Here, in this desert region between the Red Sea and the Dead Sea, the conditions for solar power couldn't be better. By the end of 2010, the Kibbutz Ketrua could be feeding energy from a five-megawatt photovoltaic facility into the grid. Apart from solar panels themselves, which are being supplied by Suntech, almost all the components of this first plant will come from Siemens. Mike Green, Chief Electrical Engineer at Arava Power, is proud to be a pioneer for green energy in Israel. "My big hope is that this will mark the beginning of a lucrative future for renewable energy in Israel," he says.

Highlights

It's 2040, and Singapore's skyscrapers have become havens of food production. The plantations on people's roofs are taken care of by "vertical gardeners" like Lee, a former architect and urban planner. His workplace on the top floor is a complex biotope in the midst of a teeming metropolis — an unspoiled garden where fruits grow untouched by genetic engineering. But this paradise too is an artificial world...

Master of the Hanging Gardens

Singapore in 2040. Lee, a former architect and urban planner, has turned his hobby into a profession. He's one of the "vertical gardeners" of this metropolis — and the master of an exotic small world located high above the city.

The old man dressed in simple overalls doesn't quite fit into the overall picture. After all, this is the sophisticated lobby of Tiger Towers, one of Singapore's most modern skyscrapers. And he certainly won't need the hedge clippers he's carrying if he's got a reservation at the gourmet restaurant in the building or if he's heading for the up-market hairdresser on the 40th floor.

In fact, Lee comes here every evening because this is his workplace. Before he retired, Lee, who is now 70 years old, was a renowned architect and innovative urban planner who accompanied Singapore's growth. But now he has turned his hobby into a profession. Lee is one of Singapore's officially designated "vertical gardeners." He strolls leisurely over to the elevators at the other end of the lobby, enters one, presses the button for the top floor, and looks into a small retina scanner, as usual.

In a fraction of a second, the fingerprint chip in the elevator button and the retina sensor recognize his identity. "Access permitted," says a woman's soft voice, and the elevator zooms upwards. The elevator doors open slowly, revealing a view of a different world. A wave of bird song and the chirping of countless in-

sects rolls toward Lee. A canopy of leaves and flowers arches over him, and there is a smell of damp earth and exotic flowers.

A narrow footpath winds its way from the elevator through the green thicket of plants and loses itself between a pair of hibiscus bushes. Lee shoos back a chicken that is about to join him in the elevator and dives into the tropical garden.

As though he had passed an invisible barrier, the temperature suddenly changes — the perfectly air-conditioned world of Tiger Towers is transformed into the hot and humid climate of a rainforest. But when Lee pulls out his PDA, this wilderness is revealed to be the perfect illusion of an exotic jungle — an ultramodern greenhouse on the top floor of one of the city's countless skyscrapers.

With just a few clicks, Lee can monitor, control, and make changes to this artificial world. Countless sensors are buried in the soil to monitor its temperature, moisture, and nutrient content. An intelligent management system automatically controls the amount of sunlight coming in as well as the ventilation and irrigation. The systems are powered by solar cells mounted all over the building. Lee is actually more of a manager than a gardener here, because the actual gardening work is done by robots that scurry through the underbrush on their metal legs.

Nonetheless, in this verdant setting Lee is more than just an extra. He played a major role when this "green floor" was designed, and the success of this concept justifies his efforts. In spite of its jungly appearance, the garden is more of a natural plantation than a park. Between the bushes and hanging vines, there are flourishing beds of vegetables, mangoes, bananas, and other tropical fruits that are sold at a profit.

The quality of these products is very high, because the fruits are not only free of genetic engineering and are organically raised, but are also growing in a natural environment — in contrast to the city's other high-rise farms, where plants are grown in dense monocultures. Lee's exclusive group of customers includes the gourmet restaurant located a few stories below. There the renowned Swiss chef Jean Amann rules the kitchen. The multi-star chef has gotten in touch with Lee again today in order to buy fresh produce from this vertical organic farm — direct from the producer.

The ringing of Lee's PDA interrupts his tour of inspection. "Mr. Amann has just arrived," announces a virtual assistant. "But I'm afraid he's lost his way." The idyll is disturbed by a crackling in the underbrush, followed by quiet cursing and a loud cackle. "Jean, have you gotten lost again!" Lee shouts into the thicket. "I'm standing at the edge of the plantation in front of the panoramic window. Come here, but use the footpath. You're confusing my whole ecological balance here."

A few seconds later, a sweaty figure comes into view and joins Lee in front of the gigantic window. Beneath them stretches the metropolis like a spiderweb, peppered by hundreds of small parks and green areas. Even the high-rises are covered with greenery — some have plants on their facades, others have dozens of green terraces. "Do you have to have your chickens running around like that?" pants the chef. "At least you got rid of those little potbellied pigs. One of them wandered into the elevator once and got out in the restaurant — that wasn't the least bit funny."

Lee grins. "Jean, my old friend, the chickens fertilize my garden, gobble up any garden pests, and ultimately end up in your cooking pots. All of them fulfill a purpose — like so many other things in this city."

He points out the window. "Just look at all the plants on the facades of the buildings. They don't just look beautiful, they also act as a natural air-conditioning system to reduce the temperature inside the buildings. That saves lots of energy and money. Or take the facades themselves. The paint on some of the buildings contains titanium dioxide, which can transform sunlight into electricity, just like the silicon in a solar cell." Lee taps on the window pane. "What's more, many windows have transparent organic light-emitting diodes attached to them to serve as light sources as soon as it gets dark.

And what you see in this garden isn't here just for its entertainment value," he explains. "Singapore is a tiny city-state that has very little available space. The vertical farms in the high-rises help us to decrease our dependence on imports. What's more, food produced locally saves immense amounts of transportation and refrigeration costs, as well as reducing carbon dioxide emissions, of course."

Lee gives the chef a slap on the shoulder. "But that's enough lecturing, let's get down to business. Today I've got something very special for you: freshly plucked durian fruits, harvested in a vertical farm for the first time ever. Take a look!" Amann sniffs at this delicacy, which is notorious for its penetrating odor. "It reminds me a bit of your pigs," says the chef with a smile. "How much do you want for them?" Lee gazes at the sunset. "For you, my friend," he says, "everything is free today. But do me a favor. Wait for a minute, so I can take you back to the elevator."

■ *Florian Martini*

It would be difficult to imagine a greener city. Here, the inhabitants all live in one gigantic building that blends in perfectly with its immediate environment. Construction materials are all locally produced and fully biodegradable. A sophisticated arrangement of gangways, ventilation shafts, and layers of insulation ensures an agreeable climate inside, even when outdoor temperature variations are extreme. What's more, it does so without having to consume a single kilowatt-hour of energy. In fact, the building is situated in such a way that only its narrow side catches the midday sun, thus reducing the effects of solar heating. Deep within the structure itself, residents tend huge gardens, which provide food for the entire city. Here, the sum total of the greenhouse gases produced by the population is merely the result of their digestive processes.

Sounds like science fiction? For termites and other insects, it's been a reality since the beginning of time. These ingenious creatures are veritable masters of green urban planning. Their nests, which can grow as tall as seven meters, not only provide a home to millions of fellow insects; they are also extremely energy-efficient and built in total harmony with nature. In this respect, at least, termites are far ahead of us. "We need to learn that life in confined spaces and sustainability are not mutually exclusive," says U.S. architect and

Termite towers (left) have been examples of sustainable architecture for millions of years. The cities of the future are set to follow nature's lead, as here, in a vision of Hong Kong's vertical farms.

Urban Nature

More and more people are moving to cities, which now account for 80 percent of greenhouse gas emissions. To steer this rapid urbanization toward a greener future, major cities are increasingly turning to new, energy-efficient technologies.

urban planner Daniel Libeskind. "Combining the two is currently the biggest challenge facing urban development."

In fact, many of today's megacities are seemingly endless concrete jungles that continue to devour space and resources. Forecasts indicate that the number of megacities — those with at least ten million inhabitants — will increase from 22 to 26 by 2015. The majority of these are to be found in emerging and developing countries — in other words, places where sustainability hasn't always been assigned top priority in the past. Here, the authorities often have limited means at their disposal to tackle the most urgent environmental challenges. These include improvements to local public transport, refurbishment of buildings, and renewal of power and water infrastructures.

Yet the battle to limit climate change could be fought most effectively in large population centers. Cities already account for 75 percent of the energy consumed worldwide and are responsible for 80 percent of greenhouse gas emissions. Today, architects such as Libeskind see a gradual change in attitude. "There's a rethink taking place," he says. "Municipal authorities are now looking at more sustainable ways of shaping rapid urbanization. That creates a lot of potential for innovation." London-based HSBC bank estimates that around 15 percent of current measures to stimulate the economy worldwide are going into green infrastructure projects such as energy-efficient building systems (see p. 34). At the same time, the latest findings in climate research may have also made cities wake up to the issue of sustainability. That's because the impact of climate change — droughts, water shortages, and rising sea levels — would hit developing and emerging countries the hardest.

Singapore has been demonstrating how to conduct sustainable urban planning in a confined space ever since it gained independence in 1965 (see p. 44). The city state, which comprises an area smaller than Hamburg, Germany, is home to five million people. Nevertheless, or perhaps because of this, it is one of the greenest cities in Asia. "We have high population growth, like other cities, but hardly any raw materials and a land area of only 710 square kilometers," explains Richard Hoo, Group Director of Strategic Planning at Singapore's Urban Redevelopment Authority. "That's why it's always been crucial for us to grow in a sustainable way." Singapore's population has increased by 70 percent since 1986.

According to Hoo, the area of green cover has also grown by 50 percent over the same period. Besides having numerous parks, which provide a welcome retreat for the city's inhabitants, as well as a natural air conditioning system, Singapore also promotes the use and development of energy-efficient technologies. Siemens, for example, runs a center of competence for sustainable urban development in Singapore and is currently working on new, more efficient methods for the treatment of water and wastewater. The company is planning to open a pilot desalination plant in October 2010. The facility will use electrical fields to separate salt from seawater in a process that requires less than half the energy consumed by conventional methods.

For instance, the company is planning to equip an entire district of Shanghai with energy-saving building systems. Municipal authorities will be able to completely cover the payments for these systems with what they save in energy costs.

At the same time, Siemens is busy developing "eco city" models in cooperation with the School of Urban Planning at Tongji University. These models are designed to ensure that megacities are planned from the very outset to be as sustainable as possible. And this year's Expo in Shanghai, with its motto "Better City, Better Life," will likewise show that China is no paper tiger when it comes to sustainability. About 70 million Expo visitors from around the world will have an opportunity to inspect a host of green solutions to the problem of exploding urbanization.

China's megacities are developing into test beds for energy-efficient, climate-friendly technologies.

Energy-efficient buildings offer the quickest route to reducing cities' greenhouse gas emissions — here Siemens' Beijing headquarters (L), Singapore skyscrapers (M), and Madrid's Torre de Cristal.

China, Singapore's huge neighbor, is also looking at ways to give urban growth a greener hue (see p. 38). There, over half a billion people already live in cities, a figure that could well double by 2030. At present, coal-fired power plants meet the biggest share of the country's energy needs, which are growing with increasing urbanization. In addition to environmental problems such as smog and wastewater pollution, this presents the authorities with the problem of rising CO_2 emissions. China has already surpassed the U.S. as the world's largest producer of greenhouse gases and, according to the International Energy Agency, it emitted around six billion metric tons of CO_2 in 2007 alone — almost twice its 2001 level. In order to prevent the fruits of its economic growth from literally going up in smoke, China now intends to use renewable energies to generate a 15-percent share of all the power it will consume by 2020. That will turn China's megacities into El Dorados for energy-efficient, climate-friendly technologies such as those from Siemens.

Photosynthetic Facades. On the other side of the world, European countries are also involved in a major effort to make urban planning more climate friendly. In Europe, where 72 percent of the population already lives in cities, compared to around 43 percent in China, the primary challenge is therefore to make existing infrastructures more energy efficient and environmentally compatible.

In a report commissioned by Siemens, research and consulting company Economist Intelligence Unit has investigated which European cities are particularly progressive in terms of sustainability (see p. 17). Heading the "European Green City Index" is Copenhagen, followed by Stockholm, Oslo, and Vienna. The Danish capital owes its top ranking to a host of energy-saving and climate-protection measures, including an ultra-efficient district heating system, the increasing use of wind power, and the introduction of electrically-powered buses in local public transport. These are all elements of an ambitious plan by municipal authorities to turn Copenhagen into Europe's first completely CO_2-free city by the year 2025 (see p. 20).

There's certainly no lack of creative ideas about how to realize this vision of the green city. For instance, Siemens researchers Osman Ahmed and Maximilian Fleischer have plans for a special facade coating that exploits the principle of photosynthesis. Like plants, buildings would then be able to convert carbon dioxide from the air into substances such as methanol, which could be used as fuels (see p. 46).

Meanwhile, other visionary technologies are already in use. In the city of Regensburg, Germany, for example, a UNESCO World Heritage Site, the street lighting is now provided — as of the end of 2009 — by highly efficient LEDs supplied by Siemens' Osram subsidiary, which use only around half as much power as conventional street lamps (see p. 54). Osram researchers are also developing organic light-emitting diodes (OLEDs). In the future, these new transparent light sources could be used as windows, where they would allow sunlight in during the day and then emit light at night (see p. 52). According to scientists such as Columbia University Emeritus Professor Dickson Despommier, though, the time has come for city planners to turn to the example of termites in order to ensure sustainable urban development (see p. 49). In harmony with nature, skyscrapers in the megacities of the future would then be able to serve as tremendous greenhouses in which vegetables, fruits, grains, and poultry are grown exclusively for local use — just as insects have been cultivating their "gardens" for millions of years.

Florian Martini

Copenhagen's extensive energy conservation and climate protection efforts make it the most eco-friendly city in Europe. The city plans to become completely CO_2-free by 2025.

What Makes a City a Winner?

The European Green City Index, a study by the Economist Intelligence Unit in cooperation with Siemens, compares the environmental compatibility of 30 European cities. Topping the list is Denmark's capital, Copenhagen.

The facts speak for themselves: Half of the world's population lives in cities, and in Europe, where urbanization is even further advanced, 72 percent of the population are city-dwellers. This situation has significant environmental consequences because urban centers account for 75 percent of global energy consumption and 80 percent of the greenhouse gas emissions generated by human activity. Cities thus offer the potential of playing a greater role than ever in the battle against climate change. How are cities dealing with this responsibility? The question gives us ample reason to take a closer look at Europe's major cities. What efforts are they making to conserve resources? How are they trying to prevent environmental damage, reduce CO_2 emissions, and maintain urban areas as places worth living in? What exemplary environmental protection projects are they carrying out?

To answer these questions, Siemens commissioned the Economist Intelligence Unit (EIU), an independent research and consulting firm, to compare the environmental performance of 30 major cities in 30 European countries. From Athens to Zagreb, from Ljubljana to Istanbul, and from Oslo to Kiev, the study targeted the largest cities in the countries in question, in most cases their capitals. In order to illustrate their environmental and climate protection performance and objectives, each of the cities was assessed on the basis of 30 indicators divided into eight categories: CO_2 Emissions, Energy, Buildings, Transportation, Water, Air, Waste/Land Use, and Environmental Governance. The methodology for the study was developed by the EIU in cooperation with independent urban experts and Siemens. "The result is the European Green City Index — a ranking of the most important European cities that is unique in terms of its broad scope," says James Watson, managing editor of the study.

"The European Green City Index provides insights into the strengths and weaknesses of each city," says Stefan Denig, project manager at Siemens. "In this manner, it supports the efforts of these cities to develop more effective climate protection measures, and it also helps with prioritization of environmental activities." Most important, however, is the fact that the study allows the cities to learn from each other, something that is well worth the effort. Whether it's Europe's largest biomass power plant in Vienna, the continent's most modern offshore wind power facility in Denmark, the recycling lottery system in Ljubljana, free rental bikes in Paris, landfills with methane production facilities in Istan-

bul, or buses equipped with systems that cause traffic lights to turn green faster in Tallinn, the study focuses attention on interesting projects in each city that can serve as models for the others.

Some Key Findings from the Study:

→ Copenhagen is the greenest city in Europe (see p. 20). The host city of the 15th UN Climate Change Conference held in December 2009 performs very well in all eight categories. Second place in the overall rankings is Stockholm, and Oslo finishes third (see p. 22), followed by Vienna and Amsterdam.

→ In general, the Scandinavian cities earn the highest rankings in the index, which should come as no surprise, given that environmental protection has been a popular cause in the region for many years. The fact that Scandinavian countries are very affluent helps as well, and cities in the region thus make the most of their financial power to promote investments in environmental protection measures. Energy-saving buildings, extensive public transport networks, and energy production from renewable sources, especially wind and water, are widespread throughout the region.

→ Eastern European cities are generally rated below average in the Green Cities Index, with the highest-ranked city, Vilnius, the capital of Lithuania, finishing in 13th place in the overall index. This result is in part due to the relatively low gross domestic product in the region and its history — after all, environmental protection was considered unimportant for the most part during the Communist era. The latter fact is reflected in the region's high energy consumption, particularly by buildings and other outdated infrastructures. But Eastern European cities generally perform above average when it comes to local public transport. The percentage of people who use public transport to get to work in Kiev, for example, which took 30th place in the index, is the highest among all the cities studied.

→ The top-ranked city in the CO_2 Emissions and Energy categories is Oslo. The Norwegian capital benefits here from its use of hydroelectric power to generate energy. Overall, renewable sources already account for 65 percent of the energy consumed in Oslo, which is also pursuing the very ambitious goal of reducing CO_2 emissions by 50 percent by 2030. In addition, the city is encouraging more extensive use of district heating systems and hybrid and electric vehicles. Oslo also operates a climate and energy fund financed by means of a local electricity tax. The fund has been used to support a large number of energy efficiency projects over the last 20 years.

→ First place in the Buildings category is shared by Berlin and Stockholm. Following German reunification, Berlin modernized a large share of its buildings in line with stringent energy efficiency guidelines. The result is CO_2 savings of between one and 1.5 metric tons per year in modernized buildings. Berlin also launched a public-private energy partnership program for its public buildings, with companies including Siemens. The private firms in these partnerships assume the modernization costs and pay back their up-front investments based on the energy savings achieved. Stockholm stands out by virtue of its exemplary energy-efficiency guidelines and construction of houses and residential areas that use very little energy. These houses have a total energy consumption of less than 2,000 kilowatt-hours per year, despite the city's cold climate.

→ Stockholm also came out on top in the Transportation category. Thanks to a perfectly structured bicycle path network, 68 percent of the city's residents ride their bikes to work, or walk — three times the average of other European cities. An additional 25 percent of the population uses the public transport system. The Swedish capital also relies on state-of-the-art technology for its public transport system, which includes ethanol-powered buses and intelligent traffic guidance systems that ensure smooth traffic flows.

→ Amsterdam led the field in the Water and Waste/Land Use categories. Average water consumption in the 30 cities studied is more than 100 cubic meters per capita per year, but residents of the Dutch capital only need 53 cubic meters. This is in part due to low water losses — only 3.5 percent of Amsterdam's drinking water is lost due to leaky pipes. In addition, the city's ever-present water meters motivate users to conserve. Amsterdam can also be proud of its high recycling rate — one of the reasons it finished first in Waste/Land Use. A total of 43 percent of all municipal waste, double the European average, is separated and recycled in the city — while most of the remainder is used to produce enough energy to supply 75 percent of Amsterdam households with electricity. Just one percent of the city's waste is disposed of in landfills.

→ Vilnius is the top-ranking European city in the Air category (see p. 31). In addition to its very low levels of exhaust gas and emissions, the Lithuanian capital also emphasizes expansion of green areas and forests — within and outside the city. Vilnius' top ranking in the Air category is also due to its small size and lack of heavy industry.

Focus on Environmental Protection. Most of Europe's major cities are already leaders in environmental performance. Nearly all the 30 cities studied — which together have almost 75 million inhabitants and average per capita CO_2 emissions of 5.2 metric tons — lie below the average emissions figure for all EU countries, which is 8.5 metric tons. The top city, Oslo, produces only 2.2 metric tons of CO_2 per capita and year. What's more, environmental awareness is increasing. Of the 30 European cities studied, 26 have developed their own environmental plan. Half of the cities also have firm, feasible CO_2-reduction targets. Copenhagen is planning to be completely CO_2-free by 2025 (see p. 20), and Stockholm intends to do the same by 2050. Still, all the cities are facing major challenges. For example, on average, renewable energy sources account for only around seven percent of their total energy supply — well under the EU target of 20 percent by 2020. Less than 20 percent of the waste in the cities studied is currently recycled, and one of every four liters of water is lost through leaky pipes.

Scandinavia has invested in environmental protection for years — resulting in top rankings in the Index.

In Stockholm, 68 percent of residents ride their bicycles to work. Berlin (right) modernized most of its buildings in accordance with strict energy efficiency criteria after 1990.

Clearly, one of the key indicators determining a city's ranking in the index is its relative level of affluence. For example, nine of the cities that made it to the Top 10 have above-average gross domestic products (GDPs). These cities not only have better, more environmentally-friendly infrastructures than are found in less affluent cities; they also are pursuing more ambitious climate and environmental protection goals — a surprising result given the fact that affluence and a higher level of development are often associated with higher energy consumption and emissions.

Getting Involved But money isn't everything, as Berlin and Vilnius impressively demonstrate. Despite having the ninth-lowest GDP of all 30 cities, Berlin still managed to finish eighth in the overall rankings, ahead of other large and more affluent cities such as Paris, London, and Madrid. Berlin also shared the best ranking in the Buildings category with Stockholm. Vilnius, with the sixth lowest GDP in the index, leaves all other cities behind in the Air category and has the best overall ranking (13th place) among the Eastern European cities.

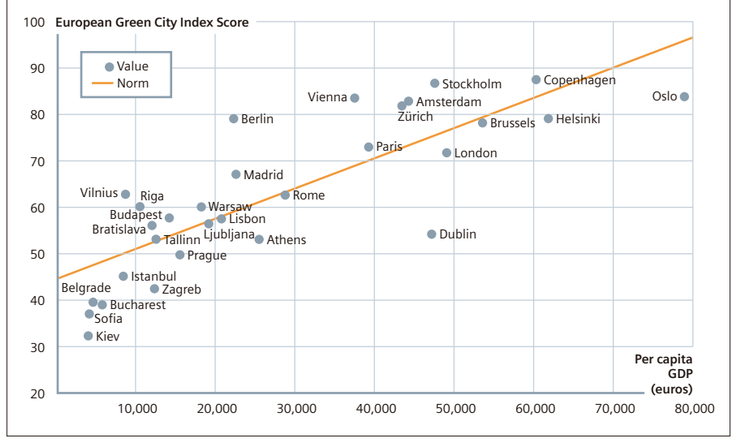
A lot of this has to do with people, however. The environmental protection efforts of individual urban residents add up. The more residents get involved, the better a city's ranking in the European Green City Index. This opens up interesting possibilities for getting urban populations involved when it comes to climate and environmental protection.

One option here is citizen participation as it's being practiced in Brussels, which launched an initiative known as *Quartier Durable* (sustainable neighborhood). The initiative calls on residents to develop green ideas for their neighborhoods. The most promising ideas receive technical and financial support from the city.

Raising awareness of environmental and climate-change issues and providing information are also indispensable elements in the battle against climate change. "Many decision-makers still don't realize that investments in energy-efficient technologies tend to pay off financially," says Denig. Whether it's better building insulation, energy-saving lighting systems, or efficient building management systems — most of these technologies require a higher initial investment, but it's one that pays off in the form of lower energy costs throughout product life cycles (*see Pictures of the Future*, Spring 2009, p. 35). "What's more," says James Watson, "if most of the residents of a city use public transport, conserve water and energy, and make 'green' purchasing decisions, the change in their behavior can add up to far greater results than what can be achieved with restrictive city regulations."

Karen Stelzner

Gross Domestic Product: A Major Factor Affecting the Ranking of almost all European Cities



Ranking of Europe's-Greenest Cities

Support for public transportation, energy-efficient buildings, and a focus on wind power have turned Denmark's capital into Europe's most environmentally-friendly city.

Wind, Wood & Two Wheels

With its first-place ranking in the European Green City Index, Copenhagen outshines 29 other major municipalities. Its title as Europe's most environmentally-friendly city is the result of a wide range of climate-protection measures, such as pellet-powered district heating, wind parks, bike paths and integrated public transit.

If there's one instantly recognizable sign of Copenhagen's green credentials its the vast number of bicycles on its streets. A considerable number of the city's 520,000 residents are avid bicyclists, even when clouds are low and the rain sets in. The city's broad cycling lanes literally teem with bicycles, bikes with trailers, and even sporty-looking tricycles complete with transport box for carrying a child passenger or packages. "If you look at photographs from the 1930s, you see a very similar picture," says Peter Elsman, deputy finance director of the city of Copenhagen. "Back then, not many people were able to afford a car; but today, having a bicycle is just part of the Copenhagen way of life. Almost 40 percent of the city's population travels by bike every day to their place of work or study."

The bicycles are a perfect symbol of Copenhagen, host of the 2009 UN Climate Change Conference, and of its current standing as Europe's greenest city. This honor was conferred back in December, during the UN conference, when Siemens and the UK's *Economist* Intelligence Unit presented the European Green City Index (see p. 17). Copenhagen's top position is, of course, a result of more than bicycles. It was made possible by a package of measures that have placed the city just ahead of Stockholm, Sweden, in the green ranking.

What makes Copenhagen the leader of the pack? For starters, its district heating system is unique worldwide. The system is very efficient and provides heating for 98 percent of all households by means of a large combined heat-and-power (CHP) plant, rather than having each household produce its own heat. All in all, while eliminating the need for private heating systems, the city's CHP plant is 90 percent efficient. Copenhagen started laying twin pipes for superheated steam as far back as 1925, initially to supply hospitals with steam to sterilize their operating instruments. Today, the city has 1,500 kilometers of twin pipes transporting superheated steam and hot water from the CHP plant to households and back again.

For many years, the plant, which also serves several communities in the surrounding area, was fired with coal. No longer. One of the cogeneration units is now fired with environmentally-friendly wood pellets, and a second is scheduled to be converted to this fuel in the near future.

Committed to Wind Power. Aside from relying on its combined heat and power plant, Copenhagen also meets some of its electricity needs with wind energy, which today meets, on average, one-fifth of the country's power requirements. The Middelgrunden offshore wind farm, located a few kilometers from the city, has been up and running for almost ten years now. The farm's 20 wind turbines were manufactured by Bonus, today a subsidiary of Siemens Wind Power. Each turbine has a capacity of two megawatts at full load. Collectively, the farm can supply around 40,000 households.

Also nearby are the 48 turbines of the Lillgrund offshore wind farm, which was commissioned in 2008. The turbines are clearly visible from the Öresund Bridge, which spans the strait separating Denmark and Sweden. Lillgrund has a total capacity of 110 megawatts. Siemens installed not only the wind turbines but also an associated offshore transformer station, which rises above the waves like a huge drum. The transformer collects power from the turbines and feeds it into Sweden's national grid, which is connected to Denmark's. Copenhagen now has plans to build more wind farms, in the city and in the Baltic.

"We have no intention of resting on our laurels," said Ritt Bjerregaard (top left) , Copenhagen's mayor until the end of 2009, at the presentation of the European Green City Index . She went on to announce an ambitious goal: "We intend to turn Copenhagen into a CO_2-free city by the year 2025."

In concrete terms, carbon dioxide-free means two things. First, reducing the current emissions level of 2.5 million metric tons of carbon dioxide a year by 1.15 million metric tons by 2025 with measures that either have been already implemented or are scheduled. Secondly, offsetting the remaining CO_2 emissions by means of projects such as new wind farms and the planting of woodlands. As the improvements of recent years show, this ambitious target looks quite realistic. While CO_2 emissions in many other cities have increased, Copenhagen's — already low to begin with — have been cut by 20 percent since 1990.

The package of measures adopted by Copenhagen also extends to transport. Buses on the city's downtown routes, for example, are now electrically powered, which reduces exhaust fumes and noise levels in the narrow streets. The city also intends to fit its entire fleet of vehicles, 600 in all, with electric or hybrid drive systems.

> "We intend to turn Copenhagen into a carbon dioxide-free city by the year 2025."

And all of Copenhagen's publicly-owned real estate is to be brought up to the latest energy-efficiency standards.

Copenhagen's approved plan of action for achieving carbon dioxide neutrality by 2025 includes construction of a new subway ring, which will connect the southern area of the city to the rail network by 2018. Already, almost everyone in the city lives within 350 meters of a public transport station. In addition, a former harbor area is to make way for a new district by the name of Nordhavn, with homes for 40,000 people. Housing is to be built according to high standards of energy efficiency, and the new development itself will provide a balanced mix of residential, office, and retail space. The result will be a compact neighborhood in which people will be able to make many of their trips on foot.

More LEDs and Fewer Cars. Lighting is an important part of every city's carbon dioxide footprint. With this in mind, Siemens subsidiary Osram has equipped a refurbished commercial building in downtown Copenhagen with light emitting diodes (LEDs). The new lighting will not only trim electric bills, but provide an intimate atmosphere for cultural events planned for the location. A total of 144 LED lamps have been installed on the first floor. Together, the lamps consume 190 watts — only about half as much as conventional halogen spotlights. In the same part of town, lighting in one street is also provided by LED street lamps from Osram.

During the Climate Change Conference, low-energy lighting projects could be found throughout the city, including a Christmas tree in front of City Hall (p. 20). The tree was illuminated by several hundred LEDs that were connected to exercise bikes. The faster people pedaled, the brighter the lights became. During her opening speech, Mayor Bjerregaard jokingly referred to it as "the world's greenest Christmas tree."

Copenhagen has plenty to do by 2025. It is essential, Bjerregaard explains, that city dwellers back environmental measures. "A lot of our CO_2 emissions are caused by the people of Copenhagen themselves. If we want to reach our target, city residents will have to change how they live. Publicity campaigns are one way to encourage this, but we also want to make sure the people are directly involved in the development of solutions." With one-fifth of all CO_2 emissions caused by transport, the plan is to encourage even more residents to use their bikes. The city is thus looking to improve conditions for cyclists even further, with facilities such as covered bike paths and bike parks. In fact, as of last fall, there are even special warning lights set into downtown roads to alert truck drivers turning right to the presence of cyclists in their rearview blind spot. If a cyclist approaches a the blind spot, the lamps start to flash. In other words, cyclists are taken very seriously in Copenhagen — another good reason for switching to two wheels. ■ *Tim Schröder*

Hydroelectric power plants and an energy-efficient new metro have helped reduce Oslo's per capita CO_2 emissions to just two tons. Small things such as an LED chandelier in the city's Opera House also help.

Green Milestones

According to a study conducted for the European Green City Index, Oslo is one of the greenest cities in Europe. The city's sustainable approach is made possible by numerous environmentally-friendly technologies, some of them from Siemens. The latter include an economical subway and high-efficiency lighting in the opera house.

Most people wouldn't be thrilled about having to get underneath a subway train. But Tor Hasselknippe views it as a welcome challenge. Every day Hasselknippe, a technical manager at Oslo's Vognselskap public transport company, inspects the Siemens trains that since 2006 have gradually been replacing the more than 30-year-old subway trains previously used in the Norwegian capital. At the maintenance center, the subway cars are jacked up on rail platforms in a vast hall. Technicians work on the underbodies and put the finishing touches on the cars before sending them out into the city's approximately 84-kilometer-long subway network. "This is one of the electric motors," Hasselknippe says, pointing to a large rectangular block underneath one of the cars. "The complete drive unit of a train has an output of 1,680 kilowatts and is also very energy-efficient. When the driver brakes, the motor goes into generator mode and sends the electricity it produces back into the grid."

Hasselknippe then knocks on the white outer wall of a car. "The entire shell is made of aluminum," he says. "This makes the train extremely light." As a result, the new subway trains consume 30 percent less energy than the old ones. "And that's not all," says Hasselknippe as he climbs into a passenger cabin and runs his hands over the seat covers. "These textiles are made of a very sophisticated material that not only meet all fire protection requirements but can also be recycled — which is true of 95 percent of the components in these trains. All of this makes our subway one of most sustainable systems in the world."

Heating on Demand. It isn't always easy to combine sustainability with the effective operation of the new subway. For one thing, around 80 percent of Oslo's subway system is above ground, which negatively impacts its energy balance, especially in winter. "The heating system still accounts for nearly 20 percent of required energy — so we need to keep working on that," says Hasselknippe. Engineers at Siemens Mobility in Vienna, Austria, are looking at ways to reduce the energy consumption of heating and climate control systems. "We've developed a heating control unit that regulates the system in line with real-time requirements," says project manager Dr. Walter Struckl. "The unit is linked to a carbon dioxide sensor that determines how many passengers are in a car based on the principle that the CO_2 content rises with the number of people present." According to Struckl, the unit can heat up air from the outside in line with actual heating needs. By contrast, conventional systems continually heat subway cars, regardless of whether or not passengers are on board. "Our technology should generate heat-energy savings of up to 30 percent," says Struckl. Sustainability and energy efficiency have been top priorities in Oslo for some time. In 2002 the city, which has a population of 550,000, launched its ambitious Urban Ecology Program to cut pollutant emissions and improve its citizens' quality of life. Among other things, the associated plan calls for a 50 percent reduction of Oslo's 1990 greenhouse gas emission levels by 2030. This green program is already producing results. A sustainability study of 30 European cities for the European Green City Index (p. 17) ranked Oslo third behind Stockholm and Copenhagen. The study even gave the Norwegian capital a top ranking for CO_2 emissions, as the city produces only slightly more than two tons of the greenhouse gas per capita — mainly because Oslo covers around 60 percent of its electricity requirement with power from Norway's large hydroelectric plants.

But there's still work to be done, so the Urban Ecology Program, scheduled to run until 2014, also focuses on expanding the local public transport network. Studies have shown that road traffic is responsible for the lion's share of Oslo's CO_2 emissions. Despite high tolls for entering the city center, some 360,000 vehicles continue to drive through Oslo every day. The city government believes that improving the bus and subway system will get more commuters to leave their cars at home. Indeed, the new subway system has already demonstrated that the government may be right. "Polls show that passengers are extremely satisfied," says Hasselknippe. "Since the introduction of the new trains, ridership has increased by around 10 percent to 73 million in 2008." He thinks even more people will switch to the subway in the future, especially now that intervals between trains have been cut in half. "Trains have been running every seven minutes 20 hours per day for a year now — and that eliminates many people's need to drive."

Another Oslo green milestone is near the city center just a few minutes from the Jernbanetorget subway station. Resembling a giant iceberg transformed into concrete, the new opera house rises up out of the harbor. The imposing building, which opened in 2008, is one of the most energy-efficient opera houses in the world — a feat made possible in part by an innovative lighting system concept that relies on light-emitting diodes (LEDs). "We equipped the entire concert hall with LEDs — there's nothing else like it in the world," says Cato Johannessen, who is managing the project for Osram Norway.

Johannessen is particularly proud of the eight-ton chandelier that hangs 16 meters above the seats. "That chandelier contains 8,100 LEDs," he says. "We've also got special dimmers for individually adapting the LED modules to the most diverse lighting requirements." The small LEDs are highly efficient, with an output of 45 lumens per watt as compared to a maximum of 12 lumens per watt for conventional incandescent lamps. At maximum brightness, the 8,100 LEDs consume just 14 kilowatts. They are as powerful as they are robust, says Johannessen. "On average, only one out of every million LEDs fails during its six-year service life, and so far we haven't had to replace a single unit," he says.

Johannessen believes Oslo will step up its use of energy-efficient lighting in the future. Small and flexible LEDs in particular offer great potential with regard to climate protection — and not just in magnificent buildings like the new opera house. "Oslo has drawn up initial plans to show that LEDs can also make streetlights greener," he says. ■ *Florian Martini*

Paragon of Efficiency

Trondheim Smart City

Even a country like Norway can become greener. Trondheim lies 500 kilometers north of Oslo. With 170,000 inhabitants, it is the country's third-largest city. In 2001 local authorities declared war on CO_2. Since then, the city has introduced a range of green measures — for which it was commended by Norway's Environment Ministry in 2008. The target is a 20 percent reduction in CO_2 emissions compared to 1991 levels by the year 2012. To help achieve this goal, Trondheim authorities intend to expand local public transport and improve the energy efficiency of the city's buildings. There is a lot of potential in the latter area according to a joint study conducted by Siemens, the city authorities, and the environmental organization Bellona as part of a pilot project entitled "Energy Smart City." The study looks at ways to save energy in the areas of residential and commercial real estate, street lighting, the power grid, and industry. It shows that by using technology already available, Trondheim could cut its energy consumption of five terawatt-hours per year by 22 percent without compromising the quality of life of its citizens. "We will realize most of these potential savings in one or two years," says Rita Ottervik, Mayor of Trondheim. A good way of cutting power consumption is to install new building management systems that intelligently control lighting, heating, and ventilation systems. In Trondheim's office properties alone, this would save as much electricity as is consumed over the same period by 4,000 households. Street lighting also offers big savings potential, despite the fact that the 22,000 streetlamps are already very efficient. Dimming them by 50 percent, for example, would cut their annual power consumption by over five gigawatt-hours (GWh) and save around €700,000 a year. Even greater savings could be achieved by upgrading the city's power grid, where every year five percent of the electricity is lost as heat while being transmitted to the consumer. Efficient high-voltage systems could cut these losses by as much as 50 GWh, thus saving around €3 million a year. According to Ottervik, before the installation of energy-efficient technology can start, it is essential to ensure that Trondheim's inhabitants back the measures. "We have to encourage our citizens to save energy," she says. Here too, Trondheim is on the right path. The project has been publicized in a wide-ranging campaign since Fall 2009. Energy saving is being promoted in the media, at symposia, in school competitions, on buses, and in messages printed on roadways.

The Cuatro Torres are the hallmark of modern Madrid, which is also setting its sights high when it comes to environmental protection. Some garbage trucks and city buses already use alternative drives (right).

An Alcázar of Sustainability

The area around Madrid is one of the fastest-growing regions in Europe. Over the past ten years, the number of inhabitants residing here has risen by nearly 20 percent. To maintain the quality of life in central Spain and safeguard its resources, the city administration is relying on efficient logistic solutions, some of which are being provided by Siemens.

Gazing out the window of a plane approaching Madrid is like going back in time. The barren highlands on the outskirts of the Spanish capital are dotted with small Castilian villages that look like relics of bygone centuries cast in stone. Such a view gives the observer a sense of what Madrid might have looked like after the city was founded in the Middle Ages, when the first settlements were established alongside a rustic Moorish castle known as the Alcázar.

Today, Madrid is the geographical, political, and cultural center of Spain — and with a population of about 3.3 million (6.3 million in the metropolitan area), it's also the third-largest city in the EU. The city continues to grow, as some 400,000 people have been added to the population since 2001. Efficient logistics systems are thus crucial for ensuring a smooth daily routine in the Spanish capital and its surrounding region.

Madrid Barajas International Airport — the tenth-largest airport in the world (50 million passengers in 2008) — is already on track in this regard. Some 60 percent of the facility's passengers now use its futuristic Terminal 4, which opened in 2006. Exceptional logistic performance is required here to ensure that everything runs like clockwork. State-owned AENA, the world's largest airport operator, ensures top performance, largely with the help of Siemens solutions. These include security, lighting and a sophisticated baggage handling system.

The airport's baggage handling system is the biggest and most modern one of its kind in Europe. Operating in the catacombs beneath the airport, the system can collect and sort up to 16,500 pieces of luggage per hour from 172 check-in counters and connecting flights, which it then transports at speeds of up to ten meters per second to gates or baggage-claim areas on conveyor belts with a total length of 104 kilometers. Each piece of luggage has to arrive at its gate within 25 minutes, even if that gate is located at the terminal for intercontinental flights, which is nearly three kilometers away. "Siemens was the only bidder at that time able to provide the technology that could win this race against time", says Nerea Torres, who is responsible for airports at Siemens Mobility in Madrid.

AENA also commissioned Siemens in 2008 to reduce the energy consumption of its already efficient baggage handling system by 30 percent by 2011 — and to do so without installing additional hardware. "Right now, for example, we're optimizing parameters in the control software so that we can adjust the system's operation to match the actual number of bags to be transported," Torres explains. "This prevents things like having entire conveyor belt segments running without any baggage." Efforts here have been successful, as Siemens experts have already reduced energy consumption by around 15 percent.

Wind Power at Las Palmas. Efficiency is a top priority overall at AENA, which operates all of Spain's airports and around 30 others around the world. "We're always looking to reduce energy consumption at every one of our airports," says José Manuel Hesse Martin, who is responsible for sustainability issues at AENA. "One of the areas we're focusing on is lighting. Terminal 4, for example, was designed to ensure that as much outside light as possible shines into the building. We're also using renewable energy. For example, we now produce more energy with wind turbines at the Las Palmas airport in Gran Canaria than the facility actually needs, and we channel the surplus into the public grid."

AENA also plans to test diverse energy optimization measures in 2010 at a small, yet-to-be-selected airport, and here too the company would be helped by Siemens. "This will be our green test lab," says Hesse. "Whether it's LED lighting, intelligent building technologies, or the generation and utilization of energy from various renewable sources — we will use the results to develop standards that will ultimately be applied at our other airports. The optimization of the baggage handling system in Barajas is only the beginning."

Those who pick up their bags at Barajas Airport can head directly to a subway station and step into a train that will quickly and comfortably take them to the center of Madrid. The city's subway is the world's third-longest such network. Only New York and London have longer networks. It is also one of the fastest-growing metro systems in the world. In fact, its total length has more than doubled since 1994. Passengers don't have to wait long for trains, either. With intervals of only around five minutes, the subway is more than capable of competing with automotive transportation. The system's 13 lines safely transport 2.5 million people a day to a total of 318 stations, thanks in part to state-of-the-art signaling technology from Siemens.

One of these lines — the Number 10 — stops directly at Estadio Santiago Bernabeu, home of the Real Madrid soccer club, which sold its former practice facility just two stops down the line, Ciudad Deportiva, for several hundred million euros in 2001. The facility where Real stars once practiced free kicks, penalty kicks, and offensive setups is now the site of the Cuatro Torres, whose modern architectural design has attracted a great deal of attention. One reason for this is that with a height of around 250 meters, the buildings' towers are the tallest structures in Spain — and are also among the most modern. "These office buildings contain state-of-the-art technologies for intelligent lighting, heating, and fire-protection, most of which were provided by Siemens," says Margarita Izquierdo, who is responsible for the Energy Efficiency Unit at Siemens Building Technologies in Madrid.

> The length of the Madrid subway network has more than doubled since 1994 — and it is still increasing.

"The technology in Torre de Cristal and Torre Caja Madrid can be centrally regulated so that only the systems that are needed at a given time actually operate," she says. To this end, Siemens building management systems utilize rooftop weather stations to continuously monitor parameters such as incoming sunlight and temperature, and then adjust lighting and ventilation systems in individual rooms accordingly.

Information from thousands of sensors in the buildings enable the systems to determine which rooms are not in use and adjust the ventilation and lighting units accordingly. "Such efficiency enhancement measures still aren't being used to a large extent in Spain, despite the high energy and cost savings they generate," Izquierdo reports. However, she expects far more orders as the Unit, which was established in 2009, identifies a growing number of potential building-based energy-saving projects. There's no risk for the customer, since Siemens guarantees a contractually-binding level of savings after modernization measures have been implemented, whereby the customer can apply the savings to pay for the efficiency investment itself.

Green Plans. In recently years, Madrid's city administration has increasingly focused on sustainability. "As one of Europe's fastest-growing cities, we need to be very proactive in terms of efficiency and environmental protection if we wish to avoid endangering Madrid's resources and the quality of life of its residents," says Ana Botella, Madrid's Deputy Mayor, who manages the city's policies with regard to environmental issues. "That's why we've initiated several programs that will make our city a pioneer in environmental protection over the medium term." For example, Madrid plans to lower the metropolitan area's greenhouse gas emissions by 50 percent from 2004 levels by 2050, and to replace at least 20 percent of its fossil energy carriers with renewable sources by 2020. "We already have a large share of renewable energy sources in the form of biomass, wind power, and solar facilities," says Botella.

Madrid has also implemented other significant measures, including watering its green areas

mainly with recycled wastewater — an impotant measure, given that the city frequently suffers from water shortages. Plans also call for a ban on conventional diesel and gasoline engines in all city-owned vehicles — in other words, the buses and passenger cars in the municipal administration's official fleet — by the end of 2010. This measure will affect the 5,000 or so vehicles operated by the city, which will then either run on alternative drive systems such as those that use electricity or natural gas, or will be equipped with hybrid systems that utilize electric drives from Siemens.

Quiet Trash Collection. Some 15 garbage trucks in Madrid are already powered by a combustion engine-electric motor that demonstrates another aspect of sustainability: silence. This fleet will be supplemented by an additional 30 vehicles by the end of 2012. Says Luis Pérez Piñeiro from the Drive Technologies division at Siemens, "These vehicles consume up to 30 percent less fuel than those equipped with conventional combustion engines."

Whereas the garbage trucks' combustion engines take over at higher engine speeds, their energy storage units (batteries) supply power to their electric motors during initial acceleration and also recover braking energy. "Unlike conventional vehicles, braking energy is not lost but instead converted into energy by the electric drive motor," Piñeiro explains. "This drive is good news for residents — particularly at night, when the trucks operate electrically.

Madrid believes that effective and efficient solutions like these are preparing the city for the future. And many city residents are responding by changing long-established habits. For example, those who wish to travel to Barcelona, which is located some 620 kilometers southeast, are now better off taking a train than flying. That's because Spain's Renfe rail company is now operating Siemens' Velaro E high-speed train between downtown Madrid and downtown Barcelona. Traveling at around 300 kilometers per hour, the train makes the trip in less than 2.5 hours

Velaro E trains, (also known as the S-103) make this run more than 20 times per day. Because passengers don't have to travel to an airport or wait at check-in counters, the train is now giving the airlines serious competition. In fact, airlines have lost some 50 percent of their passengers to Renfe on the Madrid-Barcelona route, which is still one of the most frequented air travel routes in the world (about 25 flights per day). This isn't surprising, since the train is just as comfortable as a plane — and even offers the same in-seat service. What's more, the Castilian villages look at least as enchanting from the ground as they do from the sky. ■ *Sebastian Webel*

New streetcars from Siemens (right) supplement traditional models as Lisbon strives to combat traffic congestion. The city is increasingly turning to solar and wind power for its electricity.

Sun, Wind and a Tram

More than ten percent of Lisbon's electricity is provided by renewable energy sources such as wind and sunlight. The city is also committed to reducing transportation-related pollution and is expanding its public transit system. Siemens is providing solutions in both of these areas.

Nights begin late in Lisbon — but they last a long time. Every evening people stroll through the alleys of the Bairro Alto, where you can hear laughter spilling from the restaurant and apartment windows, which are kept open even in the winter. The streets are the center of life in Lisbon. Still, it can get cold in the Portuguese capital; temperatures often dip below 10 degrees Celsius in the winter. Due to a lack of central heating, many apartments and other buildings operate portable electric heaters that not only warm up the rooms they're in but also the alleyways, as their heat escapes through open windows and doors.

"Change has to begin in people's minds, of course," says Prof. José Delgado Domingos. He isn't bothered by the festive nature of the Portuguese, but he'd like to change their attitude toward energy conservation. Delgado Domingos is the director of Lisbon's e-nova environmental agency, which is planning an energy-efficient future for the metropolis from offices in a nondescript townhouse not far from the Bairro Alto.

With its population of around two million, Lisbon is working hard to expand its public transport system — a step designed to decrease the flood of approximately 400,000 vehicles that travel into the city every day via the Tejo Bridge and other access roads.

The city has launched initiatives to encourage energy conservation and is now in the process of building a recharging network for electric cars that will encompass around 300 stations by the end of 2010 and 700 stations by the end of 2011. A disproportionate number of the capital's residents currently drive to work, leading to relatively high levels of greenhouse gas emissions. Lisbon's production of 7.5 tons of CO_2 per resident and year puts it above the average for the cities investigated for the European Green City Index (see p.17).

However, for a growing number of residents, the commute to work is becoming more pleasant and environmentally friendly. The city has had electric trams for almost 110 years, as the first streetcar entered service in 1901. However, tourists appear to be the only ones who enjoy the clattering, jingly ride through the Bairro Alto on the old narrow-gauge tracks. By contrast, on the south side of the Tejo River one can see how a modern streetcar system makes a public transport network more energy-efficient and cost-efficient.

Here, 24 Siemens Combino trains link Lisbon's southern suburbs with the Estação de Pragal railway station via three lines with a total length of around 20 kilometers. Passengers can transfer at the station to a rapid transit train that takes them over the Tejo Bridge and into the city center. In this way, commuters can avoid the hopelessly congested road that shares the same bridge. The Siemens project, comprising the trains, electric system, signaling devices, control center, passenger information system, and project management, is headed by Herbert Seelmann. He gives the clerk at Estação de Pragal a euro for a tram ticket and receives 20 cents in change. The ticket is cheap because the system is still being subsidized. However, as soon as daily passenger volume exceeds 90,000, the system will be able to pay for itself and will no longer require public funding.

This will probably take another few years, however. In the meantime, city planners are thinking about extending the lines. One destination they're eyeing is the major airport planned for the southern part of Lisbon.

Siemens engineers are also testing a tram of the future at a rail depot located near the terminal station. The unit is a prototype equipped with so-called ultracaps — capacitors that use braking energy to recharge, after which they temporarily save this energy and then release it when the tram accelerates. The innovative system also includes rechargeable batteries that enable the trams to travel short distances without any contact to overhead lines. This feature can be very helpful in the event of a power outage and, most importantly, would eliminate the need to build overhead lines in areas where they might be considered an eyesore (see *Pictures of the Future,* Fall 2007, p.74).

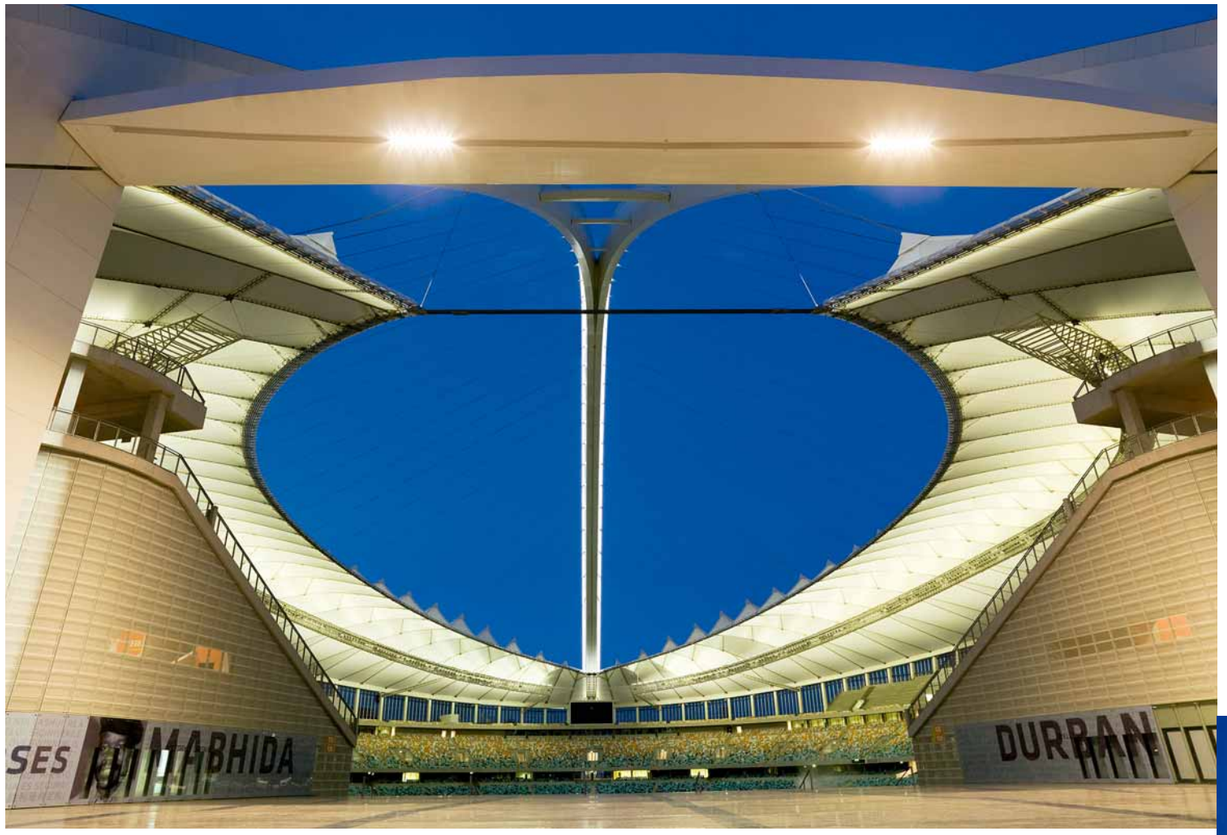
Although streetcars do not use diesel fuel, it is nevertheless necessary to produce electricity in order to operate them. Such power generation is often surprisingly environmentally friendly in Portugal, as a growing amount of energy is produced in onshore wind power facilities. Many of the country's wind power facilities, whose combined capacity already totals around two gigawatts, use Siemens turbines. In Sabugo, just a few miles from Lisbon, Siemens manufactures key components for turbines that are used in 26 countries. The Sabugo facility produces extremely compact and robust transformers that are installed in the difficult-to-service windmill nacelle, a type of engine room located more than 60 meters in the air.

Catching the Sun. In addition to its extensive investments in wind power, Portugal is determined to make the most of the sun. Thanks to policies designed to promote investment in photovoltaic systems, private households receive 60 euro cents per kilowatt-hour of electricity generated with roof-mounted solar cells. Even major solar power producers get 30 cents. Tecneira, a company that operates wind farms, also operates one of Portugal's ten largest solar parks in the Alentejo region south of Lisbon, an area of sheep meadows where for thousands of years olives have been ripening in the sun.

> By the end of 2011 Lisbon expects to have approximately 700 recharging points for electric vehicles.

But since the end of 2009, the region has been harvesting the sun's energy more directly. Here, 45,440 solar panels are lined up in long rows. This 10-megawatt photovoltaic unit can supply up to 8,000 people with electricity. Siemens provided the devices' inverters, which convert direct current into alternating current, and also supplied the facility control equipment. This new green energy source in Alentejo seems to be reviving a rural region that had been steadily losing young people to the country's larger cities, especially Lisbon.

Renewable energy is just one example of a new industry that is creating jobs and attracting young people back to the countryside. Still, the young people certainly won't want to miss the Bairro Alto, whose bars, clubs, and discotheques have a magnetic appeal. But the energy for all that nightlife is increasingly coming from coastal wind turbines — from the stiff Atlantic breezes that are especially strong in the evening, when the sun disappears into the sea at Europe's westernmost point and the solar power units in Alentejo have shut down for the night. ■ *Andreas Kleinschmidt*



Moses Mabhida Stadium in Durban offers impressive energy efficiency — much of it based on LEDs from Siemens' Osram subsidiary, which use 20 percent less power than fluorescent lights.

Preparing for Kickoff

The 2010 Soccer World Cup has prompted substantial investments in South Africa's infrastructure, many of them based on Siemens technology. Now taking shape is a rail system linking Johannesburg and Pretoria, energy generation and storage systems, efficient stadium lighting projects, and steps for broadcasting sporting events.

Tshepo Maseko is sipping his cocktail at News Café Sandton, currently his favorite bar. The keys to his BMW are on the table in front of him. With his fast car, Maseko really does get through Johannesburg's seemingly endless traffic jams more quickly than do other drivers. "But the trick isn't the more powerful engine," says Maseko, an actor from the poplar soap opera Isidingo. "The trick is to always take the right shortcut at the right time of day."

Sometimes Johannesburg strikes Maseko as being overly full — too many people, too few trees, too much air pollution. This doesn't diminish his enthusiasm for South Africa's largest city, however. "I wouldn't want to live anywhere else. The different people, the music, the vibes — the city is on fire. I love Jo'burg," he says. Jo'burg, as many South Africans call Johannesburg, is his hometown. Maseko grew up in the township of Soweto, attended acting school — and made his own way. The soap opera in which Maseko appears is a kaleidoscope of South African society. It celebrates the community despite the weighty legacy of apartheid, despite the uncontrolled HIV/AIDS epidemic, and despite enormous economic inequality. Some of the viewers, living in much less favorable conditions, may dream of doing what Maseko did.

Many young, well-educated South Africans do, in fact, come to live in Johannesburg. Like the prospectors of the 19th century, they hope to find work and a golden future there. Now that production of gold, once South Africa's principal export, is declining — many deposits have been completely depleted — the resource of the future for a growing number of people is education. For good jobs, people are even willing to leave the beaches of South Africa's other metropolis, Cape Town.

As population has grown, however, it has come at a price. Johannesburg appears to be growing uncontrollably. In fact, it is likely that over the next 5 years it will converge with Pretoria, the South African capital, to form an agglomeration of roughly 15 million inhabitants. That's a major challenge because public transit is rare, and most people avoid it because it is often inconvenient and associated with the city's high crime rate. Nevertheless, things are set to change, as the Soccer World Cup has brought substantial investments in infrastructure that are designed to improve the standard of living in the long term.

From Road to Rail. Siemens Mobility Director Kevin Pillay, who supports Metrorail, the operator of the commuter rail system in South Africa, firmly believes things will get better. The public information systems at major stations are being overhauled just in time for the World Cup. Siemens is responsible for the design, implementation, and integration of these new systems. "The modern signaling, public address and display information systems we are installing will not only increase the efficiency of the entire system, which will be in full operation during the World Cup; they will also enhance its reliability, safety and attractiveness," says Pillay. "Hopefully, more people will take the train after the World Cup, because we desperately need to move a lot of our road traffic to rail."

Whereas the Metrorail project uses existing rails and trains, a line unlike any the African continent has ever seen before is currently under construction. With parts of the route high above the ground on concrete pylons, the Gautrain, as the system is known, will link Pretoria and Johannesburg using standard gauge track rather than the narrow gauge commonly used in South Africa.

The first segment between Johannesburg's international airport and the city's Sandton business district will be completed in time for the kick-off of the World Cup. "To ensure the reliability of the Gautrain's data system, our team has installed a total of 3,000 kilometers of fiber optic links along the tracks. These links are used for such things as controlling the signaling systems," says Martin Venter, a Siemens Industry systems engineer, just as one of the trains races past him on a test run at a top speed of around 160 kilometers per hour.

"If the data link were to fail, the Gautrain as a whole would come to a stop," explains Ray Holmes, a systems manager on the customer side. "But that is precisely the reason why we chose Siemens for this crucial component. We know and appreciate the company for its absolute reliability, especially when it comes to critical applications like this one."

Siemens' fiber optic data network is configured as a so-called Open Transport Network. The cables are laid out in a ring along the route and thus ensure the flow of data in both directions. A second ring ensures full system availability in the event of faults. Installation is more expensive than with alternative solutions, but system operating costs are expected to be substantially lower than for Ethernet, for example.

Green Energy Paradise. South Africa also intends to reduce its carbon dioxide emissions. John Hazakis, Siemens Director for Energy Solutions, Products and Renewables in South Africa, is convinced that green energies therefore must — and can — have a future in South Africa as a complement to fossil fuels. "Wind, water, solar power — regardless of which renewable energy source you look at, the natural conditions in South Africa are outstanding," he says.

> Wind, water, solar power: South Africa has outstanding natural resources for a green future.

Developing these resources, however, requires political will and a corresponding awareness on the part of users, since South Africa's extremely low consumer prices for electricity, which are equivalent to three euro cents per kilowatt-hour, would most likely increase significantly. Suitable locations for wind turbines can be found on the west and south coasts of the country, near Port Elizabeth and in the vicinity of the Karoo desert plateau in the interior. A pumped-storage electrical power plant with a capacity of 1,330 megawatts is being built in the Drakensberg mountains in the eastern part of the country. It could one day serve as an energy storage module in a smart grid. Siemens served as a local partner for Voith, which built the plant and is responsible for the

Rail transport in South Africa is becoming more attractive as the country invests in control systems.

project. And when it comes to using the sun's energy, South Africa's solar irradiation data are hard to beat. Solar thermal and photovoltaic applications are promising given the intensive sunshine throughout the country. "If we all set off in the right direction, roughly one tenth of South Africa's demand for electricity could be met by renewables before the end of the decade," says Hazakis.

Expansion of South Africa's overall electrical generating capacity is another urgent task. If the current economic crisis had not led to a reduction in economic activity and a drop in demand for electricity, fatal power outages would have been a real possibility during the World Cup in 2010. Back in 2007 and 2008, in response to this known weakness, orders were placed for 10 gigawatts of new baseload capacity. New gas turbine power plants, such as those located in Cape Town and Mossel Bay use Siemens turbines. What's more, all ten World Cup stadiums in South Africa are illuminated with energy-efficient lamps from Osram (see *Pictures of the Future*, Fall 2009, p. 4).

The Moses Mabhida Stadium in Durban is particularly impressive. Thousands of LED lights illuminate the venue, which can hold up to 70,000 spectators. A 350-meter-long arch spans the ellipse of the stadium, reaching the height of a 30-story building. At night, its light is visible from kilometers away. Nonetheless, the building's lighting is extremely energy-efficient. Its Osram LEDs consume around 20 percent less energy for the same light output than alternative solutions such as fluorescent lamps would require.

High Tech Everywhere. Siemens technology will accompany the expected 3.5 million visitors to the Word Cup every step of the way, starting with their arrival at airports. Passports will be scanned at border checkpoints and automatically compared with a visa file; Siemens was the systems integrator. At the Sandton Convention Center, one of the most important World Cup centers, building systems from Siemens will provide a reliable communication structure. The South African Broadcasting Corporation (SABC), the most important radio and television network in the country, is responsible for broadcasting the World Cup games throughout the entire world. Siemens is currently refurbishing two television studios with state-of-the-art equipment that SABC will later be able to seamlessly integrate into a new overall technology concept.

"In our role as technology partner, we are advising SABC on which market solutions best meet the network's requirements and how they can be integrated cost-effectively. We are not supplying Siemens hardware, but rather our know-how," explains Klaus Pachner, project manager at Siemens IT Solutions and Services. He leads the way to Studio 6, which at first glance resembles a furniture warehouse. Couches, tables, and cabinets are arranged into little rooms. A familiar face is also here: Tshepo Maseko. "Isidingo" is being recorded in Studio 6, which has become a second home to Maseko, albeit one with pitfalls. "Be careful," he says, "they are in the process of rehanging the lamps. Something might fall from the ceiling. Until we get new equipment, such as a lighting system, we make the best of what we have." Laughing, he adds, "It's a typically African solution. If I learned one thing from the poverty in the township, it's optimism. You can convert negative things into something positive through personal effort."

Maseko has no doubt, however, that things won't just be improvised for the World Cup in South Africa. "We will show the world what our country can do. If there is one thing that holds the people in our country together, it's sports. The world will see all South Africans celebrating the World Cup together. Regardless of the color of their skin, and regardless of which car they drive," he says. ■ *Andreas Kleinschmidt*

Soon to become a pedestrian zone, Vilnius' historic city center is a UNESCO landmark. Many of its buildings, such as the new Swedbank headquarters, are equipped with energy-efficient Siemens technology.

Baroque Pearl in a Green Ring

Vilnius, the capital of Lithuania, is continuously improving its quality of life. Stringent traffic management and reductions in building energy demand are the key.

From the top floor of the brand-new 60-meter-high Swedbank building, Lithuania's second-largest bank, CEO Antanas Danys has a spectacular view of Vilnius' historic city center. Magnificent Baroque, Renaissance, and Gothic buildings form a historic ensemble that is unmatched in Europe. It's beautiful, but not very practical for Swedbank, whose 800 employees used to be scattered among ten different locations — but now all of them work in the most modern building in Lithuania's capital city.

Architect Audrius Ambrasas has designed a workplace that values transparency, with glass offices and conference rooms that seem to float between the building's floors, as well as a huge lobby with a bistro. But there's also plenty to smile about when it comes to costs. Siemens building technology regulates the building's air conditioning and ventilation system, with sensors measuring the temperature and the air's CO_2 content. If values are too high, parts of the glass facade open up automatically to let in fresh breezes from the Neris River. This has decreased power costs by a fourth, even though the office space is now 20 percent bigger than before.

Lithuania has many advantages for business. Its people are highly educated. Although the country has a population of only 3.4 million, it boasts 49 institutions of higher education, including 15 universities. Vilnius, which has 550,000 inhabitants, occupies 13th place on the European Green City Index (see p. 17) — the highest rating of all the Eastern European cities on the Index. There are many reasons for that. A city ordinance protects its surrounding forest, extensive parks and plantings. Several international hotel chains have opened branches in Vilnius. Many of them use Siemens building technologies. Traffic is strictly managed. "Our historic city center is a UNESCO World Heritage Site, and its narrow alleys are not suited for motorized traffic," says Vilnius' mayor, Vilius Navickas. One-way streets and pedestrian zones keep drivers out of the city center. However, the number of private cars has increased about fourfold since the country gained independence in 1990. This has caused traffic jams around the city center and a relatively high level of CO_2 emissions.

The city's environmentally-oriented traffic management strategy has a number of components, including smart traffic management. Here, a Siemens system uses loop & video detectors at some 200 intersections to measure traffic density and adjust traffic lights accordingly. "On average, this saves drivers about 30 percent of driving time and ten percent of fuel," says Kestutis Ciplys, who is in charge of the Siemens traffic management system in Vilnius. The traffic lights use ultramodern LEDs that need only one fifth of the energy required by their predecessors.

The city also intends to expand its ring roads and keep the historic city center as free of traffic as possible through tolls and stringent parking space management. Although plans for a subway or streetcar system are far from fulfillment due to the financial crisis, 60 buses of the local transit company already run on environmentally-friendly natural gas, and 100 additional buses will be converted this year. Freight traffic also plays a major role in Lithuania, and Vilnius is a major hubs. Siemens has developed freight locomotives with modern three-phase alternating-current drive technology for the state railroad company. The new locomotives use 40 percent less diesel than the old ones and can transport twice as much freight. Lithuania now has 34 of the 44 locomotives it ordered, which means it has the most modern rail fleet in Eastern Europe.

First in Air Quality. There are a number of reasons why Vilnius took first place in the Air Quality category in the Green City Index — even ahead of Stockholm. For one thing, despite the country's eventful history — between phases of independence it has been part of Germany, Poland, Russia, and the Soviet Union — its natural resources were largely spared. Its gigantic forests, which Lithuanians hold in almost mythical awe, have remained intact. Most of the country's jobs are in agriculture, mechanical engineering, and a rapidly expanding furniture production industry. The country's main source of energy is Russian natural gas, rather than outdated coal-burning power plants, which are among the worst air polluters in Eastern Europe. Nor does Lithuania have any heavy industry. The few industrial plants built in the Soviet era were not economical and were closed down.

Vilnius intends to make the most of its citizens' high educational level. "The crisis is an opportunity to create more highly qualified jobs," says Swedbank's Danys. The universities are working with startup companies to create a cluster of expertise in laser technology and biotechnology. Barclays Bank from the UK has set up its European IT service center in Vilnius, and many Scandinavian companies are on the lookout for investment opportunities. Siemens operates in Vilnius with some 100 employees in the Industry, Energy, and Healthcare sectors.

One example of profitable new ideas is Vichy Aqua Park, which was opened in 2008. The adventure pool attracts up to 1,500 visitors a day. Facility Manager Jurga Mekaite has to maintain the right temperature throughout the complex, ensure that the water is continuously purified and optimally chlorinated, and adjust the lighting system. Most of this work is done by a Siemens building management system that ensures that only as much energy, water and chlorine are used as the optimal operation of the complex requires.

Vilnius has fewer inherited environmental problems than other Eastern European cities. Nevertheless, in an effort to improve the environment, the city is subsidizing energy-saving renovation projects in buildings. One milestone was Siemens' modernization of the city's water supply in 2007. This included the installation of 11 new water pumping systems that improved the system's performance twofold while reducing its energy consumption by 40 percent. Other major challenges, such as improving the waste removal system, still lie ahead. But the overall mood is optimistic. Vilnius offers a high quality of life that continues to attract investors, tourists, and students from abroad. ■ *Katrin Nikolaus*

Yekaterinburg consumes too much energy. Building retrofits and advanced technologies — turbines from Siemens, for example — could reduce energy requirements by 44 percent.

Large power plants in the middle of cities that are already plagued by pollution? That's exactly the approach Moscow took to address the problem it had with the new Moscow International Business Center (MIBC). The Center is similar to business districts such as Canary Wharf, which is located in London, UK, and La Défense in Paris, France. But the MIBC required more electricity and hot water for its operation than the public grid could provide. In order to supply this city within a city, local authorities teamed up with a private investor to build the Moscow City power plant close to a residential area. They were able to do this because modern combined-cycle power plants produce a relatively low level of emissions. The plant is equipped with two Siemens SGT-800 gas turbines.

"Nyet" to Waste

Better building insulation and new power generation structures could help Russia to significantly cut its primary energy consumption, according to a study conducted in Yekaterinburg. Siemens technology could achieve much of the savings.

Steam spews from district heating pipes that are several meters in diameter. In the icy winter air, it forms what looks like giant puffs of cotton, producing a fairy tale winter scene. In reality, however, the scene is a showcase for waste, as each white puff indicates a leak through which a tremendous amount of hot water is being lost. District heating systems can be found in nearly every big city in Russia. But some parts of these systems are more than 50 years old and could thus be much more efficient.

The Russian government has now declared war on such waste. Plans call for the country to reduce its primary energy consumption by 40 percent by 2020 from 2007 levels. A recent study on energy consumption and energy-savings potential in the city of Yekaterinburg in central Russia on the eastern side of the Ural Mountains shows how this objective can be achieved.

Siemens Management Consulting and BASF, supported by representatives of the city and of its Swerdlowsk administrative district, recently analyzed the city's energy consumption and determined the costs and energy-savings potential associated with various measures, including the installation of thermostats for heating units and use of building insulation materials and energy-efficient lighting systems. The partners found that by implementing only those measures with the best cost-benefit ratios, an investment of €3.6 billion would be necessary. However, this would result in energy savings of 44 percent.

Urban Power Plant. It was concluded that building retrofitting and insulation would generate exceptional savings benefits. Installation of heating control devices alone could save the equivalent of 3.8 terawatt hours of primary energy per year — which isn't surprising, given the Russian penchant for moderating the temperature of heated rooms by opening windows. Investment here could be recouped within just a few months. Another key lever involves restructuring energy production. "In many Russian cities, the water for district heating is produced in gas-fired boiler houses right in the middle of town," says Alexander Gushchin, Regional Sales Director at Siemens Industrial Power Oil and Gas in Moscow. "Electricity, on the other hand, is often generated at power plants outside the city. However, if you built combined-cycle power plants within a city, you could produce both electricity and hot water in an energy-efficient manner."

Gushchin believes that combined-cycle power plants could also be used in many other cities. "If you operate gas and steam turbines in sequence, as is the case in Moscow, you can achieve an overall efficiency of nearly 90 percent," he says. Standalone boiler houses can achieve an efficiency rating of around 90 percent as well, but the production of electricity just outside a city is a lot less efficient. In fact, the old steam-turbine plants still in operation around the Russia achieve efficiency levels of only around 35 percent. "If you replaced the existing boiler houses with combined-cycle power plants, you could produce the same amount of hot water and electricity with 30 to 40 percent less gas," says Gushchin. Essentially, this is possible for two reasons: Waste heat is utilized and modern combined-cycle plants produce electric power much more efficiently.

According to the study, applying such a structure to Yekaterinburg could save 5.7 TWh of primary energy equivalent per year. And if all the leaks in the country's district heating network were then plugged, Russia's ambitious energy-savings goals would appear to be realistic. The fairy tale clouds, however, would disappear.

■ *Andreas Kleinschmidt*

The Metro is Paris' most important mode of transport. Glass walls between platforms and trains and new Siemens driverless systems will increase throughput on overloaded lines.

Fast Tracks, Bright Lights

Paris has one of the world's densest and oldest subway networks. Automation technology from Siemens is making the system more energy efficient. Meanwhile, light sensors are helping buildings to cut power consumption.

In Paris the air is burning — literally. As you stroll through the city, it's impossible to miss the many small mushroom heaters blazing away on café terraces and inside poorly-insulated brasserie conservatories. Even though they only burn for a few hours a day during the chilly months of the year, each one of them generates as much carbon dioxide per year as a mid-sized automobile. Yet who would be so mean as to forbid the Parisians to use their patio heaters? After all, when temperatures fall, how else can they enjoy a petit noir outdoors, either after work or on the go?

For many Parisians, saving energy is important but should not compromise the French way of life. Public transport is a good example of how this can work out. Here, too, comfort is the prime motivation, though there's good reason for that. Only 20 percent of commuters travel by foot or bike, compared to 68 percent in Stockholm. At first that seems surprising. After all, there is a widespread network of bike paths in Paris, and authorities created a bike rental system in 2007, with 20,000 bikes at 1,450 automatic stations, all free of charge for the first 30 minutes.

One of the main reasons Parisians prefer not to use pedal power is the superb subway system right at their doorstep. It is not only one of the densest metro networks in the world but also, at 214 kilometers, one of the longest. The first station opened in July 1900 to mark the World's Fair. In fact, many of the stations are showing their age and can hardly cope with today's rush-hour passenger volumes.

One way of raising throughput is to reduce intervals between trains. This is now being done on Line 1 — the oldest and, with 750,000 passengers a day, one of the most frequented routes — in a joint project between the Paris transport authority RATP and Siemens. In fact, Siemens has been supplying the Paris Metro lines with signaling technology and advanced driver assistance systems for the past 30 years. Now there are plans to introduce driverless trains on Line 1 — with Siemens technology.

At present, stations are being fitted with glass walls to separate platforms from tracks. These will incorporate automatic doors that open to let passengers safely enter trains. This will help to reduce maintenance costs and cut the current intervals between trains from 105 to around 85 seconds, as well as increasing flexibility and reliability. Such fully automatic subway trains with Siemens-technology have been in service on Line 14 of the Paris Metro for 12 years. With an average speed of 40 km/h, it is substantially faster than the other lines, which operate at around 25 km/h.

Seventy Percent Less for Lighting. Energy saving continues after the daily Metro ride to work — at least for employees at the Parisian headquarters of the OECD, the Organisation for Economic Co-operation and Development. Although parts of the building are 50 years old, it is now able to adapt automatically to prevailing weather conditions. In the course of general refurbishment, a Dali Multi intelligent lighting system from Siemens' subsidiary Osram was installed. The system comprises around 1,000 lamps with sensors that determine how much light is actually required and then tailor the lamps' output accordingly. The lamps have replaced conventional ceiling lighting that provided each workstation with constant illumination throughout the day. Whenever employees leave their offices for a longer period, the lights now go off automatically. Similarly, when it's cloudy and less natural light enters through the windows, the lamps automatically brighten.

Independent measurements have shown that energy consumption for lighting has fallen by as much as 70 percent compared to before the refurbishment. Bernard Balia, former head of facility management at OECD, was responsible for the project. "The system makes us more adaptable. Instead of everyone having uniform lighting, employees can now help to determine the right amount of light for their needs. And the system is economical, since lights only get switched on when they are actually needed," he says.

Outside, on café terraces, patio heaters continue to singe the Parisian air whether anyone is there or not. Perhaps one day they too will be fitted with sensors, allowing them to blaze into life only when actually needed. After all, when it comes to preserving the French way of life, some small sins should be permissible — if, that is, real crimes against the environment are avoided.

■ *Andreas Kleinschmidt*

Huge Growth Market for Green Urban-Infrastructure Solutions

Cities are growing at a breathtaking pace worldwide. More than half of the world's population already lives in cities, and this figure is set to grow to 70 percent by 2050. This trend is creating huge challenges for city managers, who will have to greatly expand municipal infrastructures because 6.4 billion city residents will need electricity, water, and transportation services in 2050, compared to 3.3 billion today. At the same time, cities will have to reduce their energy consumption and CO_2 emissions. At present, they already account for 75 percent of the energy consumed worldwide and are responsible for 80 percent of greenhouse gas emissions. Climate protection measures thus promise to be particularly effective in cities — and will open up market opportunities for green urban-infrastructure solutions.

The potential in this regard is huge. After all, a large part of the infrastructure in emerging markets and developing countries will have to be completely renewed, as these countries account for 95 percent of the world's population growth. Many industrialized countries will also have to modernize their infrastructures. Business consulting firm Booz Allen Hamilton estimates that the world's cities will have to spend around €27 trillion over the next 25 years to modernize and expand their infrastructures. Of this amount, €15 trillion will be spent on water management systems, €6 trillion on power grids, and €5 trillion on road and rail networks.

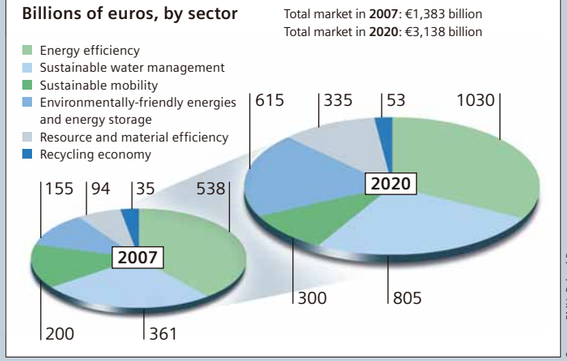
To allow cities to satisfy their infrastructure needs in a climate-friendly manner, they will have to employ energy-efficient technologies. Using Munich as an example, the Wuppertal Institute and Siemens conducted a study that showed that energy-efficient solutions could transform a city with some one million inhabitants into an almost completely CO_2-free area (*Pictures of the Future*, Spring 2009, p. 6). Major reductions in CO_2 emissions could be achieved by expanding local mass transit systems and introducing technologies such as state-of-the-art building systems, traffic management systems, and electric vehicles. Growing demand for electricity could also be met in an environmentally-friendly manner by boosting energy efficiency. The systems that could be employed here range from combined heat and power plants to smart grids and techniques for transmitting electricity with minimal losses.

The German Environmental Ministry (BMU) estimates that the global market for environmental technologies will more than double between now and 2020, to over €3 trillion. This development will be boosted by the financial crisis. For example, London-based investment company HSBC estimates that around €300 billion or about 15 percent of the amount being spent on economic stimulus programs worldwide is flowing into the creation of green infrastructures, with about 68 percent of this sum being invested in energy-efficient technologies.

The energy-savings potential from buildings is particularly large, as they account for about 40 percent of global energy demand. Around 30 percent of this demand could be eliminated through improved insulation, controlled air-conditioning, and efficient heating systems. According to the BMU, these measures would suffice to give the global market for building systems a major boost and increase its volume by more than €400 billion by 2030. The Federation of German Industries (BDI) expects the worldwide market for power plant technology to grow by five to ten percent a year. Demand is particularly high for more efficient and low-CO_2 plants. At the same time, the global market for renewable sources of energy is expected to grow three-fold or even six-fold over the next 15 years, expanding from €45 billion to as much as €250 billion.

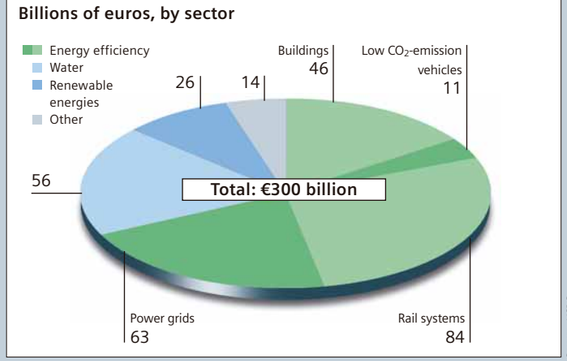
To create "green" cities, city managers will have to invest huge sums in complex projects. Because municipal budgets will often not suffice for such tasks, cities will have to work with private investors. Each year, the private sector accounts for up to 15 percent of the investments made in infrastructure projects worldwide. Such investments are frequently made in the form of public-private partnerships (PPP), whereby companies not only supply products and services, but also conduct project management and provide long-term financing for a part of the costs. Siemens' energy-saving performance contracting represents a special kind of PPP. Here, the use of environmental technologies is financed solely through the savings achieved in energy costs. To date, Siemens has implemented more than 1,900 such projects for buildings worldwide with guaranteed savings of €2 billion and a reduction of 2.4 million tons of CO_2. For the affected cities this means greener buildings — for free. ■ *Anette Freise*

The Global Market for Environmental Technologies will Grow to over €3 Trillion



Source: BMU, Roland Berger

Economic Stimulus Programs Include €300 Billion for Green Solutions Worldwide



Source: HSBC

San Francisco: Why it's Getting Tougher to Get Greener

Paul Pelosi Jr.,41, is President of the San Francisco Commission on the Environment. Under his leadership the city conducted energy efficiency programs yielding a 28 MW reduction in electricity use. Recycling was increased from 46 to 70 percent, and CO_2 emissions were cut by six percent, to below 1990 levels. For over 15 years Pelosi has been advising companies on finance, infrastructure and sustainability. He earned a BA in History and a JD/MBA, focusing on International Business.

What do you like about San Francisco?
Pelosi: I love the people and the open atmosphere. It's a compact town in which walking is a viable alternative to driving a car. When it comes to environmental action, you will meet many interesting people who truly care about the issues and want to make changes.

It must be a lot easier to introduce new environmental protection policies in San Francisco than in other areas of the U.S.
Pelosi: It's the other way around. It is more challenging to move forward in San Francisco, because we already have gone so far down the road. We recycle, we have implemented efficiency-enhancing equipment, and we have economic incentives in place. The quick wins and the big savings have already been made. The marginal utility of additional measures tends to decrease over time. But if you go to, let's say, Oklahoma, large gains are still to be made, environmentally and economically.

You once worked in banking. Do you do cost-benefit calculations before you start green initiatives in San Francisco?
Pelosi: Before we adopt an initiative, we usually carry out a thorough analysis. For instance, we took a close look at our recycling policies some time ago and found that in order to make them sustainable, we would have to align them more closely to the dynamics of the market. Waste contains very valuable elements. For example, certain metals can be harvested, but their prices fluctuate wildly, creating a level of economic risk no private partner in a recycling regime would have accepted. Therefore, on a wholesale level we signed futures contracts securing stable prices for the metals in our waste. On that basis, we collaborate with private players who do the operational part.

How can technology help to limit environmental impact?
Pelosi: Technology is a tool. It should be designed in a way that effectively addresses the most relevant problems. When I think about water treatment and energy efficiency, Siemens' portfolio comes to mind. Many of these technologies open the door to decentralization. The smart grid, which Siemens is promoting, is going in that direction. With its help, we are able to diversify power sources and enable communities to develop their own unique solutions to local challenges. This could make it possible for the city to close coal burning power plants in the future. In the past two years, we have been able to close two such facilities, in Bay View and Potrero Hill.

Per person and per year, the amount of CO_2 emitted by the residents of San Francisco is half as much as the average for the entire U.S. – a great success, but still twice as much as in Copenhagen...
Pelosi: This difference can be reduced over time, in that we make use of new technologies that lower energy consumption. We can learn a lot about this process from the successful examples that we are seeing in Europe, particularly with respect to improving energy efficiency.

In what ways will San Francisco change by 2050?
Pelosi: Let's hope it won't be under water! Due to climate change, if we don't cut CO_2 emissions drastically, parts of the city quite possibly could be under water. We will divert most of our waste from landfills to recycling; most buildings will be LEED-certified, which means they will meet very high standards for environmentally sustainable construction. These buildings will also be more agreeable places to work, because they will have more natural light and ventilation. The city will maintain its commitment to parks and greenery. You will see windmills in town, you will see tidal and wave energy plants. You will see electric cars and improved local transportation and more photovoltaic systems. I would love to live in San Francisco in 2050 — as long as it isn't under water.

■ *Interview by Andreas Kleinschmidt*

Returning to a Sense of Irreplaceability

Daniel Libeskind, 63, is one of the most renowned architects worldwide. For many years he taught architectural theory at Harvard, Yale, and the University of London. Libeskind completed his first building, the Jewish Museum, Berlin, at the age of 52. The project, which was inaugurated in 1999, put Libeskind on the map. Since then he has been involved with groundbreaking architectural projects such as the redevelopment of "Ground Zero" in New York. His projects increasingly reach out into the sphere of urban design. In 2009 he presented an energy-efficient prefabricated villa.

What, in your opinion, is a livable city?
Libeskind: An open, democratic city, a city where you can participate in the shaping of its future. There has to be excitement. There has to be tension in terms of technology, politics, buildings — a certain air of creativity and innovation. You can have a city where everything is perfect and everything is running efficiently and smoothly, but you want to commit suicide because there's no spirit in it. Or you live in a city with huge problems, but there is potential in it and you can participate in the city's remaking. The latter is obviously more inspiring.

Which city comes closest to your ideal?
Libeskind: It would have to be a combination of several cities: a bit of Berlin and its creative flair, a bit of greater New York, including parts of Queens and Brooklyn, a piece of Milan and its classy style, a bit of Kyoto with its orderliness, a bit of São Paulo and its chaos. That would be the kind of global city that I like.

Cities built from scratch with the aim of being paragons of efficiency would therefore be rather unappealing to you?
Libeskind: Not necessarily. When I say that a great city needs a bit of messiness to be more livable, I am really referring to the intellectual capacity for change in a city. It can be observed in Berlin, a city of constant change. It would be possible to find it in a city built from scratch. Brasília proves the point. Masdar City might as well. It is not about particular buildings, it is about an ambience that sets people free.

Energy efficiency is becoming more and more important in both architecture and urban design. What does this mean for your work?
Libeskind: Enhanced energy efficiency does not conflict with a beautiful form of architecture. However, a great and sustainable building should not have engrained in its aesthetics the statement: Here we are saving energy. Great architecture will still be about human dreams, human aspirations. But technology can help us to get there. New technology gives us incredible opportunities. It is not a barrier to great architecture, nor is it the expression of great architecture. I see it as an enabler.

How important a role does energy efficiency play when it comes to your own projects?
Libeskind: In December 2009 CityCenter was opened in Las Vegas. It's a mixed-use urban complex with a surface area of more than 1.5 million square meters. Its total cost of approximately $11 billion makes it the largest privately financed development in the United States. It is huge, but it expresses an architectural vision. And it is also green. The entire building is gold LEED certified, meaning that it fulfills the highest standards for energy efficiency. *(photo at left)*

Siemens delivered solutions for CityCenter totaling around $100 million...
Libeskind: Yes, Siemens building technology features prominently in it. CityCenter uses low-wattage lighting sets from Osram, for example and produces its own energy in a highly efficient cogeneration power plant. The shower heads, faucets and toilets reduce water use by 30 percent. I think every building should have some of these features in order to be called a piece of architecture. And then there's the prefabricated villa I designed last year. We used wood as its base material. Photovoltaics produce energy, and the orientation of rooms with regard to light sources and the proportions of rooms enable a low-energy footprint. It will be one of the most energy-efficient, carbon-neutral buildings on the market. Sustainability is the way forward. Great architecture has to embrace this trend.

In what ways has the global financial and economic crisis affected architecture?
Libeskind: Some huge projects — like the Burj Khalifa Tower in Dubai — obviously had to be completed in spite of funding issues. Other, more recent projects may have been scrapped or downsized. But good architecture is never just about throwing money at projects. We were able to deliver the Jewish Museum in Berlin for several million dollars under budget. There are limits to everything, and the fact that the world appears to be running out of resources is a powerful reminder of this. I see the current situation as a chance to bring back a perception of architecture as something irreplaceable. It is not just another consumer item, but something we need for life.

■ *Interview by Andreas Kleinschmidt*

The Yas Marina Formula One circuit runs into the night. Sophisticated technology from Siemens, which could also be used in Masdar in the future, makes it possible (right).

A Desert Full of Contrasts

Abu Dhabi is preparing for the post-oil era — with energy-efficient technology from Siemens. As a potential technology partner, the company is working with the Masdar Initiative to develop concepts for the CO_2-free desert city of the future.

Greater contrasts are hard to imagine. About nine percent of the planet's known oil reserves can be found beneath the desert sands of Abu Dhabi, yet this is also where the world's first CO_2-neutral metropolis — Masdar City — is being created (see *Pictures of the Future,* Fall 2008, p.76 and Fall 2009, p.34). Just a few miles away, on Yas Island, racing cars are roaring around the most modern Formula One circuit in the world. Meanwhile, taking shape on nearby Saadiyat Island is a leisure and vacation paradise, which will also be a habitat for rare animal species such as the hawkbill turtle.

Abu Dhabi is growing, and in the process it must strike a balance between all of these paradoxical developments. But one thing is clear: The future belongs to energy from renewable sources. With the Masdar City project, which is currently being concretized, municipal leaders are showing their commitment to this trend. The city is being built near the international airport. And by relying on renewable sources of energy — including photovoltaics and solar thermal technology — it should be able to self-sufficiently cover the needs of its roughly 40,000 residents and an expected 50,000 commuters. These needs will be relatively modest — thanks in part to ultramodern building management systems. Siemens could play an important role in Masdar City in areas including a planned smart power grid system, the transportation system, and infrastructures for power generation.

Masdar City is only one of the projects that Siemens has been working on in Abu Dhabi. In 2008, for instance, the company built a transformer substation near the city, on Saadiyat Island, which is expected to provide the power supply for the entire island. The facility was designed to supply enough power for up to 150,000 people, who will ultimately live in almost 50,000 private apartments and houses on the island or stay in up to 29 hotels there.

Siemens and its Austrian consortium partner PKE Electronics AG supplied and installed all the electrical and electronic systems and equipment for the Yas Marina circuit on neighboring Yas Island, including the control and monitoring systems needed for racing, the various security and access systems, and the power supply, a 22 kV medium-voltage network with 18 transformer units. At this circuit, for the first time in the history of Formula One, a race started in daylight and ended after dark. This is also why race marshals no longer wave flags to signal important messages to drivers. This job is now performed by very bright LED panels alongside the track.

Siemens' activities in the emirate go well beyond infrastructures. The company has invested a total of $75 million in two Masdar Clean Tech funds; the most recent of which was launched in January 2010. The fund invests primarily in companies in the fields of green energy technologies, environmental resources, energy efficiency, and materials efficiency. "We regard this as a strategic investment that also strengthens Siemens' role as a technology partner for Masdar over the long term," says Joachim Kundt, CEO of Siemens in the Lower Gulf Region.

Another Masdar investment — the London Array wind park, for which Masdar is acting as an investor and project developer — is also based on Siemens technology — although it's in the UK, far from the sands of the emirate. Siemens Energy was commissioned to equip the offshore wind park, which is located at the mouth of the Thames, with 175 wind turbines and to connect it to the power grid. With an output of 630 megawatts, London Array will be the world's largest wind park of its kind when it is completed in 2012.

Through its investments, the emirate is making it very clear that the contradictions in the here and now may one day in hindsight turn out to only have seemed paradoxical. After all, Abu Dhabi is preparing thoroughly for the post-oil era by working with its partners to develop and apply new technologies — until the day arrives when it will cost more to extract the planet's remaining oil than to use alternatives such as solar and wind power.

Who knows? Maybe by then, at the Yas Marina circuit, the racing cars won't be powered by combustion engines — and then, only on special occasions for true fans, there will be races featuring the vintage gasoline-powered cars of yesteryear. ■ *Andreas Kleinschmidt*

Shanghai's Pudong district is said to have the greatest number of skyscrapers per square kilometer in the world. Siemens solutions ensure an efficient power supply.

China's Cities Come of Age

The new cities now springing up in China to accommodate millions of people need one thing above all: efficient infrastructure that meets the needs of residents and the requirements of environmental protection. China plans to demonstrate its ability to address this challenge at this year's Asian Games and especially during EXPO 2010 in Shanghai. It will be supported here by Siemens' expertise and technology.

China is confronted today by an unprecedented wave of urbanization. In just the last few decades, hundreds of millions of people have moved into cities from the countryside, and well over half a billion Chinese now live in urban areas. By 2030 — in just 20 years — that number might double. The new urban residents will need housing, electricity, and water. In addition, the continuously growing Chinese middle class is further increasing the country's huge appetite for energy by purchasing more and more electrical appliances such as vacuum cleaners and microwaves. The middle class will also continue to buy cars as long as public transport systems in the cities remain overburdened. Traffic jams and days of smog are already the rule; as a result, China is now the world's largest producer of pollutant emissions.

The Chinese government is constantly searching for effective infrastructure solutions that can address 21st-century urban requirements. In some cases the government is being helped here by Siemens, a company whose involvement in China dates back 130 years and whose experience includes the introduction of efficient technologies in many Chinese cities. Siemens coordinates all of its activities in China from its headquarters in Beijing, a 123-meter-high glass tower that was inaugurated in August 2008. Thanks to a smart building management system, its own wastewater recycling system, and a heat recovery system, the building requires about 30 percent less energy than comparable buildings without such technology.

Two major events will dominate 2010 in China: the Asian Games in Guangzhou (November 12-27) and the EXPO 2010 in Shanghai (May 1-October 31. See box p. 41). China would like to use these events to demonstrate its ability to overcome the challenges associated with urbanization. The Asian Games will be the highlight of the year in Guangzhou, the capital of Guangdong province in southern China. Preparations have been running at full speed for several years now, with workers hammering, building, and renovating around the clock. Guangzhou, which has over ten million residents, intends to put its best foot forward by ensuring professional management of the millions of sports fans who will stream into the city.

Public transportation is a key area. "Guangzhou will expand its subway network from five to eight lines in time for the Asian Games, and an additional seven lines will be added by 2020," says Liu Hao from Siemens' Mobility Division. His team and colleagues, including local partners, are managing the delivery of 79 subway trains for three subway projects to the city's public transport operator. Siemens has equipped these trains with, among other things, intelligent control technologies and a propulsion system that converts braking energy into electricity that is then fed back into the grid. "The propulsion system can result in significant energy savings," says Liu.

The extent to which the expansion of the subway system will affect road traffic is gradually becoming clear. Today, some 3.6 million people use the system. Following the system's expansion, however, passengers will be able to travel to Guangzhou's new railway station, which will be opened in time for the Asian Games.

Serving some 200,000 people per day, it will be the biggest train station in Asia. The Guangzhou New Railway Station will feature Siemens switching systems, which will ensure reliable distribution of electricity.

Guangzhou obtains much of its power from hydroelectric plants located 1,400 kilometers away in Yunnan province. The delivery of electricity over such a long distance is made possible by what is currently the world's longest and most powerful high-voltage direct current transmission system.

Built by Siemens, the transmission system transports cleanly-produced power at a record 800,000 volts and an output of 5,000 megawatts to the megacities on China's southeastern coast. The network supplies up to five million households with electricity; its use of hydropower also reduces China's annual CO_2 emissions by 33 million tons as compared to the same output achieved with coal (see *Pictures of the Future,* Fall 2009, p.24).

One of the major consumers of this clean power will be the West Tower, whose height of 432 meters will make it the second-tallest building in China. After it opens in October 2010, the glass giant will be visible from a distance of several kilometers at night — thanks to more than 10,000 LED fixtures from Osram, which will underscore the building's diamond-patterned facade.

> Shanghai just keeps growing. Since 1990, the city's population has almost doubled to 14 million.

"Special software will regulate each LED and the color of the light it produces," explains Li Gang, Osram project manager in Guangzhou. "Osram offered the best computer-controlled illumination system from a single source. Our LEDs also consume up to 80 percent less electricity than conventional outdoor lighting systems, and with a lifespan of around 50,000 hours, they also last much longer."

People from around the world will visit EXPO in Shanghai (left) and the Asian Games in Guangzhou (right). Advanced rail systems will limit traffic jams.

Symbol of Urbanization. While Guangzhou is impressive, it offers only a taste of things to come in Shanghai, China's most important industrial city and one of the fastest-growing cities in the world. Shanghai's population nearly doubled between 1990 and 2008. Today, with about 14 million people, its population density is 7,200 residents per square kilometer, double that of Berlin. No other city in China symbolizes the country's fast pace of development as does Shanghai, where growth can be seen everywhere. Considering all of this, it's no surprise that the city is Siemens' most important market in China. Back in 1904 the company opened its first permanent office for China in Shanghai. Today, Siemens' employs 13,000 people in Shanghai, making it the company's largest location outside of Germany. All of Siemens' sectors are represented here — and all of them have helped make Shanghai more efficient (see *Pictures of the Future,* Spring 2004, p.11).

But Shanghai's exuberance comes at a price. The city's energy requirements are growing by more than 1,000 megawatts (MW) per year. This huge thirst for energy is being quenched by facilities like the Waigaoqiao coal-fired power station, where Siemens has installed several 1,000 MW steam turbines and generators. Today, Waigaoqiao is one of the most efficient coal-fired power stations in the world and covers approximately 30 percent of Shanghai's power requirements.

But despite Waigaoqiao and many other power plants, Shanghai's energy authority is being pushed to the limits of its capacity. In December 2009, the city's electricity requirement reached 19,000 MW on some days, and a power shortage seemed imminent.

To meet the growing need for electricity in Shanghai and throughout the country, China plans to build not only powerful coal-fired plants but also more facilities that utilize renewable and CO_2-free energy sources. The focus here is on wind power. In May 2009 China's national energy agency announced plans to generate 100 gigawatts (GW) of power with wind energy by 2020. By comparison, 120 GW of power is now pro-

Siemens provides efficient solutions. Examples include the Siemens Center in Shanghai (left), the Waigaoqiao power plant (center), and a drinking water processing plant in Wuxi (right).

duced with wind worldwide, which means that China may soon become the world's biggest market for wind energy. Siemens is therefore expanding its global production network for wind power plants. Among other things, the company is building a new rotor blade plant in the Lingang New City industrial area just outside of Shanghai.

"In September 2010 about 200 people will start work in Lingang. The blades they will produce will help us to generate an annual wind turbine output of 500 MW," says Dr. Martin Meyer ter Vehn, General Manager of Siemens Wind Power Blades. "Over the long term, we plan to build both rotor blades and entire wind turbines in the 2.3 MW and 3.6 MW class in Lingang for China, the Asia-Pacific region, and other markets. We also plan to increase the facility's maximum annual output to about 2,000 MW." Meyer ter Vehn is certain that Siemens will be successful. "China has huge potential, especially in the offshore segment. That's because the ocean here is very shallow for many kilometers off the coast, which makes it perfect for such facilities — and as the world market leader for offshore wind power plants, Siemens is the perfect supplier," he says (see *Pictures of the Future,* Fall 2009, p.16).

Strategies for Reducing Energy Demand. Still, it will take more than efficient electricity providers to ensure that a city like Shanghai gets the energy it needs. Energy consumption also has to be reduced, and this especially applies to Shanghai's older buildings. Yangpu is a good example of how to address this problem. Formerly an industrial zone, the district now serves as Shanghai's center of knowledge and innovation, housing the renowned Tongji and Fudan universities, among other facilities. To reduce Yangpu's energy consumption, Siemens has entered into a strategic partnership with the district's administration.

The initial goal is to employ state-of-the-art building technologies to reduce energy consumption by about 16 percent at the administrative headquarters, and later at the Yangpu Commercial Center office complex. Other buildings will follow. The client bears no financial risk, as an energy performance contracting model will allow the district to pay the installments for financing the project solely through the energy-cost savings achieved.

Whether it's mass transit, energy generation or health care, Siemens is involved in Shanghai's infrastructures.

At EXPO 2010 Siemens will demonstrate how energy efficiency, comfort, and convenience can go hand in hand in Yangpu District. The company plans to open its new Shanghai headquarters in Yangpu to coincide with EXPO. The complex will consist of four glass office buildings housing some 2,000 employees. Thanks to efficient building technologies, heat pumps, and cold-storage and waste heat recovery systems, the complex's energy use is expected to be about 25 percent below the U.S. standard for energy consumption. The company's goal is to achieve a LEED certificate issued by the U.S. Green Building Council.

"Increasing building energy efficiency is one of Siemens' biggest strengths in Shanghai," says Dr. Meng Fanchen, Siemens General Manager in Shanghai. "Our goal — and that of China — involves much more than that, however. We need to align the infrastructure of entire cities with the needs of their populations and the requirements of environmental protection. We especially need to do so with the cities that are now being built to accommodate the 13 million people who move into urban areas from the countryside each year." That's why Siemens is working with Tongji University on eco-city models, which will be used to give these "instant cities" as sustainable a design as possible from the very beginning (see p. 104). "Along with energy supply and building management systems, this approach also includes an efficient public transport network, top-quality medical care, and the provision of clean drinking water," says Meng.

These also happen to be areas in which Siemens boasts extensive expertise in Shanghai. The company is supplying key components for Shanghai's subway system. For instance, Siemens is building 58 trains for Shanghai's Line 11 — together with China's CSR Zhuzhou Electric Locomotive Co., Siemens systems will also be used to stabilize the energy supply for the new subway Line 13, which will shuttle between the city center and the EXPO site.

To improve medical care in Shanghai, Siemens is now planning a cutting-edge, IT-integrated, energy-saving and environmentally-friendly hospital in a public-private partnership with Tongji University and Germany-based hospital operating company Asklepios Kliniken. The new facility, which will be built in the Shanghai International Medical Zone, will feature state-of-the-art medical equipment and IT solutions from Siemens that offer patients high-quality and efficient treatment at affordable rates.

Affordable Drinking Water and Pig Iron. Siemens is also a pioneer in water treatment technology. At the end of 2009, the company completed construction of China's largest ultrafiltration membrane facility in the city of Wuxi, one of Shanghai's neighboring cities. The new plant can process 150,000 cubic meters of drinking water per day. The system forgoes chemical pretreatment and delivers high-quality water while taking up very little space. The plant's operating costs are also lower than those of conventional water treatment facilities.

A similar efficiency coup is expected to be achieved with another Siemens-built facility in Shanghai. In November 2007, Siemens-VAI handed over the world's largest Corex plant to steel giant Baosteel. The new facility has the capacity to produce 1.5 million tons of pig iron per year (see *Pictures of the Future*, Fall 2006, p.39). The Corex system requires no special coking coal or coking plant. This results in much lower material costs for pig iron production as compared with conventional processes.

The new plant in Shanghai has also reduced pollutant emissions by as much as 90 percent (see *Pictures of the Future,* Spring 2009, p.20 and Fall 2009, p.62). What's more, the Corex process produces a gas that can be used in a combined cycle plant to generate electricity in a cost-efficient manner — yet another benefit that Baosteel appreciates. The company commissioned Siemens to build a second Corex facility before the first was even finished. This technology could also develop into a huge success for Siemens, as China is currently producing approximately one half of the world's steel. A cost-effective and environmentally friendly system such as Corex is therefore very interesting for the Chinese market.

"Whether it's buildings, industrial plants, transport, or water supply — all the components needed for an eco-city are here," says Dr. Meng. "Our job is to combine them to create infrastructure concepts aligned with the needs of entire cities." Despite the huge urbanization challenges megacities like Shanghai or Guangzhou face, Meng believes China is on the right track. One can therefore expect EXPO 2010 to attract officials from major cities worldwide who are seeking the best ideas for sustainable urban development. EXPO's motto — Better City, Better Life — will be just as much on display outside the Expo center in Shanghai as within the exposition gates. ■ *Sebastian Webel*

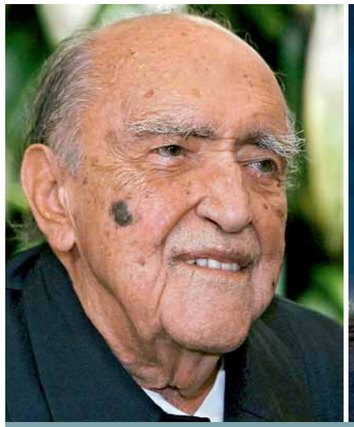
Siemens at EXPO 2010: Efficient Solutions for Urban Life

When EXPO in Shanghai opened its doors on May 1, 2010 in the eastern part of the city, the 5.28-kilometer-long exhibition grounds attracted the attention of representatives of major cities from all over the world. That's because the participants of this year's World's Fair, which is titled "Better City, Better Life," emphasize solutions for urban development — in an age when urbanization is one of the biggest challenges being faced throughout the world. Expo organizers expect to attract 70 million visitors from over 200 nations and international organizations by the end of October.

Siemens is working closely with Expo organizers, as was the case at many previous World Fairs. This year's World's Fair is particularly important for Siemens, which is the official Global Partner of EXPO 2010 Shanghai China, because the company is becoming increasingly involved in providing urban infrastructures and has an expanding range of solutions designed specifically for improving living conditions in cities. Siemens demonstrates these during the exhibition at several individual pavilions. Here Siemens, for example, presents numerous energy, industrial, and health-related solutions that range from electric mobility systems and models of wind turbines to scenarios depicting tomorrow's technologies. Furthermore, many of the facilities at EXPO 2010 also have Siemens technology inside, although this may not be immediately obvious to most visitors.

For example, Siemens is providing the Hamburg House with state-of-the-art technological solutions in order to ensure a very high level of energy efficiency. The building is a passive house, which requires virtually no energy from outside and emits only minimal amounts of greenhouse gases. Sensors measure various factors, such as temperature, air quality, the slope of the sun's rays, and the number of people currently present in the building. The building's control system uses this information to calculate in real time what the optimum position of the blinds should be, as well as the extent to which the rooms should be heated, cooled, or ventilated.

Siemens is also focusing on the permanent facilities that will serve as Shanghai's new green landmark once the exhibition is over. These include the theme pavilion, the EXPO Center, the Culture Center, and the huge China Pavilion (picture above), which covers a total area of 160,000 square meters. Thanks to cutting-edge building systems from Siemens, these structures consume up to 25 percent less energy than traditional buildings and reduce labor costs by up to 50 percent. For example, the energy-efficient LEDs that Osram installed in the China Pavilion consume up to 80 percent less electricity than conventional incandescent lamps. In this way, Siemens is helping EXPO to demonstrate how to create a better city for a better life.



Monuments designed by Niemeyer include the Cathedral of Brasília, a gracefully curved concrete and glass structure, and Brasília's National Theater (below right) — a World Heritage Site.

Brazil: Approaching its Moment in World History

Oscar Niemeyer, 102, is known for spurning the straight line. When designing buildings for Brasília in the 1950s, he used reinforced concrete to create remarkably daring, curvilinear shapes. One of the few architects who has ever actually realized a city from the drawing board to completion, Niemeyer gave Brazilian architecture an image known worldwide. Born in 1907 in Rio de Janeiro into a family of German ancestry, Niemeyer still works on his projects every day in his studio on the ninth floor of a building on the Copacabana.

Many Brazilians are convinced that their country is experiencing a magical moment. The economy is posting stable growth, oil has been found off the coast of Rio de Janeiro, and now the Olympic Games are coming to the city...

Niemeyer: I agree completely. In theory, Brazil offers everything that people need in order to be happy. In addition, the country's political system has been stable for quite some time now, thanks to the fact that we have a highly competent president. The soccer World Cup in 2014 and the Olympic Games in 2016 will be very important and wonderful events for the country and for Rio de Janeiro in particular. Brazil will be host to the whole world, and we will demonstrate to everyone what we can do. Brazil's moment in world history has finally arrived.

For Rio's urban development this also presents opportunities and risks. Do the residents of Rio, the "Cariocas," have the resources to realize a new vision of the city?

Niemeyer: Sure they do. Rio is prepared to adapt to the new situation. And for a city that is already as beautiful as our city is, these efforts are well worth it. The big challenge here, however, is to structure investments so that everyone can benefit — and that also means poor people. We will find intelligent ways to expand the infrastructure in a manner that improves life for as many people as possible. And we will do it too. Don't forget the sense of enthusiasm that is currently powering our country.

A major problem for Brazilian cities is uncontrolled growth. Is good quality of life still possible in metropolitan areas with 20 million residents?

Niemeyer: Approximately 12 million people currently live in greater Rio. The unabated growth of the big cities is an enormous problem, also in Rio — just in terms of the impact on the environment alone. And then there are logistics issues. How do you ensure an adequate water supply for all these people, for example? An isolated solution isn't the answer because, after all, the phenomenon isn't an isolated problem; it grows out of a variety of causes, above all social ones. This is why there is no one single great plan that provides a vision for the solution to the problems faced by Brazil's cities.

Brasília, the capital, was supposed to be precisely such a great plan...

Niemeyer: Brasília was something else entirely. The city was designed as a vision symbolizing progress for the whole country. We found an empty location on which we could realize it. But even there we have been confronted with reality. The city we built back then was designed for a population of about 500,000; today 2.5 million people live there. That doesn't mean Brasília is a broken dream. But dreams must give way to reality sooner or later. The problems of Brazilian cities can be solved only through the day-to-day efforts of urban planners and politicians working to improve things step by step. I hope that the end result will be cities that are more humane, with simpler structures.

How can Rio be given a more humane urban design?

Niemeyer: The answer is simple: Provide relief for the people living in misery in the slums, the favelas. Make living conditions possible that allow human dignity, through investments that really help the people. The approaches we are seeing today at the national and local levels aren't bad. If you asked me to name the three things I would like to see the government change, my answer would be: reduce poverty, reduce poverty, reduce poverty. The fact that it takes kids who live on the outskirts of the city hours to get to a public school means that they just don't attend school. That's one of the worst things as far as I'm concerned. The infrastructure must serve the people's needs and be nearby. The people have to have access to such things as movie theaters and schools. Without social change, however, we won't be able to move in this direction.

What role does innovation and modern technology play in your work?

Niemeyer: I take a pragmatic view. Technological progress is important and valuable if it serves people's needs. When I think back to the work done for Brasília, I have to say that for us — meaning architects — life was more difficult than it is today. Fifty years ago, if we wanted to build a dome with a diameter of 40 meters, it was possible but required an enormous effort. Not very long ago we built such a dome in Spain. There were no problems, as if making something like that were an everyday task. That's mainly due to innovation and the advance of technology.

An important new development for many architects is the growing importance of energy-efficient buildings. Does that also apply to you?

Niemeyer: Sure, that's the future. Architecture is part of society and therefore must bear responsibility, also for its impact, for example, on the environment. In my professional life as an architect, however, that was a less important factor. I claimed to build things in a responsible manner, in that I built for a majority of the people, not for a privileged minority. And I hope people see this reflected in the buildings. But in the meantime, awareness of the need to conserve energy has also become part of an architect's responsibility.

What are you working on right now?

Niemeyer: I am keeping myself very busy. But we've talked enough about architecture for now. You know, life is much more important than architecture.

■ *Interview by Andreas Kleinschmidt*

Rio in 2020

During Carnival, bus riders in Rio certainly don't have to worry about dying of thirst despite temperatures of around 40 degrees Celsius. Merchants sell cold drinks out of Styrofoam chests filled with ice for two reais (€0.80) in the steaming hot buses. The empty cans are snapped up by trash collectors at bus stops. Around 100,000 people in Brazil earn their living by collecting cans. This is an example of how economic incentives make sustainable resource cycles possible. But Rio, which is home to six million people and an additional six million in the greater metropolitan area, has set its sights much higher when it comes to sustainability. In 2014, the city will play host to a number of matches for the soccer World Cup. In 2016, Rio will be the host city for the Olympic Games. Associated investments with an estimated value of around $10 billion are intended to produce a sustainable legacy for the city of Rio de Janeiro, primarily in the form of new traffic corridors and other infrastructure. Moreover, these things themselves should also be sustainable — in other words, reliable and efficient in operation while at the same time frugal when it comes to energy consumption.

"The major events ahead are a giant opportunity to invest in the sustainability of the city," says Luiz Fernando de Souza Pezão, Deputy Governor of the State of Rio. "Energy-efficient technologies have tremendous potential in this regard, as does the generation of renewable energies." The Rio of 2020 could therefore differ in significant ways from the Rio of 2010. The hope is that the people will enjoy a faster commute to work in air-conditioned subways instead of in overcrowded buses. Hydropower will continue to account for a major share of the energy mix, but an increasingly large fraction of the energy mix will come from wind power. Cars will — as they already do — run on ethanol rather than gasoline, but an increasing number of people will leave their cars at home. Siemens is already working on the sustainable solutions of tomorrow. An extension of the Line 1 subway to the Ipanema district of the city was opened in December 2009. Here, as in the rest of the subway system, Siemens provided, among other things, the electrical equipment, lighting, and monitoring and information systems. The line is now to be extended just in time for the Olympic Games to Barra de Tijuca, where the majority of the Olympic sports facilities will be located.

The Fall 2010 issue of Pictures of the Future, will report in detail on the infrastructure projects for Rio and Brazil's development opportunities.

Singapore is studying efficient systems to desalinate seawater (left). Urban planners can simulate the effects of different scenarios on their city at the Siemens "City of the Future" center (right).

Green Test Bed

Singapore is one of the world's richest cities — not just in terms of money but also with regard to environmental protection and sustainability. Siemens has been helping the city-state to move toward a green future for more than 100 years.

Returning to Singapore from a trip abroad in the 1960s, Prime Minister Lee Kuan Yew developed a novel idea. He decided that his small island nation needed to set itself apart from the cold gray cities in the rest of the world. His simple recipe for prosperity and development was "Plant trees."

Today, some 40 years later, the former developing nation has become an international trade and financial center. Some five million people are crowded into this humid metropolis, which occupies an area smaller than that of Hamburg. Despite that, or perhaps because of it, sustainability is a major reason why this Asian tiger has become so successful. Green areas in the city have increased by 50 percent since 1986, for example, even as the population grew by 70 percent. This is one of the things that distinguish Singapore from nearly all other major cities around the world. "Our limited space makes it vital for us to be different," says Andrew Tan, CEO of Singapore's National Environment Agency. "Having a well-functioning city with a clean environment gives us a valuable competitive advantage."

Unlike other large Asian cities, Singapore has developed into a true garden. Exotic plants dominate the canyons between Singapore's skyscrapers, and the city's boulevards are lined with trees. Just a few kilometers away is a lush rain forest that contains more tree species than the entire North American continent.

The government plans to increase Singapore's green spaces by an additional 900 hectares between now and 2020, and it has come up with a solution to the problem of a lack of space on the ground. "We've launched a program that supports the planting of green areas on building rooftops," says Richard Hoo, Group Director, Strategic Planning, at Singapore's Urban Redevelopment Authority. "We want to plant 50 hectares of greenery on buildings by 2030, including green areas on rooftops, facades, and terraces." These "sky-rise gardens" are meant to serve as natural air conditioners. Depending on how much is planted, the result could reduce ambient temperatures by as much as four degrees Celsius.

But this garden city also needs lots of water. In view of this Singapore is laced with a 7,000-kilometer network of drains and canals that transport water from its tropical rains to 15 huge reservoirs, which store and treat it — and serve as communal recreation areas. The latest project, Marina Barrage, is a reservoir, a flood barrier, and a recreational attraction. In addition to harvesting rain and importing water, the city relies on two other sources: high-grade reclaimed water, called NEWater, and desalinated water, which is still an energy-intensive source. "It's crucial for us to develop processes that produce the same amount of purified drinking water that we have now, but utilize less energy," says Yap Kheng Guan, Director of Singapore's water agency.

This will require systems like those developed by Siemens Water Technologies in Singapore. In 2002 the company installed a new membrane filter system at the Kranji water treatment facility in the northern part of the island. This facility now converts 80,000 cubic meters of wastewater per day into clean water, most of which is used by the country's semiconductor industry (see *Pictures of the Future,* Spring 2006, p.22). What's more, Siemens is now poised to launch another groundbreaking technology that is sure to attract a lot of attention. In October 2010 the company will begin operating a pilot facility that can desalinate 50 cubic meters of seawater in a highly efficient manner using electrical fields. The process uses 50 percent less energy than the best conventional technologies (see *Pictures of the Future,* Fall 2008, p.39). And scientists in the company's labs in Singapore are already preparing their next innovation. "We're working on a new wastewater treatment technology that requires much less electricity than conventional techniques," says Dr. Rüdiger Knauf from Siemens Water Technologies. "In this process, carbon from the wastewater is bonded to microorganisms that are later converted to biogas." The gas can then be used to generate electricity. "So in the end, we expect to derive the same amount of energy from the process that is put into it," Knauf adds.

Green Test Bed. The development of green technologies is as much an opportunity as it is a necessity for Singapore. The government anticipates that the cleantech sector will create turnover of roughly €1.6 billion by 2015 and will also create 18,000 jobs. "We want to become a global hub for the development and production of green technologies," says Manohar Khiatani, CEO of JTC Corporation, which is responsible for developing industrial sites in Singapore. In order to give cleantech companies an appropriate setting and offer them a test bed for their innovations, JTC is building Singapore's first "green" business park, in which buildings will be linked by trellises covered with plants to lower temperatures throughout the entire complex.

> International companies can use Singapore as a test bed for sustainable technologies.

"Environmental sustainability will be the natural direction businesses will take in order to move forward," says Khiatani. "Our CleanTech Park will be emblematic of that." Singapore expects its green revolution to lead not only to economic success but also to new ideas for balancing high population growth with sustainability and limited space — for example, with the "living laboratory" strategy (see interview on p. 46). This strategy allows international companies to use the city as a test bed for developing sustainable technologies that can be made ready for market. Such companies can also apply for government support. The government then takes over projects whose innovations offer a solution to Singapore's pressing issues, as was the case with Siemens and its water treatment technologies.

Singapore is pursuing a similar approach in the energy supply sector. The country currently obtains 80 percent of its electricity from gas power plants. To reduce its dependence on gas, it plans to improve efficiency and promote renewable energy sources such as solar power. A smart electricity grid with some 5,000 smart electricity meters is now to serve as a test field. "We want to examine how an increasing amount of solar energy can be integrated into the grid and how a smart grid can help consumers optimize their electricity use," says Lawrence Wong, CEO of Singapore's Energy Market Authority. "Along with the smart grid, the government is also test-bedding electric cars and rolling out a network of charging stations to serve the initial batch of electric cars expected in the coming year. Both projects will prepare us for the future," he adds.

Sustainable Economics. The future of major metropolitan areas is also the focus of the "City of the Future" center of urban development expertise operated by Siemens in Singapore. Here decision-makers from around the world can check out solutions for cities and learn how to manage urban growth more sustainably. "We've developed an interactive game that allows visitors to manage a virtual city," says the center's director, Klaus Heidinger. Here, four players take on responsibility for a city over a simulated period of 50 years. "You lose very quickly if you don't play as a team," he says.

Losing means risking bankruptcy for your virtual city — something that can happen very fast. If, for example, the player responsible for infrastructure builds too many roads, the level of environmental pollution will automatically increase and the quality of life index will fall. If one of the other team members fails to counteract this development quickly by building green power plants that offset the higher emission levels, for example, the simulated city will collapse and go bankrupt. Even some real-life mayors would have problems with the game, according to Heidinger, especially if they aren't able to make some fast decisions. Yet another Siemens application developed at the center

will help with such quick decision-making: "City Cockpit" is a software solution that enables decision-makers to view up-to-the-minute city data on their PCs. Such data can include everything from particulate levels to tax revenue. "This software makes it possible to nail down practically every problem in a city in just two minutes," says Heidinger.

Singaporeans know how to address rapid growth and make fast decisions to prepare their city for the future. But they also like to slow down at least once a year when Singapore's Prime Minister traditionally plants a tree somewhere in the metropolis — just as the nation's founding father, Lee Kuan Yew, did for the first time some 40 years ago. ■ *Florian Martini*

Lead Market for Sustainability

| Interview

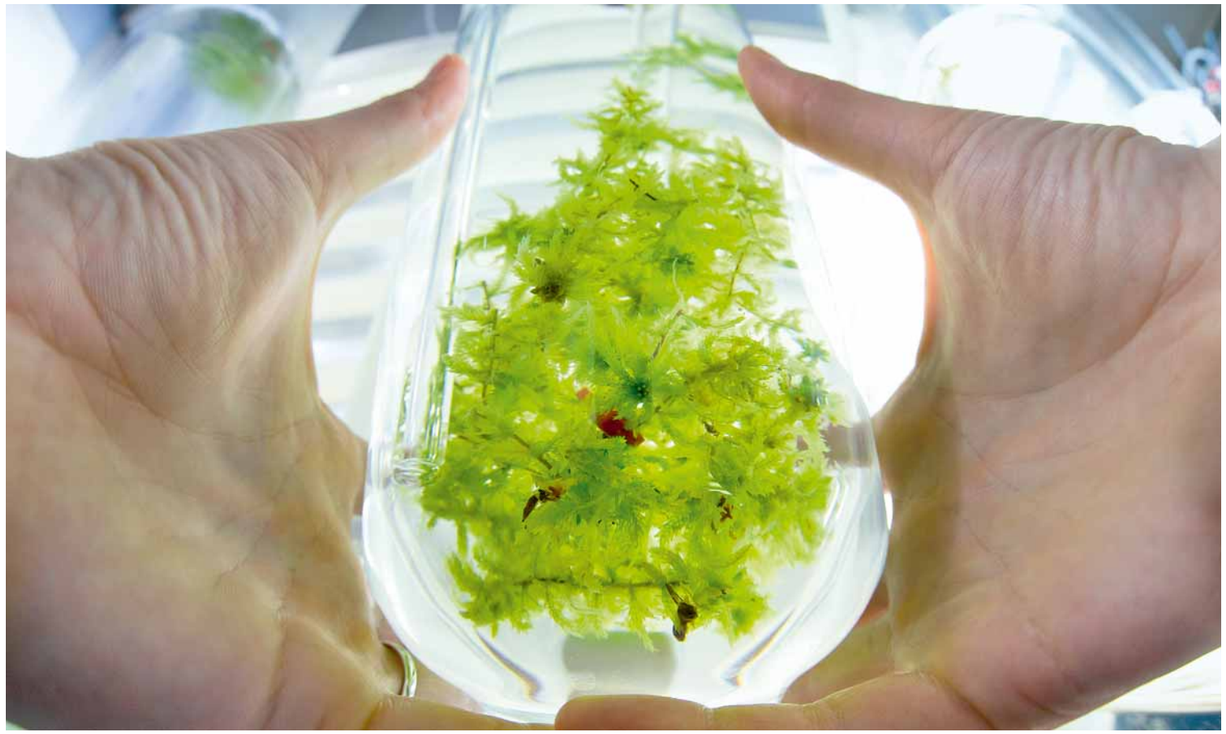
Dr. Beh Swan Gin (42) is the Managing Director of Singapore's Economic Development Board. A medical doctor by training, he has worked for 16 years at the Board, which considers itself a "compass" for Singapore's evolution as a business center.

The Kranji NEWater treatment plant transforms wastewater into potable water.

What role does sustainability play in Singapore's development?
Gin: Singapore is an island with limited space and resources. Here, land has always been a luxury that must be managed carefully and efficiently. It's basically thanks to our founding fathers that we are often held up as an example of sustainable urbanization. Back in the 1960s, they made a conscious decision to give precedence to sustainable development. They wanted Singapore to become a garden city that prospers economically while growing in harmony with nature.

To what extent can sustainability also promote economic development?
Gin: In Singapore we combine our own need for sustainable solutions with innovative ideas from companies around the world — to both sides' benefit. Companies such as Siemens can use our city as a test bed and collaborate with local universities and institutes to see whether their ideas work. If they do, Singapore can then serve as a lead market. We thus use Singapore as a sort of living laboratory for innovations.

Can you give us a concrete example?
Gin: Take water technologies. The idea of the living laboratory was born when we were looking for new solutions in the field of water treatment in order to become less dependent on imports. Solutions that would be of interest to Singapore — highly efficient, space-saving technologies — did not exist at that time. We thus established the optimal conditions for companies from around the world to develop and test new innovative ideas here. Many of those innovations are now in use in Singapore.
■ *Interview by Florian Martini.*



Algae use CO_2 to create biomass. What's more, they do so five to ten times more efficiently than land plants, and could replace petroleum as a source of fuel or plastics.

Turning Carbon into Cash

Carbon dioxide is more than just a greenhouse gas that promotes global warming. It makes plants grow faster and serves as a feedstock for chemical products and fuels. That's why Siemens researchers want to do a lot more with it than just pump it underground.

If Dr. Osman Ahmed had his way, every building on earth could become a tree. Ahmed, who heads Research and Innovation at Siemens' Building Technologies division in Buffalo Grove, Illinois, would be happy to see "green" buildings everywhere — metaphorically speaking, that is. "If we apply the principles of photosynthesis to facade coatings, every building could convert carbon dioxide (CO_2) in the air into other carbon compounds, such as methanol," he says when describing his "Building as a tree" vision, which he is promoting together with Prof. Maximilian Fleischer from Siemens Corporate Technology (CT) in Munich, Germany. Such coatings should contain nanoscale pigment particles that help to capture sunlight in the same way as the chlorophyll in plants, as well as titanium dioxide, which is also found in wall coatings and toothpaste and, like the silicon of a solar cell, can convert sunlight into electricity. "The coatings can be green like a leaf, but also orange, pink or gray," Ahmed adds.

Solar energy captured this way could be used to convert CO_2 into fuels like methanol that would then be conveyed through a system of capillary pipes into a tank inside a building. From there it could be transported to other locations or used on site if needed to produce heat and electricity. Ahmed is particularly impressed with the method's tremendous potential. "By harnessing just a quarter of the solar energy falling on buildings in the United States, a major portion of the carbon dioxide emitted in the U.S. could be reused," he says.

But achieving as much as 25 percent efficiency in such systems is still just a vision — albeit an attractive one. The German Chemical Industry Association (VCI) considers synthetic photosynthesis to be "one of the most attractive variants" for the reuse of CO_2 "in the long term." In fact, shimmering red dye-titanium dioxide cells that convert sunlight into electricity already exist. They are being manufactured by Australian solar cell company Dyesol for deployment on roofs and have an efficiency of ten percent. And Welsh firm G24 Innovations has been producing such solar cells as plastic-packaged electricity suppliers on a roll since late 2009. Using sunlight to convert CO_2 and water into methanol and oxygen, however, is still a matter for scientists conducting basic research. Their studies focus on finding suitable and stable catalysts for the chemical reaction.

Synthetic photosynthesis is one of many options when it comes to reusing climate-damaging CO_2 rather than just blowing it into the atmosphere or burying it underground. After all, everything that is produced today using fossil raw materials — from fuels to plastics — could theoretically also be produced from carbon dioxide.

Experts representing science, business and industry took a closer look at the most promising ideas for the recycling of CO_2 at a workshop in Bonn in the fall of 2009. The colloquium was organized by Siemens and the German Federal Ministry of Education and Research (BMBF). "Our primary goal was to illustrate the potential for realization of the various strategies for using CO_2," says Dr. Jochen Kölzer of Siemens CT. The BMBF alone will invest €100 million over the next five years in research and development in this field.

Biofuels from Algae. One of the methods discussed at the Bonn workshop was algae-based CO_2 recycling. "Algae use photosynthesis to build new biomass from the carbon atoms in carbon dioxide, and they do so five to ten times more efficiently than land plants," reports Dr. Manfred Baldauf, a chemist at Siemens CT in Erlangen. The resulting biomass could be used in the future to produce biogas, biodiesel, and bioplastics. Potable water is not needed for the cultivation of algae; the tiny organisms thrive in brackish water or even seawater. "Algae harvesting does not consume acreage that would otherwise be used for the cultivation of food crops, since bioreactors can be built on wasteland," says Baldauf.

The workshop revealed, however, that an area equivalent to roughly 7,000 soccer fields would be needed to convert the CO_2 emissions of one 100 megawatt coal-fired power plant. With its 600 square meter algae pilot facility at the Niederaußem lignite-fired power plant outside of Cologne, for instance, power plant operator RWE Power stashes away less CO_2 in an entire year than the power plant produces in just 15 seconds of operation.

Research in this area is nevertheless meaningful because algae can process CO_2 directly from a power plant's flue gases. In fact, power plant waste heat even promotes their growth. Scientists at numerous research institutions

are working on making the process more efficient. They want to not only increase the amount of light that is input into algae systems but also develop methods for recycling algae nutrients such as phosphates and oxides of nitrogen. In addition, industrial wastewater could also be used as a source of nutrients.

CT researchers have developed a method by which algae can be easily harvested: adding magnetite particles to the algae. A magnet can then collect the algae without the water in the culture tank having to be drained. One of the advantages of this concept is that because water loss is minimized, it opens the door to algae production in drier areas.

An Industrial Raw Material? When it comes to recycling CO_2, researchers can look to some proven technologies for inspiration. After all, carbon dioxide has been an important source of carbon for the chemical industry for decades. Roughly 110 million tons of CO_2 are reacted here each year, reports Dr. Michele Aresta, a professor of chemistry at the University of Bari, Italy. Carbon dioxide is used as a feedstock for urea, which can be further processed into fertilizers and synthetic resins. The salicylic acid in Aspirin is also manufactured with the help of CO_2.

One process that could become particularly important for future carbon dioxide recycling is the production of methanol. This alcohol is currently produced industrially from synthesis gas, a mixture of carbon monoxide and hydrogen. It is also technically possible to produce it from CO_2 and hydrogen.

Today, methanol is used primarily as a solvent and as a starting substance for industrial chemicals. It can also be used in fuel cells for the generation of electricity or as a fuel. "Methanol could essentially be used right away as a gasoline additive without any need to establish a new infrastructure or to put in new pumps at gas stations," says Siemens chemist Baldauf. Methanol can also be converted into dimethyl ether as an additive to diesel fuel. Even methane, especially in the form in which it occurs in natural gas, could one day be produced in large quantities from CO_2 and hydrogen and then fed directly into existing gas supply networks.

The deciding factor for a climate-friendly CO_2 balance for methanol and methane production is the source of the hydrogen. "If hydrogen is extracted from natural gas or petroleum, as is typically the case at the moment, harm to the environment exceeds the benefit," says Baldauf. This is because ultimately more CO_2 is released than can be captured by the reaction to produce methanol. Researchers are therefore working, for example, on methods for producing hydrogen from water using algae or electricity from renewable sources. "If the hydrogen were produced in wind farms or solar parks, it could be processed further into methanol or methane directly on site," explains Baldauf. "That would simultaneously provide storage media for excess wind or solar energy." The hydrogen could, of course, be used directly as a source of energy, which would be twice as efficient from an energy point of view. One argument against this approach, however, is that a separate infrastructure, including refueling pumps, would have to be built for transporting it.

Mineralization: Long-Term Answer? A technology that is further away from realization, but that offers perhaps the greatest potential is mineralization. "With mineralization, CO_2 is chemically bound in silicate rock containing magnesium or calcium," reports Baldauf. This process occurs spontaneously in nature, albeit slowly. The products of mineralization are carbonates — chalk-like powders that could be used as fillers for the paper industry or in construction. Magnesium carbonate is familiar to anyone who's ever climbed or done gymnastics. It gives your hands more grip and helps to dry perspiration.

Mineralization could have tremendous potential. "Theoretically, the rock in a single large mountain in the Sultanate of Oman could take more carbon dioxide out of circulation than we could ever produce worldwide," said Professor Ron Zerhoven of the Abo Akademi in Finland at the Bonn workshop. However, the rock would first have to be mined and ground to provide the greatest possible surface area for the chemical reaction, thus accelerating the reaction — an extremely energy-intensive procedure. Furthermore, millions of tons of carbonate would have to be transported and stored.

> Wind power can produce hydrogen, which can be combined with CO_2 from the air to form methanol.

Algae use CO_2 from power plant flue gas to grow. Silicates can thus be transformed into useful substances such as magnesium carbonate (right).

Many methods for using CO_2 are still in their infancy. "Most of them are technically feasible, however," emphasizes Dr. Günter Reuscher of the Association of German Engineers. The most important objective is now to prepare comprehensive energy and CO_2 balances and review the economic feasibility of industrial implementation. These analyses must also be compared to the balances for alternative strategies. "Only then will we be able to say which technological option is best from an environmental point of view," says Reuscher. The possibilities for recycling CO_2 must not be used as an excuse to be less careful in the future when it comes to the use of fossil raw materials. As Reuscher points out, "It will always more efficient to avoid carbon dioxide production than to recycle it."

Nevertheless, investments in research and development, as well as continuing work on the part of chemists and engineers, could turn carbon dioxide into a best seller one day. This has already happened with a Dutch oil refinery. Its carbon dioxide waste gas is used as a growth accelerator in nearby greenhouses. Here, the gas vilified as a climate killer has turned into a cash cow and even sells out from time to time.

Andrea Hoferichter

Vertical farms could feed megacities. Even today, greenhouses on rooftops would be sufficient to feed much of New York City's population.

Food Where it's Needed

In the future, high-rise urban greenhouses may be able to help feed a growing world population, while making it possible to turn some farmlands into forests.

Dickson Despommier, a parasitologist at Columbia University in New York City, has an office on the second floor of a 15-story building overlooking the Hudson River. From here he can see the George Washington Bridge and the wooded cliffs of New Jersey on the opposite bank. Despite his great location, the 70-year-old scientist is dreaming of a very different kind of high-rise.

What Despommier has in mind is the following: a 30-story skyscraper with a transparent facade behind which green colors ranging from pastel to emerald hues shimmer in the sun. Instead of having interior walls, each floor would contain hydroponic fields of wheat, barley, or corn; shelves with lots of vegetable plants and colorful flowerbeds; areas in which chickens would be free to roam; and water tanks for breeding fish or shrimp. Heat and light would come from solar cells, geothermal sources, wind or hydro power, and fertilizer would be obtained from the sewage system and livestock manure.

This is Despommier's vision of a "vertical farm" that would provide fresh food to thousands of people from a downtown location. And while the idea might seem bold, it actually fits in ideally with the current wave of modern green urban planning, as the skyscrapers would simply add another urban oasis to complement today's parks. What's more, people could obtain fresh vegetables, fruit, grains, and poultry every day from such farms, thus eliminating the need to have food shipped in from afar — not to mention from the other side of the globe. "Many environmentally-conscious people say we need to purchase locally produced food — but you can't get any more local than your own neighborhood," says Despommier.

Despommier has two arguments that support his vertical farm concept. The first involves global population growth. The U. N. estimates that by 2050, more than nine billion people will be living on the planet, the majority of them in cities. This will create the need for almost one billion more hectares of arable land — an area around the size of Brazil.

Second, vertical farms would help to fight climate change in two ways, as Despommier explains: "On the one hand, food produced locally all year round would have a tremendously positive impact on transport and refrigeration costs, as well as on CO_2 emissions. In addition, land currently used for agriculture could be returned to nature, creating giant carbon sinks."

There's no doubt that Despommier is reaching for the skies, so to speak. Nevertheless, the concept he and his students came up with ten years ago could be feasible. For example, highly efficient greenhouses have existed for some time in places where one might not expect to find them. One such greenhouse, known as Eurofresh, is in the middle of the Arizona desert. At 128 hectares, it's the largest hydroponic greenhouse in the U.S., and is capable of delivering produce all year round, including 80,000

metric tons of tomatoes annually. The greenhouse also requires around 70 percent less water than a conventional field, while occupying much less space. That's because in a hydroponic system, water enriched with nutrients is not absorbed by soil but instead provided directly to the plants rooted within a container of soilless material — and where there's no soil there are fewer pests. Dangerous diseases and parasites are thus less of a problem here than in open fields, which means fewer pesticides are needed as well.

According to Despommier, Eurofresh demonstrates just how much can be grown indoors today using state-of-the-art technology. Still, he criticizes the fact that Eurofresh is located too far from a major metropolitan area and delivers too much of its produce throughout the entire U.S. "Even if you leave out the transport and energy costs, a lot of vegetables spoil en route," he explains. Nevertheless, Despommier envisions his vertical farms as something akin to Eurofresh, except his facilities will be multi-storied and located directly in urban areas.

It's no surprise that architects, who have a reputation for getting excited about futuristic concepts, have already submitted countless proposals for vertical farms. One of them is Oliver Foster from "O Design" in Brisbane, Australia. Foster's design calls for an airy, 12-story farm that was so appealing it was featured in "Science Express," a train-based exhibition, which is partially funded by Siemens and toured various German cities in 2009 (see *Pictures of the Future*, Fall 2009, page 82). Currently Foster is working on a vertical farm design for Singapore.

Every floor of the round building Foster planned is six meters high, to let in as much daylight as possible. The structure would feature white and reflecting surfaces, which together with LEDs would help to better distribute light throughout the building. Foster's design also features an adjacent garage whose roof would serve as a fruit plantation. The garage itself would be linked to the farm by a bridge. "You could also easily integrate a restaurant into the complex," says Foster, "and use the farm's food produced on site."

> A thirty-story building could cultivate as many plants as a ten-square-kilometer conventional farm.

Despite all the enthusiasm, several questions remain open, most notably those involving costs. For one thing, property values are very high in major cities. When pressed about this, Despommier says every city has enough abandoned areas to accommodate vertical farms, and city-owned properties could also be used. "In New York, for example, we have Floyd Bennett Field in Brooklyn, an airfield measuring about five square kilometers," he explains. "There's also Governors Island in New York Harbor. It has 70 hectares, and the city has been trying to figure out what to do with it for years."

Producing food in megacity high-rise buildings would not only significantly reduce CO_2 emissions, but would also cut transport, refrigeration and storage costs.

Despommier also points out that even though vertical farms take up little space, they can more than measure up to large agricultural facilities. That's because crops can be grown all year round, which means lettuce can be picked every six weeks, and even corn and wheat could be harvested three or four times a year. Specially cultured miniature grains could also be used. Their stalks could be grown more closely together and on two levels rather than just one level on each floor. This type of thinking leads Despommier to the following conclusion: "A 30-story building located on a 0.6 square-kilometer block in New York could cultivate as many plants as a ten square-kilometer farm."

Rooftop Plantations. A vertical farm needs to have a well-functioning irrigation and ventilation system and enough light and electricity — all at an affordable cost. That's why Gene Giacomelli is cautiously optimistic about the prospects for vertical farms. An expert from the Controlled Environment Agriculture Center at the University of Arizona in Tucson, Giacomelli planned and built a food growth room for the Amundsen-Scott U.S. research station in Antarctica in 2004. "It's still not clear how we can solve the problem of producing enough light at an affordable price for all the plants in such a building," he says. "That's why it's still easier to grow crops outside in fields. But the obstacles aren't insurmountable."

Despommier, for his part, won't be put off by a couple of stumbling blocks; but he has scaled down his plans somewhat and become more flexible. For one thing, he has decided that the first vertical farms wouldn't need to be 30 stories high or have to feed 50,000 people. Instead, he's now promoting a pilot project involving cooperation with universities and agricultural companies to initially test various technologies. He also welcomes small steps in the right direction, such as greenhouses on rooftops, which if set up all over New York could produce enough food to feed a significant proportion of the city's residents.

Public authorities are taking Despommier's ideas seriously. Several cities, including New York and Newark, New Jersey, and even the government of Jordan have expressed interest in his vertical farm concept due to their desire to reduce pressure on water resources. The problem is that budgets are tight at the moment, which means no great progress can be expected for now. Still, Despommier believes that the approaching challenge will ultimately force people to put his plan into action. "Nothing motivates people more than trying to avoid impending doom," he says, "which is exactly what we're facing with overpopulation and climate change. Vertical farms could help us out of the mess we're in right now."

■ *Hubertus Breuer*

Thanks to lighting and building technology from Siemens, the Vancouver Convention Center (left) and the headquarters of Germany's Süddeutscher newspaper meet the highest efficiency standards.

A Holistic Approach to Buildings

Today's buildings could achieve energy savings of up to 50 percent. All that's needed is an intelligent combination of lighting, air conditioning and safety systems.

Buildings literally gobble up energy. In fact, energy expenditures account for around 40 percent of a building's total operating costs. All in all, buildings are responsible for 40 percent of primary energy consumption worldwide and around 21 percent of greenhouse gas emissions (*Pictures of the Future*, Fall 2008, pp. 48–79). But the potential for savings is also considerable. "Lighting accounts for 19 percent of total electricity consumption worldwide," explains Peter Dobiasch, a specialist in professional lighting systems at Siemens' Osram subsidiary. "The use of more efficient lighting systems across all forms of light source would reduce power consumption by a third."

Even greater savings can be achieved when energy sources and energy consumers are optimally harmonized. That's just what the Siemens Building Technologies division (BT) is now doing in partnership with Osram. An optimized configuration in an office building might look like this: a presence detector to recognize if anyone is in the room; an air-quality sensor to measure the CO_2 level — if no one is there, lighting and ventilation can be switched off; a dimmer system with a brightness sensor to determine how much, if any, artificial light is required; sun blinds and louvers that automatically track the course of the sun so as to let in the optimal amount of daylight; and a temperature sensor to measure heat input so that the system can determine whether a combination of increased shade and artificial light would be more energy-efficient than turning up the air conditioning. "Smart algorithms are used to calculate which mix saves the most energy," Dobiasch explains. "A building can achieve savings of as much as 50 percent. Today, Siemens is the only company offering such a holistic system for reducing energy costs."

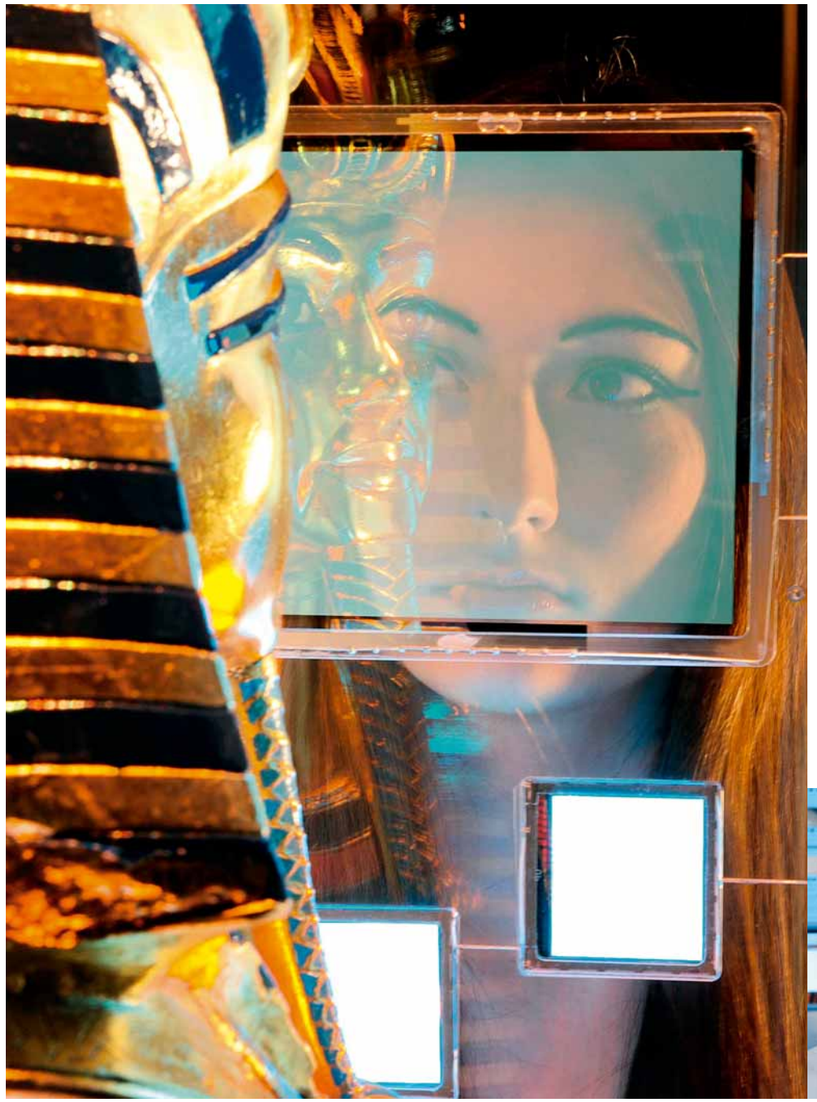
In fact, as Dobiasch explains, Siemens even guarantees that its predicted energy savings will be achieved. "The investment pays off — as a rule, within two to five years," he says. Siemens offers a special contracting service in this field. Once engineers from Siemens and lighting designers from Osram have analyzed a building's requirements, the company will provisionally finance the installation of the new technology. This means the customer doesn't have to pay up front but can instead amortize the investment by means of annual savings in energy costs. To date, Siemens has completed over 1,000 such projects worldwide, with guaranteed savings of €2 billion and a reduction in CO_2 emissions of 1.4 million metric tons.

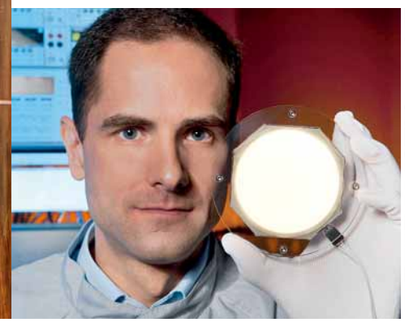
Joint projects of Osram and Siemens BT include the installation of an integrated building management system for the extension of the 100,000-square-meter Vancouver Convention Centre in Canada. As a result, the building has received gold certification of its fulfillment of the Leadership in Energy and Environmental Design (LEED) standards. This U.S. rating system awards points for low energy consumption, green building design, waste reduction, and reduced CO_2 emissions. The Vancouver Convention Center has a 2.5-hectare green roof that will help make the building completely CO_2-neutral from 2010 on.

In early 2010 the Munich headquarters of newspaper publisher Süddeutscher Verlag, with office space for 1,850 employees, was also awarded the gold LEED certificate — the first office building in Germany to receive this honor. This client's specifications were stringent, including energy efficiency and an optimal working environment, but also flexibility to accommodate different users and potential tenants. The solution was to install an innovative building automation system from Siemens along with individual room control systems featuring presence detectors, so that lighting can be switched off or dimmed when less light is required. In addition, an electronic system provides an optimal mix between a geothermal heat pump, power consumers, incident solar radiation, and ventilation, thus maintaining ideal temperatures in the building without having to draw on the municipal district-heating system.

"Osram and BT have a lot more ideas for the buildings of the future," explains Tobias Huber, Head of Lighting Business Development at BT. In the event of a hotel fire, for example, the following scenario would be possible: Presence detectors register which rooms are occupied and room lighting is activated to wake the occupants. The blinds are automatically lifted so that access to the windows is not blocked. At the same time, the lighting system is switched to an emergency power supply, lights illuminate the escape route in the halls, and presence detectors help rescue workers locate injured persons.

■ *Bernhard Gerl*





At Siemens' Osram subsidiary, researchers are working on lighting tiles like the Orbeos (left) as well as on transparent OLEDs that could someday serve as light-emitting windows (right).

Walls of Light

Organic LEDs (OLEDs) are extremely thin and lightweight surface-emitting lights that will radically change the way we provide illumination. Although mostly confined to labs, OLED technology is moving toward commercialization. In 2009 Osram became the first manufacturer to put an OLED tile on the market.

Would you like to have a look?" says Dr. Christoph Gärditz, who works in business development for LED and OLED lights at Osram Opto Semiconductors, a Siemens subsidiary. Gärditz is referring to "Orbeos," the world's first commercially available OLED light tile. In his hand is a thin, palm-sized sheet of non-reflective glass that glows a pleasant white. It weighs little more than an envelope. "This is a pioneering product on the road to making OLEDs fit for general-purpose lighting," says Gärditz, who points out that it is a good example of why organic light-emitting diodes (OLEDs) will completely change our idea of lighting (*Pictures of the Future,* Spring 2007, p. 34). Most lamps in use today, whether in the form of an incandescent bulb, a halogen spotlight, or a light-emitting diode (LED), are point light sources. OLEDs, on the other hand, are flat and emit colored or white light uniformly across their entire surface.

At its core, an OLED consists of several layers of specially designed materials that together are only 500 nanometers thick — a hundredth of a human hair. These layers are sandwiched between two electrically conductive contact surfaces and a cover and base made of glass. Each layer of plastic consists of chains of small organic molecules. When an electrical current is applied, charge carriers, in this case electrons and electron "holes," move along these chains. The holes are places that are available to electrons. Starting from a higher energy level, the electrons can fall into these empty places and in the process emit their excess energy in the form of light. As a result, the layer glows, and the type of molecule that is involved determines the color of the light. The color of the light is not restricted as much as that of an LED but instead spans a fairly wide range. This is important for white OLEDs, which consist of red, green, and blue light-emitting layers stacked on top of one another — because the more continuous the spectrum of a lamp is, the more true-to-life colors will appear in its light.

Because they are so thin and light, OLEDs can be mounted almost anywhere, and they can therefore convert walls into light sources. With their diffuse light and their good color rendering, large white OLED ceiling lights will make us feel as though we are sitting under the open sky. In laboratories, developers are also working on transparent OLEDs that could be commercially available in two to three years. Among other things, this requires replacing one of the two metallic contact layers with a different material. The plastic layers themselves are already transparent. Glass coated with transparent OLEDs could one day be used in doors, display windows or room dividers either to provide transparent visibility or to produce light itself.

Researchers are also working on making OLEDs more stable with respect to ultraviolet light. This would made it possible to produce windows that would let sun in during the day and give off light themselves at night. In principle, OLEDs would also be flexible if it weren't for their glass and brittle contact layers. In the lab, researchers are experimenting with plastic foils, thin-film techniques, and other contact materials to make flexible OLED lamps. In a few years we could encounter these as luminous roof linings in cars or as lighting columns. Further into the future, OLEDs will be flexible, and will be able to provide illumination in unprecedented ways as light films.

OLEDs had their largest public showing to date at the Light & Building trade show in April 2010 in Frankfurt, Germany. There, Osram made the topic of OLEDs a special focus of its presentation and pulled out all the stops by showing a variety of lighting installations and illumination techniques in order to give architects and light designers food for thought.

OLEDs are manufactured in a high vacuum. A glass substrate less than a millimeter in thickness is supplied with a transparent, electrically conductive contact layer, and then the individual substances are vapor-deposited on this layer one after another, followed by another metallic layer. At the end, a desiccant and a glass cover are added in order to protect the plastic layers from oxygen and moisture. Finally, the finished substrate is divided into individual light tiles that are checked in a quality control inspection. OLEDs emit light through the glass substrate, while the metal contact at the back of the plastic layer reflects the light like a mirror.

Durable Light Sources. The Orbeos delivers 25 lumens per watt (lm/W) and thus already surpasses modern halogen lamps. In the lab, researchers can already get 60 lm/W from OLEDs. And in the next few years, they want to increase the efficiency to 100 lm/W — which corresponds to the level of LEDs in use today. To achieve this, Osram developers have to use special films to prevent the light leaving the OLED from being reflected at the boundary where the glass meets the air, which causes it to remain unused inside the lamp. When it comes to generating more light inside an OLED, the structure of the layers is crucial, says Dr. Karsten Heuser, who manages the OLED department at Osram. "Without good component architecture — the intelligent combination of molecules and right layer thicknesses — you can't achieve good results even with the best materials," he says.

> OLEDs now last five times longer than incandescent bulbs and are more efficient than halogen lamps.

The material itself is also important. Electrons don't always release their energy as light when they connect with a hole. But the probability of producing light can be increased by integrating metals like iridium into the layers. In addition, an OLED's service life — the time it takes for its brightness to diminish by half — depends on the stability of the molecules. "As a rule, an OLED ages faster when it's operated at a higher brightness," says Heuser.

At the moment, OLEDs reach about 5,000 hours, which is five times longer than an incandescent bulb. In a few years they will be able to last for 10,000 to 20,000 hours — new robust substances are expected to increase the longevity of the molecules that emit blue light in particular. But OLEDs can also age in storage if moisture and oxygen seep into their plastic layers. Good encapsulation is therefore a key issue for developers. OLEDs now last for about eight years in storage.

Today, OLEDs are still expensive, because they are made in small batches in labs. In its present form the Orbeos tile costs about 250 Euros. But high-volume production lines will lower the costs considerably — and this also applies to organic materials, which are still being produced in very small amounts. Instead of glass substrates from the LCD industry, developers want to someday coat window glass or even plastic films; the latter is a possible solution for flexible OLEDs.

Researchers would also like to replace the glass cover with a special thin-film encapsulation. This technique offers such good protection that no desiccant is needed. That would reduce costs and increase transparency. Still needed, however, is a substitute for the transparent contact layer that now consists of brittle indium tin oxide — and new production strategies for flexible OLEDs.

It will thus be at least five years, Heuser believes, before the first flexible product is ready. And light-emitting wallpaper is still a relatively long way away. "It's one thing to bend the OLED once into a certain shape, but being able to roll it up and unroll it repeatedly is something else. That poses a much more complex challenge, especially when it comes to encapsulation," says Heuser. Nonetheless, one day we'll wonder how we ever did without the lightweight panel lights. In three to four years, estimates Gärditz, glass-based OLEDs will be so bright, have such a long service life, and be so cheap to make that they'll start popping up in living rooms and bedrooms. ■ *Christine Rüth*

World Heritage in a New Light

Streetlights that use light-emitting diodes (LEDs) cut electricity consumption by up to 80 percent. Not only are LEDs efficient; their light can also be optimally directed.

A stroll after dark in the historic city center of Regensburg, Germany, raises a question. Do modern LED streetlights fit in harmoniously in the narrow medieval lanes of a World Heritage Site city? The light comes from quite a variety of lamps. Some alleys are bathed in a yellowish, almost otherworldly light. Then, just a few steps away, narrowly-focused light cones create a pattern of light and darkness on the cobblestones. Illuminating two of the narrow lanes are cylinders with many tiny points of light — lamps with light-emitting diodes (LEDs) developed by Osram Opto Semiconductors. The lamps were manufactured by Siemens in Regensburg and are designed to be screwed directly into the streetlight sockets. Up to 54 individual LEDs fit into one cylinder.

New LED street lamps from Osram light Regensburg's historic center. The lamps cut electricity consumption by 80 percent and have twice the lifespan of conventional lamps.

The warm light cast by LEDs on the city's historic facades makes the city appear every bit as picturesque by night as by day. The alleys are also more brightly lit, with hardly any dark corners. That's because many of the LEDs create long light cones along the narrow streets, while a few also focus light downward. The LEDs that light the opposite walls are adjusted to use only 30 percent of the electricity required for lighting sidewalks. This is another reason why the lamps require only 40 watts compared to the 90 watts required by their predecessors. "Another advantage of LEDs is that their light can be directed at specific points," explains Dr. Martin Moeck, Project Manager at Osram. "This isn't possible with conventional lamps, so they often have to be overly bright in order to illuminate areas they otherwise couldn't reach. LED lamps can focus their light more effectively, so they're a lot more energy-efficient." Alfons Swaczyna, Head Construction Manager and Director of the Civil Engineering Office of the municipality of Regensburg, also likes the new lamps. "The LEDs have reduced light pollution, meaning light that used to glare into residents' windows or up into the sky," he says.

Comfortable Color. LEDs stand out due to their high energy efficiency and their light's excellent color reproduction. And they can do much more than conventional lighting. LEDs are immediately bright when turned on and can be continuously dimmed down to full darkness. With many other lamps, the gas discharge that produces light stops working if it drops below a certain level. And in the future it will be possible to automatically regulate the color of LED streetlights by, for example, mixing light from a white LED with that of a red one. All this makes the little diodes ideal partners for smart controls. Their longevity also makes them very attractive for municipalities. At over 50,000 hours of light, their service life is twice that of conventional lamps, and they need to be replaced only every ten years.

Energy-efficient street lighting has become an important issue in many cities — especially following the European Union's regulation that in 2009 heralded the end of incandescent lamps. The regulation will also progressively phase out less efficient streetlight lamps by 2015, including widely-used mercury vapor lamps, which only deliver 50 lumens of cool white light per watt (lm/W).

An alternative here is the high-efficency sodium lamp, which illuminates many highways with 120 lm/w. "However, sodium's energy efficiency comes at a cost. The quality of light is inferior," says Matthias Fiegler, who is responsible for Osram's global product portfolio for outdoor lighting. People often find it difficult to recognize colors and contrasts in yellow light, which also often gives them an uneasy feeling. This is why these lamps are less suitable for residential areas.

Among conventional technologies, ceramic metal halide lamps are now leading the way. The powerful beams of white light produced by these lamps reproduce colors very well. They are mostly used in areas requiring a tremendous amount of light, such as stadiums. Today's LEDs, with their 100 lm/w energy efficiency and a color rendering index of 80, are almost on a par with ceramic metal halide lamps. The index measures the extent to which a lamp can reproduce colors in comparison to natural daylight (index 100).

Nevertheless, there's still room for improvement with LEDs. Researchers hope to achieve 150 lm/w and are working on reaching a color rendering index of 90. All in all, LEDs offer the greatest potential for savings. Compared to the oldest systems based on mercury vapor lamps, LEDs could reduce energy consumption by up to 80 percent, says Fiegler. "And LEDs can be combined with control systems that can exploit their ideal dimming characteristics," he adds. "But the key factors for LED use in long-term street lighting will be standardization and modularization, for instance in the form of exchangeable light modules." Osram, in cooperation with international committees, is moving forward in these areas.

Cutting Costs in Half. Procurement costs for LED lamps, however, are two to three times as high as those of conventional light sources. The amount cities could save by using LEDs depends on the technologies they are currently using. Experts forecast, on average, a 50 percent reduction in electricity use and amortization periods of between ten and 20 years. To ease the transition, Osram is developing "contracting models" in cooperation with municipalities, energy providers, and financing partners like Siemens Financial Services. Such models enable cities to use energy savings to pay for the investment in installments. Osram also plans to cut lamp costs by half, so that the purchase prices of future LED systems will be at most only 50 percent more than those of conventional lighting systems.

Many projects are now being financed through funding programs, as is the case in Regensburg. The city won first prize with its LED lighting concept in Germany's "Energy-Efficient City Lighting" competition. It will therefore receive a refund of 60 percent of the costs incurred if it replaces all 250 lanterns in the historic city center with LED lights over the next two years. In the future, Regensburg's soft LED lighting will enchant visitors and inhabitants at night — while using only half as much electricity as it did in the past.

■ *Christine Rüth*

In Brief

■ The process of urbanization is progressing rapidly worldwide — with far-reaching consequences for the environment. More than half of the world's population already lives in cities, which generate 80 percent of greenhouse gas emissions and consume 75 percent of the energy used worldwide. Forecasts indicate that the number of cities with more than ten million inhabitants is set to rise from 22 to 26 by 2015. Most of these megacities will be in developing countries and emerging markets, whose infrastructures are often lacking when it comes to sustainability. To blunt the impact of this rapid urbanization, municipal authorities are increasingly turning to energy-efficient technologies and sustainable city planning concepts. (p. 14, 34)

■ In a study conducted on behalf of Siemens, the *Economist* Intelligence Unit drew up the European Green City Index, which evaluated the sustainability efforts of 30 key European cities. Copenhagen comes out top, followed by Oslo, Stockholm, and Vienna. The cities received their good rankings in recognition of their energy-saving and climate-protection efforts. (p. 17, 20, 22)

■ Due to a lack of space and resources, Singapore is forced to implement sustainable urban planning in a confined area. To this end, it encourages international companies to use the city state as a test bed for green innovations, making it one of Asia's greenest megacities. China is also looking at ways of giving urban growth a greener complexion — for example, through the use of highly efficient Siemens technologies. A wide range of solutions will be presented at EXPO 2010 in Shanghai in line with the world fair's slogan of "Better City, Better Life". (p. 38, 44)

■ To turn the dream of a green city into reality, scientists all over the world are working on new kinds of technologies and visionary ideas. Researchers at Siemens, for example, want to install transparent organic LEDs in buildings or exploit the principle of photosynthesis to create a special façade coating. Energy-saving LEDs from Osram are already being used in streetlamps in Regensburg. Some scientists would also like to transform skyscrapers into greenhouses in order to at least partly meet demand for food in megacities with locally-grown products. (p. 46, 49, 52)

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LINKS:

European Green City Index:
www.siemens.com/cities
Expo 2010 "Better City, Better Life":
http://en.expo2010.cn
Future Dialogue:
www.future-dialogue.org
Daniel Libeskind's website:
www.daniel-libeskind.com
LEDs: www.osram.com/led
Vertical farms: www.verticalfarm.com
Singapore on the Web: www.gov.sg
Article on Moscow City power plant in *Venture* magazine: www.energy.siemens.com/hq/en/energy-topics/publications/venture

High-level representatives from science, industry, and government got together at the Future Dialogue conference in Berlin to discuss ways of combating climate change.

What is a Sustainable Future?

Great minds think alike, the saying goes. However, thinking along the same lines is not always enough. Only dialogue between science, industry, and government can produce the concrete steps that are needed when it comes to dealing with severe challenges such as climate change. To make this dialogue happen, the Max Planck Society and Siemens initiated the Future Dialogue discussion forum.

Dennis Meadows, the keynote speaker at the Future Dialogue discussion forum, looks around the auditorium. The room is filled with approximately 500 decision-makers from the areas of politics, academia, and business from all over the world. They have gathered in Berlin to discuss some of the most pressing issues that are haunting mankind today — questions such as climate change and advancing resource depletion — and how megatrends like increasing urbanization and demographic change are affecting them. Meadows, co-author of the controversial book *The Limits to Growth,* pauses in order to emphasize what he is about to say. No one budges, no one coughs. Meadows then goes on. "We are already beyond the limits, using 1.3 Earths instead of one. The habits that gave us growth and progress in the past will not give us growth and progress in the future," he says. "We will see more change over the next 20 years than in the entire past 100." (see p. 57)

Sentences like this spurred controversy in follow-up panel discussions and break-out sessions at Future Dialogue. It was controversy that led to results. Future Dialogue, which took place for the first time in late 2009, was initiated by the Max Planck Society and by Siemens in cooperation with the Economist Intelligence Unit — a globally leading consulting company for economic analysis that has its headquarters in London. The line-up of speakers was impressive, including, for example, star architect and urban planner Daniel Libeskind (see p. 36) and Lord Nicholas Stern (see p. 58), author of the Stern report on climate change. In breakout sessions, clear requirements were defined regarding the responsibilities of government, business, and science. Government, the participants concluded, ought to measure all initiatives according to the clear goal of reducing the global carbon footprint, engage voters with the attractive side of shifting to a low carbon economy, and ensure that basic research receives adequate funding, thus giving it a chance to develop breakthrough innovations.

Businesses, in turn, should work more closely with researchers to improve the connection between invention and innovation, an effort in which Siemens is actively involved, particularly with regard to green technologies. "When I think about water treatment and energy efficiency, for example, Siemens' (technology) portfolio comes to mind," says Paul Pelosi Jr., President of San Francisco's Environment Commission and a speaker at the Future Dialogue conference (see p. 35). "Many of these technologies open the door to greater decentralization. The smart grid, which Siemens is promoting, is going in that direction. Decentralized production and consumption help us to diversify our energy sources and enable communities to develop their own unique solutions to local challenges."

Conference participants unanimously agreed, however, that it's not only businesses and governments that need to do their homework — science too has to make sure performance incentives encourage scientists to spend more time communicating effectively with the public. For the science community, that means looking beyond basic research and toward application-oriented solutions. As Peter Gruss, president of the Max Planck Society, stressed: "Science in the ivory tower is a thing of the past."

In order to make innovation resound in society as a whole, creating a compelling vision that engages the public and shores up its support is crucial. Or, as one participant put it, "The Apollo program fired up the imagination of a whole generation. What could be the Apollo programs of the 21st century?" Peter Löscher, CEO of Siemens AG, was not shy about giving examples by referring to just a few visions linked to the Siemens portfolio: Desertec (see p. 8); electromobility, including all of the infrastructure it will require; smart grids — the intelligent power distribution networks; and personalized healthcare. "The key thing is that you have a long-term, reliable framework you can work towards," said Löscher as he summed up the discussions.

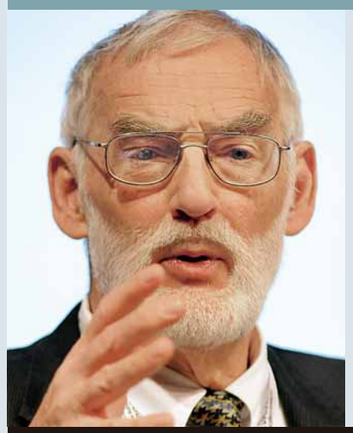
Siemens CEO Peter Löscher (left), President of the Max Planck Society Peter Gruss (center), and former German Foreign Minister Joschka Fischer (right) emphasized the importance of collaborative action.

Toward the end of the conference, participants agreed that market-based solutions have the highest probability of success as long as government establishes a practical framework. "Government influences the market and sets the framework," said Joschka Fischer, former German foreign minister and former leader of the Green Party. "If, for example, you switch the framework of markets by pricing carbon at a global uniform level…you change the markets, and this could have a tremendous effect in changing behaviors toward goods, services, and the overall approach to the use of energy." At the same time, targeting individuals and their everyday choices is the other key element necessary to making change happen on a large scale, as was pointed out by Meadows: "Sustainability is not a question of devices, but of attitude."

The upshot of the conference could not have been clearer: Neither the market, nor government, nor industry alone can be the key. Instead, only when these three elements work together is it possible to achieve real success in dealing with the most pressing issues of our time. And that, in fact, was the purpose of the conference.

■ *Andreas Kleinschmidt*

Is "Sustainable Development" an Oxymoron?



Professor Emeritus Dennis L. Meadows (67) co-authored *The Limits to Growth*. As early as 1972 Meadows drew attention to the fact that a growth-based economic model would conflict with the finiteness of resources in the period 2010–2050. His works have stirred great controversy and have been published in 30 languages, selling 30 million copies. Meadows has a BA in Chemistry and a PhD in management from the Massachusetts Institute of Technology.

| Interview

What's your definition of sustainable development?

Meadows: In my opinion this is an oxymoron, a term with nonsense meaning. To many people, "development" seems to imply that we can simply keep going as we have for the last 100 years, depleting resources on a large scale and polluting heavily. And adding some kind of "sustainability" makes the detrimental effects of our model of development go away. I am more interested in the term "resilience." This concept is about how to structure a company or a city or a country so that it can continue to function quite well even in the face of major shocks. Implementing policies that give you resilience tends to make the system more sustainable.

Can you provide an example?

Meadows: The financial system is a good example. It is not very resilient. It was structured in a way that small changes in the prices of assets in the United States could spill over and infect banks and economies all over the world. That is a what I would call a fragile system that must be changed.

Is the financial crisis somehow analogous to the environmental crisis we are heading for?

Meadows: Yes, in terms of the environment we will see similar results, systemically speaking, as we have seen in finance. Like the financial crisis, climate change or energy scarcity

are not going to proceed in a nice orderly, uniform way. Sometime in the foreseeable future there will be discontinuities, which will put us in a mode of crisis. I hope we will be better in dealing with them than we have been in dealing with the financial crisis. To prepare ourselves, the most important thing is to increase our time horizon. And certainly we must also develop new technologies. But we should not believe that technologies as such are the solutions for our problems. Hunger, climate change, inequality, conflict, energy depletion, falling water tables, derive from a set of values, ethics, and behavioral practices we have. If we don't change them we will continue to

"Technology is important but it is only a tool," said Dennis Meadows (right) to Siemens CEO Peter Löscher.

have these problems. Technology is important but it is only a tool for achieving our goals. The key is to rethink the goals.

How can individuals help to improve the resilience of man-made systems?
Meadows: When I try to help people think about changing, the first thing I do is give them tools to measure the consequences of what they are currently doing. I refer them to a website where they can calculate their ecological footprint or I may give them some readings, helping them to become more aware of the energy needed to produce their food. Only when people understand the consequences of their own behavior can they develop a real interest in changing it.

In what ways have you changed your life to make it more sustainable or resilient?
Meadows: The most valuable thing I could do for the environment would be to stop traveling by plane. Nevertheless, I still do it. It is the largest fraction of my ecological footprint. Beyond that I have done a few things. For example I converted my house to being more energy-efficient. I heat it with solar and wood. When I buy a car I keep it for 10–15 years, rather than replacing it every few years. And I have adopted a policy in my house that when I buy something new, I have to throw out something that is already there. This makes it much more difficult to grab something in a store. All these things are trivial, but this is the level on which — on aggregate — significant changes can happen.

In short, when it comes to energy, we will all have to tighten our belts?
Meadows: It is unsustainable that a few percent of the global population accounts for the lion's share of energy and resource consumption while two billion people make ends meet on less than $2 a day. In traditional societies most energy that was consumed was in the form of foods. Eighty percent of the population was busy producing energy, be it through hunting or agriculture. Today, with cheap oil, people who harvest energy, for example on oil rigs, represent a tiny proportion of the population. The rest can be professors, journalists, sportsmen or hairdressers. But we will run out of energy, and will have to change to a different system at some point. It will not be like the Dark Ages. But it will be a society in which a lot more than one percent of society will have to work to harvest energy. And this is a shift we had better start preparing for now to make it less disruptive.

Do you expect this shift to be a smooth process?
Meadows: To be honest, no. I expect severe disruptions from this, much bigger for example than the financial crisis that began in 2008. I strongly believe that we will see more disruptive changes over the next 20 years than in the past 100.

Interview by Andreas Kleinschmidt

The Future Belongs to Low-Carbon Industries

Lord Nicholas Herbert Stern (63) became famous almost overnight after publication of the so-called "Stern Report" in 2006. The Report furnished a detailed quantitative analysis of the potential economic effects of, and policy towards, climate change (see *Pictures of the Future*, Spring 2007, p.85). Stern studied mathematics at Cambridge University and earned a PhD in economics at Oxford University. He has held posts as Professor at the London School of Economics and as Chief Economist at the World Bank. He recently updated his report on climate change.

You call for drastic reductions in CO_2 emissions in order to avoid the most catastrophic effects of climate change. Does this mean that we will have to compromise our standard of living?
Stern: I don't think this is the kind of language that brings us forward. It will not be about compromising living standards, but about making changes in lifestyle, about investing, and about using energy more efficiently. Changes of this kind do not mean compromising living standards. We will simply build an economy that is greener, safer, and more biodiverse, as well as more dynamic and innovative. From my point of view, that means an improvement in living standards. For instance, think about the ways people move around. We can make public transport much more attractive, thus providing an incentive to reduced use of personal transportation. We can make the use of hydrocarbons — or fossil fuels in general — much more expensive by taxing them more heavily and we could use the proceeds to fund better public transport and to promote greener private transport. Obviously, we have to provide incentives to people in order to support responsible behavior, and economic incentives are often the strongest ones. But it comes down to individual responsibility as well. Just as most people now know better than to drink and drive, in the future they may not want to pollute.

In which ways have you changed your life to reduce your carbon footprint?
Stern: I use public transport more often than in the past, being helped by the fact that I do not like driving, so it is not a big sacrifice. Sometimes it is inevitable to use my car, as I mostly live in rural Sussex and only partly in London. However, in London public transport is a lot more attractive than driving anyways. This is partly due to the congestion charge, which serves as an appropriate economic incentive. In addition, I have made changes to my house, which dates from the 15th century. For example, we have installed a ground source heat pump. And we buy our electricity from a wind energy company. So the heating and electricity side is in principle zero carbon. But I fly far too much and I will try to get that down over time. However, the subject I am now dealing with professionally is quintessentially international. So I am working with India, China, the African Union, and the U.S. and traveling is unavoidable.

How can technological innovation contribute to diminishing climate change?
Stern: Technology will be central in helping to make change happen. For instance, there are ways to enhance energy efficiency in everyday life. We can increase the use of renewable energies and develop new generations of nuclear reactors. On the other hand, we have to learn more about energy storage, carbon capture and storage, and reducing the cost of producing renewable energy. Innovation in these fields is crucial.

How can multinationals help?
Stern: Multinationals have one big advantage. In spite of the much-criticized concept of shareholder value and the pressure deriving from it, they can and often do take more of a long-term view when it comes to future markets and product development. At least they are more able to do so than smaller companies. What we can say confidently at this point is that the future of this planet and its economies lies in low-carbon industries. Those who do not follow this route will be stranded. So multinationals that are looking ahead already heavily invest in these areas. And they should do so, as a duty to their shareholders and other stakeholders.

Will investing in low carbon industries spur economic growth?
Stern: Let me put it this way: The high-carbon economy we have now really is the slow growth option for the world economy. The high-carbon economy will kill itself, first through rising hydrocarbon prices and secondly, and more fundamentally, because of the more and more hostile physical environment it will create. Let us not underestimate the damages we are likely to inflict on the planet by continuing to emit greenhouse gases at a high and increasing rate. Over the next 30-60 years we could see temperature increases that take us out of the range of human experience and, over 100 years or so, far out of that range. We have to reduce those risks. The low carbon growth route is the only possible growth route. We have to transition to it over the next two or three decades. It will be a period of enormous innovation, inventiveness, and creativity that will make it a dynamic growth period.

What do you say to critics who suggest that there may be superior benefits if our society invests in the prevention of AIDS and malaria, rather than in carbon emissions reductions?
Stern: Proponents of this approach are deeply confused from an economic point of view. They set out different kinds of programs and regard them as separate, consequently pitching malaria prevention against the fight to manage climate change. But in fact these issues are logically intertwined and must therefore be treated in conjunction. Let's follow through with an example. Climate change will radically alter health prospects for millions of people in different parts of the world as well as future standards of living, which, again, affect health prospects. Rising temperatures will make malaria an even bigger problem than it is today. Migration, triggered by climate change, can contribute to rising rates of HIV infection. Therefore addressing climate change means addressing malaria and HIV indirectly at the same time, and we must address malaria and HIV directly as well. The challenges of climate change and development must be tackled together.

Interview by Andreas Kleinschmidt

Highlights

2020

An elderly woman is found dead in her home. She appears to have died of natural causes. But an on-the-spot investigation of her electronic medical records shows that she had a retinal prosthesis to correct her macular degeneration. What's more, the prosthesis turns out to have memory functions – complete with wireless access. Playback of the woman's final experiences leads to the discovery of molecular foul play.

Happy Forever...

When it comes to criminal investigations, evidence should be fresh and uncontaminated. By 2020, police organizations will ensure that these goals are met by using devices as small as a smartphone to identify blood-based biomarkers and molecular traces of incriminating substances at the scene of the crime itself.

Sooner or later, we all have to cash in our chips. For most of us it's natural. For a few, it's not. My job is to discover the difference. It was a cool, sunny Monday morning in June. After a week of rain, it was the kind of day you feel like calling the office and telling 'em you've got better stuff to do than analyzing the results of molecular tests or figuring out whether grandpa broke his neck on the stairs or had a little help from the Mrs. For 84-year-old Henrietta Gabrielli all the signs indicated a natural-causes ticket to the happy hunting grounds. Almost all the signs.

"Sorry to bug you first thing on a Monday morning, detective," said the medic whose vehicle had responded to the 911. "But the guy looks kind of nervous." He gestured over his shoulder at a man shifting nervously from foot to foot near the sofa where Miss Gabrielli's body slouched. Even from where I was standing I could see the sweat stains on the guy's shirt. "Who's that?" I asked. "He's the one who called us. Name's Pulsifer."

"Taken care of the preliminaries?" I asked. "Routine blood test," said the medic. "Analyzer found what you'd expect – a high level of troponin – you know, one of those proteins released by cardiac cells in response to damaging events. Pulsifer said the victim sounded short of breath when she called him. Put the two together and it

looks like a brainstem stroke leading to respiratory depression and cardiac arrest. Shall we put the body in the ambulance?"

I walked over to Pulsifer and introduced myself. "You related to the victim?" I asked. "No," he said. "Just a close friend. Known her for years. My mother used to be Miss Gabrielli's housekeeper. When mom passed away, I just felt – you know – obligated. Miss Gabrielli was so alone. No friends, only one or two distant relatives down south." "Perfect situation," I said provocatively as I took in the size of the house and the apparent quality of its furnishings. "You wouldn't happen to be in the old gal's will, would you?" I said.

Before Pulsifer could respond, the medic interrupted. "Detective, we've gotten a sign-off from a relative on Miss Gabrielli's medical records. Better take a look." He handed me his smartphone. Gabrielli had apparently been very health conscious. The records indicated that back in 2015 she had had a full genome scan. Predispositions for various heart diseases had been identified. After that, Gabrielli had apparently lived like a saint. A diagnosis of stroke was starting to look implausible.

But here was something that caught my attention: Just a year ago Gabrielli had had a retinal prosthesis installed as a result of macular degeneration in her right eye. And apparently the implant – a microchip that interfaced directly with her optic nerve – was outfitted with memory functions. What's more, the chip was wirelessly accessible to allow for maintenance and upgrades. "Cool," I said to the medic. "Let's see if it'll bark." A few minutes later, after another sign-off, we were able to download an access code from Gabrielli's medical record and use my smartphone to tap into the chip's content.

Key images from the last 48 hours flashed by like a high-speed silent movie. It was all routine stuff. Then, at about 18:30 the previous evening Pulsifer appeared in the images. After what appeared to be a few formalities, he took a small gift-wrapped package out of his jacket pocket and handed it to the victim. Inside was a silk scarf. He helped Gabrielli fasten it around her neck. Then he was gone. After that, the victim apparently sat on the couch and eventually fell asleep. The only other recorded event was her phone call to Pulsifer this morning just before she expired.

Something was fishy. I looked down at Gabrielli. There was the scarf – a pretty, understated pink with an unobtrusive flower pattern. Just the kind of thing to melt the old gal's heart.

"What was the occasion for the gift?" I said to Pulsifer. "No occasion," he said. "I work for a ladies' apparel distributor and Miss Gabrielli liked fine things. I often gave her gifts from our collections to brighten up her life."

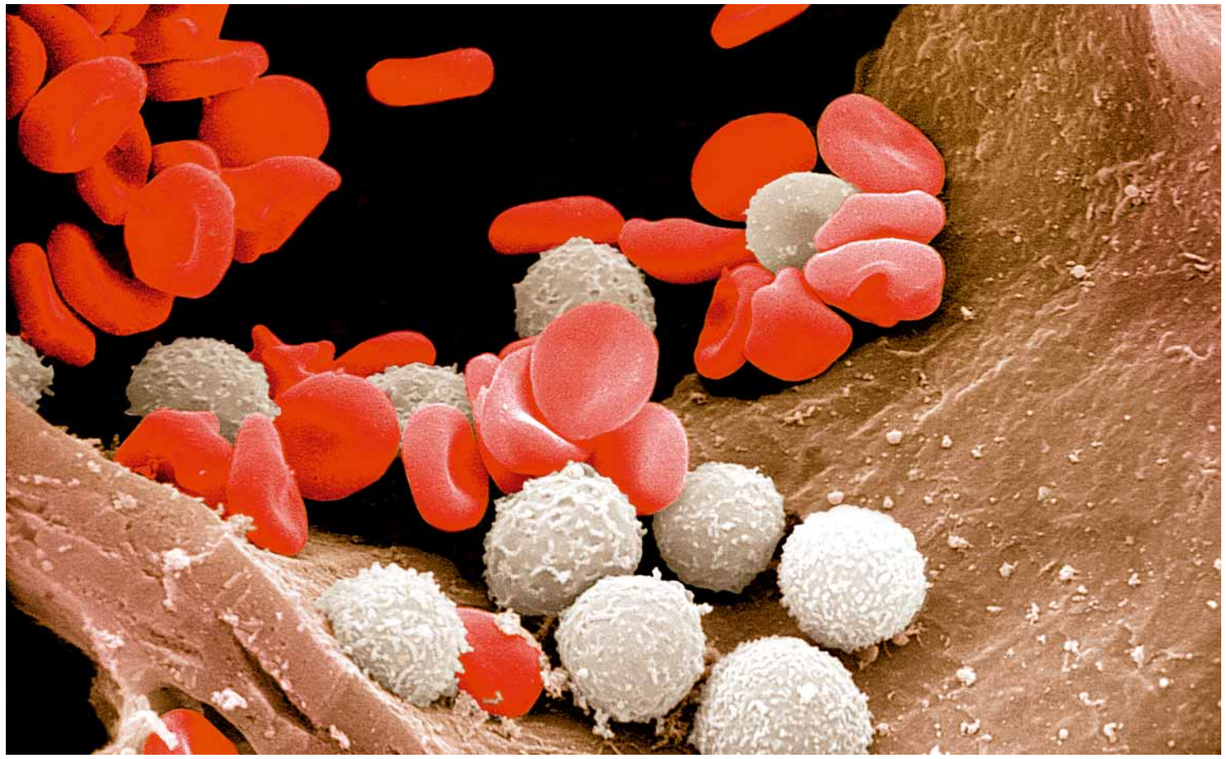
I knelt down and looked carefully at the scarf. It had a dark pink inner lining. Not wanting to contaminate any potential evidence, I unsealed a package of sterile surgical gloves and pealed back a couple of millimeters of the scarf that had been in contact with the victim's skin. Then I extended a flexible antenna-like aspirator nozzle from my smartphone, activated the vacuum, and brushed the nozzle head back and forth against the smooth silk.

Inside the device, I knew, nano particles from the scarf's surface would be detected by a vast selection of "catcher molecules" embedded in a tiny piece of specialized material. Each molecule that was caught would electronically signal its identity to a specialized chip beneath the material that would in turn process the information, compare it to an online database, and assemble a graphic representation of the results. The technology saves police time and delivers clean results that stand up well in court.

Within seconds, a long red column marked "Fentanyl" had developed in the display. As anyone in my field can tell you, Fentanyl is a powerful – and potentially deadly – analgesic. In powder form, it can be absorbed transdermally. Once in the body, its effect is irreversible. Generally speaking, it causes the victim to progressively retain carbon dioxide, leading to increasing shortness of breath and the outward symptoms of brainstem stroke.

I stood up and looked Pulsifer in the eye. "Why'd you do it?" I said shaking my head in disbelief after I had secured his damp wrists behind his back with handcuffs. Though the morning was still fresh and cool, Pulsifer's face was covered with beads of sweat. His eyes went red and I could see that he was crumbling inside. In little more than a whisper he said, "She treated me like her son. But she wanted more and more of my time. Finally she began nagging me to move in with her. I couldn't do that. But I couldn't just leave her. So I thought I'd give her a gift that would make her happy forever."

■ *Arthur F. Pease*



Is a cancer cell hidden among these red and white blood cells? Molecular detectives at Siemens are developing technologies that may be able to provide an early warning for high-risk patients.

Targeting the Nano Frontier

Researchers are drilling deeper than ever before into the nano-level worlds of cells, proteins and nucleic acids. To do so, they are developing devices and technologies that hold the promise of on-the-spot, rapid, reliable and affordable diagnostic information.

Question: How much information can you squeeze out of a drop of blood or water, a cubic centimeter of air, or a few voxels worth of imaging data? Answer: More and more with each passing day. Across the board, from nanowires designed to wring information from cells (p. 65) to spectroscopic analyses that identify the constituents of factory emissions (p. 70) and the distribution of atmospheric carbon dioxide (p. 72), and from programs that identify the genetic signatures of new viruses (p. 66) to microchips that can identify antibiotics, hormones and bacteria in a drop of water (p. 74), scientists are finding an expanding universe of information in smaller and smaller spaces.

At Siemens, one of the most far-reaching developments to emerge from this trend is a growing understanding of how we can extract health-related information from the nano-sized offspring of genomic activity – nucleic acids and proteins. Cardiac biomarkers are a case in point. Take troponins, for instance – proteins released by cardiac cells in response to damaging events, such as an infarction. "What's needed if a heart attack is suspected is a rapid, inexpensive, automated test to measure troponin levels that can be administered on the spot and can provide actionable information," says Siemens Principal Research Scientist Dr. Walter Gumbrecht, who is recognized as a world leader in so-called "lab-on-a-chip" technology.

With a view to providing that kind of information, Dr. Gumbrecht has teamed up with Michael Pugia, PhD, one of Siemens' 12 "Inventors of the Year 2009" and a leader in the field of microfluidic diagnostic systems. Based at Siemens Healthcare Diagnostics in Elkhart, Indiana, Pugia is credited with 203 inventions and 140 patents. Now, he and Gumbrecht have come up with a concept called an "electrochemical camera" that can squeeze remarkable amounts of information out of any liquid it is programmed to analyze.

The device combines pixel-sized resolution based on CMOS microchip sensing (thus the term "camera") with a revolutionary paper-like substance imbued with a range of "catcher" molecules that respond to target substances. The combination is brilliantly economical because instead of exposing the chip to liquids, only a disposable strip of "paper" is affected. The paper is mounted on the chip and the two are placed in a reader. The paper is then exposed to a target body liquid, as well as reagents that are piezo-jetted onto the paper's surface to catalyze reactions with the substances searched for.

If a doctor suspects that a patient may be experiencing a heart attack, the reader would expose a drop of the patient's blood to reagents that would activate troponin-sensing catcher molecules in the paper. "When they bind with target substances, these catchers emit electrons to the chip's sensors," explains Pugia. "Within seconds, the device not only confirms the presence of troponin, but provides a read-out of its level."

Desktop Diagnostics. Probably still several years away from market introduction, electrochemical camera technology could change the face of diagnostics. "Because it relies on processes that are extremely rapid and reliable, It would open the door to desktop testing in the doctor's office or emergency room for conditions such as stroke and infarction, and could make it possible to test patients before they enter a hospital for dangerous bacteria such as methicillin-resistant Staphylococcus aureus (MRSA), a major cause of hospital-acquired infections and deaths," says Gumbrecht.

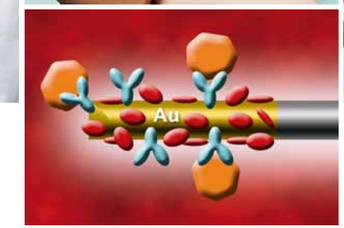
The technology also holds the potential for improved accuracy in the treatment of chronic conditions, such as diabetes. Desktop testing for blood-based diabetes biomarkers – now under development at Siemens – would make on-the-spot adjustments to treatment possible, thus eliminating millions of follow-up visits and reducing healthcare costs. Working along these lines, Pugia and his team have discovered a new marker for a gene fragment that controls the body's insulin production. "Regular testing

for the level of this marker," says Pugia, "could lead to new treatments for the disease, and even the ability to forestall it.

Similar advantages hold for the application of the new technology to PSA (prostate-specific antigen) tests, which are administered to tens of millions of men worldwide each year. "I believe that a PSA test running on an electrochemical camera-based device will be competitive with central lab tests," says Hanjoon Ryu, Senior Vice President for Point of Care Testing at Siemens Healthcare Diagnostics in Deerfield, Illinois. What's more, he points out, thanks to the reusability of its chip, the technology may be affordable enough to even serve rural populations in the Third World.

A technology that could bring affordable molecular-level testing to a doctor's desktop, whether his or her office is in Manhattan or a dusty village in Mozambique, offers vast advantages for patients and healthcare systems. "For the first time, patients will be able to get answers to many fundamental diagnostic questions directly from their physicians," says Ryu. "By the same token, this trend could take a huge amount of pressure off of hospitals, which are today congested with patients suffering from minor conditions."

And that trend, once set in motion, will accelerate rapidly. Already, electrochemical camera technology can detect nearly 100 proteins – many of them in less than a minute. "Looking ahead," says Pugia, "we expect to discover a growing number of proteins, and thus be able to work with partners to engineer a wider spectrum of catcher molecules to detect and quantify them."



Michael Pugia (left) uses catcher molecules and a microchip (right) to identify disease-specific proteins. Other researchers are developing technologies for fishing tumor cells out of a patient's blood stream (center).

Catching Cancer's Messengers. Only a few cubic inches in size, the electrochemical camera holds the promise of performing many of the tests that today are conducted by specialized machines in central labs. But what about a diagnostic system small enough to fit on the surface of a catheter? That's the idea behind the "liquid biopsy," a technology now being developed at Siemens that is designed to intercept and identify so-called "circulating tumor cells" or CTCs, thus providing an early warning system for people who have been treated for cancer and are at risk of recurrence.

Unlike the proteins that can signal cardiac distress, diabetes or prostate inflammation, which may be present in significant quantities in blood, CTCs are extremely rare – approximately one tumor cell among one million white blood cells. Released into the blood by a primary tumor, some CTCs (those with stem cell qualities) are thought to be the mechanism behind metastatic colonization, and are thus in the crosshairs of some of today's most exciting oncology research.

"CTCs may be only one of many cancer biomarkers," says Karsten Hiltawsky, M.D. PhD, manager, business development, at Siemens Healthcare, "but, in my opinion, they have more potential because they can be far more easily characterized in terms of the kind of cancer they represent. Simply put, you are dealing with an entire cell rather than just a molecule such as a protein. "

Developed by a team led by Dr. Daniel Sickert at Siemens Corporate Technology (CT) in Munich, Germany in collaboration with Siemens Healthcare, the liquid biopsy catheter has a unique surface coating which, like the "paper" used in the electrochemical camera, is imbued with specialized catcher molecules – for example antibodies to cellular surface molecules – that are common to most cancer cells. "They catch any tumor cell that comes into direct contact with them," says Hiltawsky. "What's more," he adds, "the catheter could be coated with antibodies for major cancer types, such as prostate, lung, etc., thus allowing the test to identify the cells' origin."

Why use a catheter instead of drawing blood and testing for CTCs? "Simple," says Hiltawsky, "the catheter works like casting a net from a speedboat. You increase your chance of catching what you're looking for as blood rushes by." Nevertheless, he admits, "the catheter catches CTCs purely by chance."

Getting around that problem is not going to be easy. But that's what Siemens CT Program Manager Dr. Oliver Hayden is exploring. Based on the idea of regularly drawing blood from people at risk of developing metastatic cancer, his work focuses on exposing blood to antibodies that have an affinity for cancer cells – antibodies that carry a detectable label.

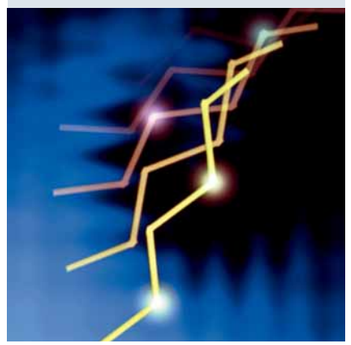
"Our work has shown that the antibodies bind CTCs or other rare cells effectively," says Hayden. The CTCs are then extracted from whole blood, filtered, and "read" by a sensor chip, using the label affixed to the antibodies. "Every time a labeled cell passes the chip's reader," says Hayden, "it essentially says, 'Hi, I'm here, and I'm a CTC.'"

And when those cells begin marching by in coming years, providing objective evidence of trends in patients' CTC counts, they might also be saying that the smallest things can make a world of difference.

■ *Arthur F. Pease*

If Nanoelectronics and Living Cells Converge...

Charles M. Lieber, PhD, (50) is the Mark Hyman Professor of Chemistry at Harvard University. His research focuses on the synthesis, fundamental physical properties, and applications of nano-scale materials with a focus on problems in the life sciences, nanoelectronic systems, and renewable energy. A recent recipient of the prestigious NIH Director's Pioneer Award, Lieber is developing active interfaces between nanoelectronic devices, cells, and tissue. Lieber holds a PhD in chemistry from Stanford University.



Where will the convergence of electronic devices and living cells take us?
Lieber: Nanowires offer an opportunity in that a cell will automatically internalize them. The idea is to build a communications bridge with cells or cell tissues that is indistinguishable from the biological system itself. This could open the door to monitoring cell activities and responses to medications in real time. A sensor package might, for instance, continuously monitor the blood for markers of anything from flu to cancer. And depending on the results, a device would automatically adjust the flow of a therapeutic substance to optimize treatment. We could do this for heart diseases or cancers by giving an at-risk individual a skin patch that would have a read-out and connection with a drug delivery system. That is the vision.

How are you realizing that vision?
Lieber: We have made nano structures out of semiconductor materials that can function as field effect transmitters (FETs) at the exact point of a kink in a wire (*image left*). Being like an arm, this allows the system to move in the 3D universe. A wire can thus enter a cell or touch a point on it such as a receptor or an ion channel. Our work in this area has, for the first time, made it possible to interrogate what is going on in a cell – without effect on a cell's functions. This line of research could open a new world of knowledge.

For instance?
Lieber: If we can build arrays of these 3D systems, then we could make a tissue around them. This could be implanted in the brain or the heart to monitor and manage cellular processes in real time — a new kind of prosthetic device. This goes well beyond today's state of the art, which is based on the use of huge — hundreds of microns — probes that cause scarring and degrade quickly. Unlike others in the microelectrode community (see *Pictures of the Future*, Spring, 2003, page 15), our lab has shown for the first time that one can interface on the sub-cellular level to cultured neurons.

Does this have implications for the field of nano-scale computing?
Lieber: You could develop a new kind of hybrid, living material — a living cell network that would be electronic and could itself be computationally active. So we have naturally asked ourselves if there is a convergence where molecules can bind to nano wires and thus produce the on-and-off messages needed for computing. The goal here is to combine the strengths of computers with human brain cells through nanoscale devices to make new types of computational systems with unique capabilities. It's a hunch. But what I like to do as a scientist is to work on things that have not already been shown to work. I think there's a world out there that will be enabled by the convergence of nano science and biology.

What applications do you foresee?
Lieber: Systems that function inside the body and that draw their energy directly from the mitochondria, for instance. This is something we are working on — in short, something like artificial tissue, but which draws power directly from the body.

Are there implications for environmental sensing, health and security?
Lieber: Yes, the problems are very similar between measuring cellular events within the body and interrogating organisms in the environment. For instance, variations of the same virus are distinguishable through slight differences in protein coatings, which are reflected in the virus's binding properties and may, in turn, shed light on the organism's level of threat.

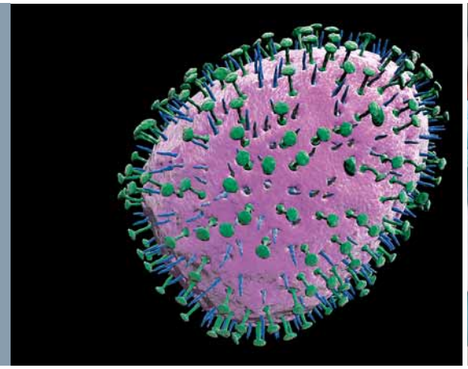
What's the timeline for some of the technologies we've been discussing?
Lieber: Sensor systems that can monitor hundreds of biomarkers for disease risks such as recurrence of cancer could approach introduction in five years. Prosthetic applications capable of creating an interface to the brain will start reaching the level of animal studies in about five years, with human applications in ten years.

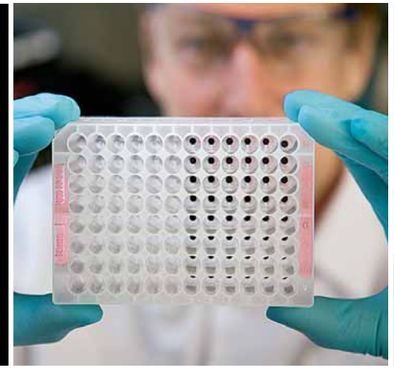
■ *Interview by Arthur F. Pease*

Scientists at Siemens' Berkeley, California research center developed an accurate test for the H1N1 virus (below). The test was made possible by a genetic identification system developed by Siemens in Princeton.

Identifying Invisible Invaders

When the 2009 H1N1 virus began claiming lives in Mexico and the U.S., Siemens became a key player in pinpointing the organism's unique identity. In doing so, the company brought together powerful computational tools, a new pattern recognition technology, and the first-ever commercial application in North America of its real-time automated genetic detection technology.





Detectives are at work at Siemens. They are sifting through lines of genetic code for evidence, developing smarter, faster tools for discovering the fugitives they are pursuing, and working closely with authorities in universities and government agencies to capture and liquidate their targets. "It's a predator-prey relationship," comments Gayle Wittenberg, Program Manager at Siemens Corporate Research (SCR) in Princeton, New Jersey. "We are getting better and better at what we do. But the bad guys — the viruses and bacteria we are tracking — are hard to identify because their genetic characteristics are constantly evolving."

Although the battle against invisible invaders such as the wily methicillin-resistant Staphylococcus aureus (MRSA) bacterium, which accounts for about 20,000 hospital deaths per year in the U.S. is just getting started, Wittenberg and other molecular detectives at Siemens have scored significant successes, most notably with regard to identifying the unique characteristics of what is now known as "the pandemic 2009 H1N1 flu virus."

The story of how Siemens researchers identified the 2009 H1N1 Flu "suspect" unfolded like a rapid-fire whodunit. On April 14, 2009, after numerous deaths in Mexico, the World Health Organization (WHO) and the U.S. Centers for Disease Control (CDC) announced seven cases of the unique hemagglutinin-neuraminidase (H1N1) flu strain in the U.S. On April 27, the WHO declared a pandemic alert level 4 on a six-point scale (with 6 being the highest level). And on April 28, the U.S. National Institutes of Health (NIH) published all available versions of the virus's genetic code on the Internet.

"As soon as that information became available, we began running it through our biomarker discovery process for the development of rapid diagnostic tests, which we call the RAPID^2 pipeline," says Dorin Comaniciu, PhD, who heads Siemens' Medical Informatics Global Technology Field at Siemens Corporate Research in Princeton, New Jersey.

Comaniciu explains that the key to the identification of any pathogen is the ability to zero in on those parts of its genome that all members of its group have in common. "No two genetic sequences in the same group are entirely identical," he says. "But some parts of their sequences are. And that is where our technology comes in — specifically our experience with machine learning and face recognition, which is a similar kind of pattern recognition problem." Using a cluster of high-performance interconnected computers, Wittenberg, Comaniciu and other SCR researchers compared the NIH's H1N1 sequences to a publicly-available database of sequences from common flu strains. Their effort paid off quickly. Within less than two days following the NIH's posting of the H1N1 genotype, RAPID^2 had identified the unique sequences — also known as "signatures" or "primers" — that distinguished the H1N1 virus from all others.

The resulting information — a digital representation of part of the virus's genetic code that is equivalent to a suspect's fingerprints — was transferred from Siemens Corporate Research to Siemens Molecular Diagnostics' world-class research and development facility in Berkeley, California. There, according to Vice President for Global R&D Management Dr. Norbert Piel, "One of our most experienced scientists was able to translate RAPID^2's computer-generated signatures into their nucleic-acid counterparts, otherwise known as detection reagents." Once these reagents had been produced, they were tested on known copies of the virus using Siemens' VERSANT automated platform for kinetic polymerase chain reaction (kPCR)-based genetic detection. "The result," says Piel, "was that on the very first try we obtained a perfect match between the signatures we had generated and those of the actual virus."

As soon as the test was ready, it was added to Siemens Molecular Diagnostics' panel of flu assays, transferred to a Mexican state lab at the heart of the pandemic, and tested in a double blind evaluation on the automated VERSANT kPCR platform. "There, results indicated that the assay was as sensitive as and possibly more specific to the 2009 H1N1 virus than a test developed by the Centers for Disease Control," says Siemens Healthcare Diagnostics Director James Uzgiris, PhD. "In this comparison to the CDC assay, our test was more specific for the 2009 H1N1 virus. We attribute this to the excellent capabilities of the RAPID^2 algorithm and to the performance of the VERSANT kPCR platform." Siemens has filed a patent application on the methods used and is analyzing whether there is a business case for developing a commercial H1N1 assay to add to its panel of flu tests.

> Only two days after NIH posted the H1N1 genetic code, RAPID^2 identified exactly what made the virus unique.

Multi-Purpose Platform. A computational system capable of zeroing in on the handful of genetic base pairs that distinguish a group of target organisms from all others (e.g. pandemic 2009 H1N1 compared to other flu viruses) is anything but a one-trick pony. Indeed, SCR's RAPID^2 technology could accelerate not only the identification of other dangerous viruses, such as new drug-resistant strains of HIV or potential bio-warfare threats, but also the characterization of bacteria and even the detection of cancer cells, thus opening the door to accelerated, more accurate and more cost-effective treatments for a wide spectrum of diseases.

Regardless of the target organism, the genetic identification process begins with DNA sequencing of a large number of individual samples. "The more sequences you analyze, the more likely the results will be to identify the handful of characteristics that all members of a set have in common," explains SCR Research Scientist Lance Palmer, who points out that high-throughput sequencing is becoming increasingly affordable — roughly $70,000 for, say, 100 staphylococcus aurous genomes. Nevertheless, as with the H1N1 virus, Wittenberg and her colleagues have found that they can cut the cost of distinguishing what makes MRSA different from Staphylococcus aureus by making use of sequencing data that is publically available. Working closely with researchers at the University of Medicine and Dentistry of New Jersey, which has one of the world's largest collections of MRSA isolates, Wittenberg has developed computationally optimized primer (signature) sets.

"The next step," she says, "will be to sequence the genetic material from a larger population of MRSA bacteria to develop a more robust group of primers. Discovering what makes this organism unique is a precondition for combating it." Wittenberg emphasizes however, that MRSA is a moving target. "This organism is constantly evolving. That calls for a

continuing process of surveillance. As new strains evolve, new primers must be identified, which makes our RAPID² pipeline an increasingly valuable weapon against these bugs."

What the Future Holds. RAPID² and Siemens' new VERSANT kPCR Molecular System (available in Europe and undergoing FDA approval in the U.S.) have already accelerated response times to new viral threats. Compared to conventional immuno-diagnostic antibody tests, for instance, which detect the presence of a virus only indirectly — in other words, only if large numbers of antibodies against the virus are in a sample — VERSANT kPCR assays do not need to wait for the body to mount an immune response. Instead, through the use of DNA primers and probes, they can identify a virus in a blood specimen and confirm its genetic identity at very low concentrations. "This is crucial because it makes earlier detection and targeted treatment possible," says Piel. "What's more," he adds, "once therapy begins, you can use follow-up tests to ensure that viral load in the patient's blood is declining. In other words, with kPCR you always do two things: identify the target and quantify its presence."

The same steps could, in principle, be employed to fight cancers (for more, see the "Trends" article in this section of *Pictures of the Future*). Here, the idea is to capture cells that have been shed from tumors — so-called circulating tumor cells — discover their origin, and, once treatment begins, determine whether their numbers are increasing or declining.

And by adding RAPID² technology to the picture, cancer "management" could be extended to its most effective level – predisposition testing. "Suppose you have two cohorts of people for whom you have genome sequences, and one group has developed breast cancer," says Uzgiris. "RAPID² might be able to identify the key genetic differences between those groups and thus help to optimize diagnostics and therapy."

That may not be as far off as it sounds. Recent technological advances have slashed the cost of human genomic sequencing from $100,000 to about $10,000. Once the price drops to around $1,000, as is expected to happen over the next few years — the advantages of individual genomic scanning will become irresistible. "Before long, a full genome scan may become something of a right of passage following a person's 18th birthday," predicts Uzgiris. "At that point, you will know your predispositions. Routine blood tests will search for signs of danger. And if a suspicious mutation is discovered 30 or 40 years later, a turbocharged version of RAPID² technology will compare it to your baseline genotype to discover the significance of the change. It all adds up to a head start in terms of preventive care."

■ *Arthur F. Pease*

> Genome tests for humans would lead to identification of predispositions and early detection of diseases.

Whereas conventional systems detect viruses based on the time-consuming response of antibodies, the latest automated molecular detection systems can rapidly identify minute quantities of pathogens in blood samples.

There's one cardinal rule for cancer treatment: The battle must begin at the earliest possible moment. Unfortunately, however, the disease often goes unnoticed for far too long. At that point, the search for metastases of a malignant tumor becomes paramount in treatment planning. Indispensable here are procedures that not only generate and display cross-sectional views of organs but that also make biochemical processes visible. That's because diseased cells reveal themselves through their altered metabolism. Tissue cells that consume an unusual amount of sugar, for example, indicate uncontrolled cell growth.

Combining 3D X-ray images with positron emission tomography makes it possible to identify the location and dimensions of lung tumors more precisely than in the past.

Hybrid Imaging Solution

When combined, computer tomography and nuclear medicine imaging give radiologists the ability to ascertain the presence of small nests of tumor cells in an anatomical context, thus detecting early tumor spread and providing potentially better outcome.

This combination of imaging capabilities (anatomical and physiological) is what make Siemens' Biograph Molecular CT (mCT) ideal for cancer diagnostics. A whole-body scanner, Biograph combines positron emission tomography (PET) with three-dimensional computer tomography (CT) X-ray images. PET scanning measures the concentration of a slightly radioactive tracer — usually the glucose compound F-18-FDG (18F Fludeoxyglucose) — which is injected into the patient beforehand.

The radioactive tracer concentrates in those areas that metabolize it fastest — in other words, tumors. During the process of glucose metabolism F-18 decays by emitting a positron, which in turn is transformed into photons that are detected by the PET unit and converted into images. At the same time, the ring-shaped CT unit produces high-resolution 3D X-ray images of the part of the body being examined. The result is a fused image that displays the location and dimensions of tumors. "Hybrid imaging provides us with significantly better information more quickly than either method would on its own," says radiologist Dr. Martin Freesmeyer, Chief Physician at the Clinic for Nuclear Medicine at University Hospital Jena, Germany, where a Siemens PET/CT unit entered service in mid-2009.

The Biograph not only takes measurements faster than any other system, it also sets new standards for image sharpness. Whereas conventional systems achieve PET image resolution of four to five millimeters, the Biograph mCT generates images with nearly two millimeter resolution throughout almost all of the recorded region. It achieves this thanks to four detector rings containing a total of 32,448 individual detectors that can capture changes in glucose metabolism that were previously impossible to resolve.

Patients benefit from the new system because it is fast. A routine scan takes no longer than five to ten minutes. Instead of having to undergo several X-ray examinations and a correspondingly high exposure to radiation, patients need only complete a single combined PET/CT scan in order for doctors to obtain precise, high-contrast diagnostic images.

Norbert Franke, who is responsible for Biograph sales at Siemens Healthcare in Erlangen, believes the reduction in required examinations offers a big benefit. "The combination of a better chance of recovery and fewer examinations reduces treatment costs," he says. A total of 50 Biograph units are now in operation in Germany. "We are now also seeing a significant increase in demand for them in Asia and other European countries," Franke reports.

Procurement costs for the devices are the main factor hindering their widespread use. A Biograph mCT can cost as much as €3 million depending on its equipment features. At the same time, however, the hybrid device lowers treatment costs by eliminating the need for multiple examinations. American and European radiologists and oncologists also believe that the use of radioactive tracers ensures efficient cancer detection.

This technology is urgently needed because 436,000 new cases of cancer are discovered in Germany each year and 211,500 people die from the disease annually, according to the German Cancer Aid Society. The World Health Organization (WHO) believes the number of cancer victims worldwide will increase by 50 percent between now and 2030 due to a rising proportion of elderly people in the global population. The most recent World Cancer Report issued by WHO predicts cancer will soon replace cardiovascular disease as the number one cause of death worldwide.

Unmasking Cancer Cells. The economy offered by a combined PET/CT procedure takes on a new dimension when viewed against the background of such alarming figures. For one thing, the success of expensive chemotherapy treatments can be monitored more effectively through molecular diagnostic techniques, and treatment measures themselves can be better planned if the cancer is detected earlier.

"Particularly in the post-treatment phase, combined PET/CT examinations are superior to all other procedures," says Prof. Jürgen Ruhlmann from Medizin Center Bonn. That's because radioactive tracers can immediately zero in on tumor cells. "Experimental data shows that combined PET/CT devices can detect nests of tumor cells measuring just under a millimeter," says Ruhlmann.

This capability enables doctors to implement countermeasures early. Many studies have shown that the combination of molecular imaging and computer tomography improves the chance of survival for cancer patients. PET/CT examinations are increasingly being used to search for lung, colon, skin, lymph node, breast, and thyroid tumors, and more and more nuclear medical specialists and radiologists are beginning to utilize high-resolution images to detect other types of cancers — including prostate, bronchial and head/throat carcinomas.

■ *Andreas Beuthner*

Siemens researchers use infrared spectroscopy to identify different types of coal and their quality. The procedure can help power plant operators to manage combustion more precisely.

Quality: Light Tells a New Story

Experts at Siemens are using infrared light to help control coal-fired power plants more precisely and prevent biogas fermenters from failing. This new measurement technology has interesting applications in medicine, and even in home ovens.

Block 2 of a major cogeneration plant in Munich, Germany burns some 800,000 tons of hard coal per year. Every day, three or four trains, each with an average of 22 cars, deliver the fuel, which is then ground into dust and blown into a boiler via 24 burners.

The power plant produces both electricity and heat. Block 2 includes a Siemens turbine, and achieves a thermal output of 550 megawatts and an electrical output of 237 megawatts. The facility is also an economy champion, as its overall efficiency level is an excellent 85 percent.

But it isn't just the quality of equipment at a power plant that determines output. Efficency also depends on fuel quality. Whereas plant operators in the past usually employed only one type of coal, today they utilize coal from all over the world in order to limit costs. Munich, for example, burns coal from Venezuela, South Africa, Poland, and the Czech Republic. But while this saves money, it also leads to quality fluctuations. That's because the calorific value of the coal varies, as does its moisture and sulfur content. "Using very poor coal can cause a plant's output to fall," says Prof. Maximilian Fleischer, a sensor expert at Siemens Corporate Technology (CT) in Munich. "If you want to always achieve the output needed, you have to adjust the amount of coal you feed into the burner in line with that particular coal's calorific value."

What's needed here is a kind of incoming goods inspection system that allows plant operators to know exactly what type of coal is being burned at any given moment. Combustion processes can then be adjusted depending on the quality of the coal fed to the furnace. Fleischer, a physicist, is working on the development of such a system using infrared (IR) spectroscopy. The idea is to employ infrared light, which is invisible to the human eye, to determine the composition of the coal. This can be done because chemical elements emit electromagnetic waves at specific frequencies after being stimulated by an energy source such as IR rays in the 0.7–2.5 micrometer wavelength range (near infrared — NIR), or the 2.5–50 micrometer range (medium infrared — MIR). Such exposure causes atoms or even entire molecules to vibrate. This energy is then radiated back, creating a "fingerprint" of the molecules present, which can be analyzed in a spectrometer.

"Measurements taken in the MIR reveal clear peaks that can be conclusively assigned to specific chemical structures," Fleischer explains. "These connections can not be as clearly established in the NIR range because the peaks are wider and therefore overlap." This is due to the fact that the molecular vibrations are coupled with one another — but here too, the information on molecular composition can be revealed using neural networks.

While this makes the NIR process somewhat more expensive than MIR, NIR spectrometers have a simpler design and are more robust and cheaper, costing between €15,000 and €25,000, as compared with roughly €100,000 for their MIR counterparts, which are therefore mainly used by large laboratories. NIR and slightly less precise micro-spectrometers (€2,000–€5,000) are thus ideal candidates for monitoring and controlling industrial processes such as coal combustion.

In the first phase of their project, Siemens experts demonstrated their ability to distinguish between different types of coal with the help of IR spectroscopy. Their NIR probe consists of a corona of infrared light emitting diodes (LEDs) that illuminate the fuel as it moves through a pipe from the coal grinder to the burner. A sensor absorbs the light reflected by the coal dust and sends it via a glass fiber cable to a spectrometer.

"As a next step, we want to ascertain the quality of the coal on the basis of its calorific value and sulfur and moisture content in order to optimize the combustion process," says Paul Herrmann from Siemens Energy in Karlsruhe, Germany, who manages the project in the Instrumentation, Controls & Electrical Strategy department. "After the current feasibility study is completed, we plan to implement this second step in the early summer of 2010 — and if everything goes well, we'll be able to get the first pilot facility up and running in 2011. That facility will be designed for long-term and continuous operation."

Information gleaned from infrared sensing will allow power plant operators to implement better countermeasures against facility contamination, since if they knew the properties of their fuel in advance, they will be able to adjust the amount of air fed in and thus avoid furnace slag formation. Slag formation occurs because coal ash begins to soften or melt at a certain temperature, which depends on the type of coal used, and settles in the boiler as a pasty mass. Operators normally have to shut down their plants once every two to three months to remove slag in what is a complicated and costly process. Slightly increasing the air supply could keep the heat under the critical value. To achieve this goal, operators need to know the precise composition of their coal. In other words, with the appropriate measures, the furnaces wouldn't have to be cleaned as often.

Why it's Worth it to Keep Bacteria Happy. Josef Götz wants to find out more about what's going on inside the reactor at his biogas facility in the German town of Markt Indersdorf. Here, bacteria produce methane gas from manure and renewable raw materials such as grass and corn silage. The gas is used to produce heat and electricity in a cogeneration plant. Götz, who is a farmer, needs to constantly keep his sensitive bacteria happy. "The bacteria must be fed raw materials as uniformly as possible and be kept at a constant temperature," he says.

The final step in the process, when the biomethane is produced, is particularly sensitive. "If you put too much biomass into the reactor, too much inhibiting acetic and propionic acids form. These damage the bacteria that make the methane," Götz says. "In the worst case, bacteria die off and the whole facility shuts down." Starting it up again can take three to six months because complex biological processes have to be relaunched and the plant operator might even have to refill the entire facility. This can result in losses of up to €500,000.

"The problem is that it's not possible to measure key indicators, such as acid concentrations, in anything close to real time," says Götz. "In this sense, bioreactors are still like a type of black box. Under optimal conditions, they produce enough biogas, but when things go wrong the fermenter can crash suddenly."

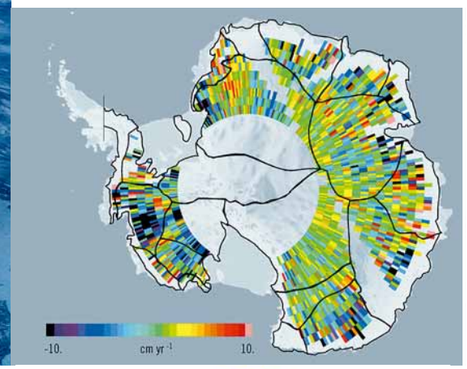
> Infrared scanners could be used to monitor food and analyze the alcohol and sugar content of cocktails.

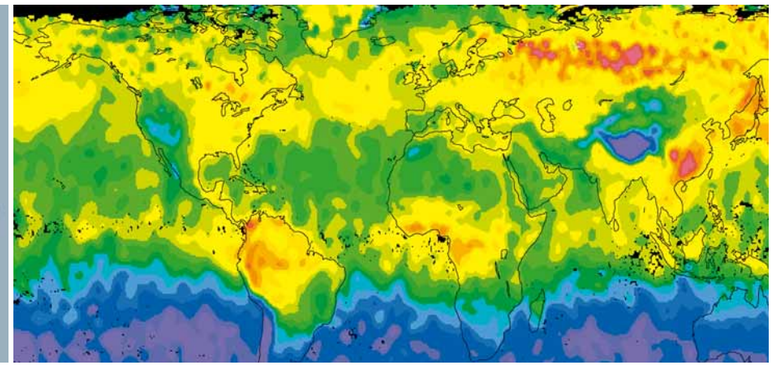
A solution, according to CT's Fleischer, could be IR spectroscopy. Fleischer plans to use NIR in the future to determine the acid concentration in fermenters — for example, through automated withdrawal of samples that are then analyzed immediately. Such a project will be launched in the summer of 2010 and will receive financial support from the Bavarian state government's Technology and Funding Center.

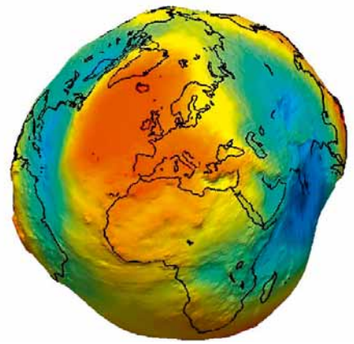
IR in the Refrigerator. Fleischer has other plans as well. If they become less expensive, small IR spectrometers could be installed in refrigerators in the future to monitor food and make sure it doesn't spoil. They could also be built into ovens to ensure that, for instance, a roast develops just the right crust. This feat could be achieved using proteins that react with fat during the cooking process. Washing machines would also be able to analyze their loads and sound an alarm if someone tried, for example, to wash a silk tie using the cottons washing program.

"IR spectroscopy can also be used in medical applications to examine suspicious-looking skin conditions," Fleischer says. "Cancer cells, for example, contain different proteins than healthy cells, which would enable a melanoma to be identified from its spectrum." Fleischer's curiosity in this area even extends to nightlife. "It's theoretically possible to put a tiny IR scanner into a cell phone and use it to measure the amount of alcohol and sugar in a cocktail," he says. After that, the cell phone could call a cab to ensure a safe trip home. ■ *Christian Buck*

A CryoSat-2 satellite monitors the earth's diminishing ice masses. Other satellites measure the earth's gravitational field (uneven earth image) and methane concentration (far right).







Eyes on the Earth

Satellites collect measurements that provide insight into volcanic eruptions, earthquakes, and climate change. Siemens is developing special test systems designed to download the huge volumes of data gathered by these costly scouts back to earth.

With winter sunlight flashing through the leaves of the olive grove, the Monte Cavo volcano's crater towers in the distance beyond the grapevines. On the outskirts of the town of Frascati, Italy, south of Rome, the grass is a deep green even in the middle of winter and stray cats are often seen roaming. The felines have found a new home here, between the olive trees and a gigantic antenna. The installation, the heart of the Centre for Earth Observation of the European Space Agency (ESA) may look like something from space itself, but it is where most of ESA's satellite signals are received.

ESA's data transmissions must always function reliably. That's why Siemens engineers are developing special equipment for thorough testing of the satellites before they are launched into space. "In satellite images trees look like little holes. We can see they are trees only because they are in straight rows," says Dieter Isakeit of Earth Observation center. The satellite images he is referring to have a resolution of one meter per pixel.

Isakeit likes the olive trees, which thrive here at the foot of Monte Cavo. The eruption of the volcano thousands of years ago replaced the soil with tuff and basalt, superb materials for containing water. "Although the volcano hasn't been active since then, we shouldn't let ourselves be lulled into a sense of false security," he says. That's because the planet's interior is in constant movement. When the continental plates, which float on a malleable mantle, grind against each other, earthquakes can result. At the plates' edges, the high-temperature rock forces its way to the surface and serves as fuel for volcanoes. "This is how the planet shows us it's alive, and always changing," says Isakeit.

Such changes are exactly what researchers at ESA want to capture. In the early 1990s they established the Living Planet program, a large-scale science project designed to provide data to help us better understand the planet Earth. The first satellite, ERS-1 — short for European Remote-Sensing Satellite — was launched into a polar orbit in 1991. Until 2000 it was busy gathering measurements related to the earth's surface, ocean temperatures, waves, air currents, and other information of importance for climate researchers. Additional satellites have joined it since then, including the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE), which was launched in early 2009. Since then the GOCE has been monitoring the earth's gravitational field with unprecedented precision. Its results are of interest to climate researchers because gravity causes bodies of water with a higher salt content to settle to lower levels — a phenomenon that drives heat-bearing ocean currents, and thus affects the climate.

The Gulf Stream, for example, warms northern Europe every year with the equivalent of the energy of 100,000 large power plants. Measuring the gravity is necessary because it is far from constant on the earth's surface. High mountain ranges increase it, and deep troughs in the sea weaken it. Yet another factor is the density of the rock in the ground. A higher density results in a higher local gravitational field. The Indian Ocean provides a clear example of how gravity changes. "If you cross by ship, you pass through a depression 100 meters deep — without being aware of it," explains Prof. Volker Liebig, Director of ESA's Institute for Earth Observation. The reason for this is that the ocean surface always adjusts itself to the earth's vertical gravitational field.

To ensure that all the information collected by GOCE reaches the earth, the satellite's data transmissions to the ground station must function reliably. Anything less than this could compromise the value of the satellites, associated scientific studies, and the hundreds of millions of euros invested in ESA's facilities.

> The satellites' measurements enable researchers to forecast climate changes and other developments.

Engineers from Siemens Aerospace Solutions have developed solutions for GOCE, including radio frequency testing equipment. This system puts the satellites' communication technology through its paces during the test phase. First of all the satellite is subjected to all kinds of stress that could occur during its mission. In a vacuum chamber, for example, a setting like that of outer space is created and the satellite is violently shaken on platforms that simulate the forces from the launch rockets at liftoff. The Siemens system simultaneously monitors the satellite's telecommunication functions to ensure they work reliably even under such extreme conditions.

Artificial Noise. A satellite has at least three antennas. One sends the telemetry data — information on the satellite's status — to the ground station. The second enables scientists to issue commands to the satellite, for instance to activate or deactivate measuring devices. Finally, most satellites use a third antenna to send measurements to the ground. Scientists test satellite to determine how reliably they can process radio signals, for example. To do this they simulate a noisy environment by deliberately introducing flaws into a signal. The result is similar to poor reception in a radio; in outer space, the equivalent of this is caused primarily by the solar wind. Test personnel observe a satellite's reactions to signals to determine whether the signals can be processed in spite of a noisy background. This makes it possible to detect and correct malfunctions at an early stage.

Satellite power is another area where researchers leave nothing to chance, relying instead on a system from Siemens. "This system makes it possible to simulate not only the power delivered by solar sails in space, but also battery behavior in the event of freak reduction in solar radiation," explains Hans Steiner of Siemens

Aerospace Solutions in Vienna, Austria. During the tests, researchers determine whether the voltage fluctuates sharply or becomes too high and puts excessive strain on the measuring devices.

Siemens engineers also developed similar test equipment for the CryoSat-2 satellite, which the European Space Agency launched early in April 2010. This satellite is to be the first to measure the thickness of sea ice. Until now it has been possible to determine only the expansion of ice surfaces, but that's about to change thanks to the radar altimeter on board CryoSat-2. This altimeter emits electromagnetic pulses and measures how long it takes them to return to the satellite after they have been reflected by the earth's surface.

To measure the thickness of ice, the altimeter has to emit two waves, one of which is reflected by the water's surface and the other by the surface of the ice. Due to the different elevations of the water and the ice, the two waves arrive at different times, enabling scientists to precisely calculate the height of the ice shelf. And because only up to ten percent of an iceberg's total mass is above the water surface, they can thus deduce the thickness of the ice as well.

The CryoSat-2 satellite is on a three-year mission to measure the planet's ice masses and thereby provide important findings concerning the exact relationship between climate change and the status of ice sheets in Greenland, at the North and South Poles, as well as the ice floes moving at sea.

Siemens systems are also being used for rigorous testing of another satellite that belongs to the Atmospheric Dynamics Mission, or ADM-Aeolus. The satellite is scheduled to enter service in 2011 and measure global wind profiles — the directions and speeds of air masses. Aeolus can do this because it has a Lidar on board, a type of radar that emits light. Airborne molecules scatter light, part of which is reflected. Depending on the velocity of the air molecules, the frequency of the light waves changes. Similarly, the altitude of the particles in the atmosphere affects the time needed for the scattered light to make its way back to the satellite. This makes it possible to further refine existing atmospheric models.

GOCE, a gravity field and ocean circulation satellite, is thoroughly tested before beginning its space mission.

Rice and Methane. Also of great scientific importance is the composition of atmospheric layers. This is being analyzed by one of the most sophisticated satellites of the Living Planet Program — ENVISAT, which, since 2002, has been measuring values including the distribution of nitrogen oxide (NO_2) and methane. The satellite measures scattered sunlight in the atmosphere and on the ground. Since light changes its frequency depending on which molecule it has been scattered by, the frequency generated by, for example, nitrogen dioxide, is different from that produced by methane. ENVISAT can measure these frequencies by means of a special spectrometer. Increased methane values have been detected in regions where there is extensive rice farming, for instance; high NO_2 values have been recorded in heavily industrialized areas.

Every day a total of about 270 gigabytes of observation data are transmitted to earth by all ESA satellites combined — as images and measurement values. The antenna in Frascati alone receives 200 gigabytes. "This data is used by roughly 3,000 project teams at many different kinds of organizations," says Liebig. "The knowledge they gain can help us learn about the causes of climate change, and maybe even better predict its effects." ■ *Helen Sedlmeier*

Siemens researchers are exploring how animal cells can be used as sensors. These new biosensors have demonstrated a high level of sensitively to any toxin that interferes with their metabolism.

Sensor Systems Based on Cells

Detecting hazardous substances in water and air currently requires time-consuming lab tests. Siemens researchers are developing sensor systems, some of which are based on living cells, to quickly detect pathogens and pollutants on site.

People in the German state of Baden-Württemberg still shudder when they think about the poison attack. In 2005 an unknown person submerged three canisters of herbicide in Lake Constance, very close to a drinking water pumping station. An anonymous letter claiming responsibility for the attack led divers to the poison in 70 meters of water. Fortunately, only small amounts of the pesticide were released into the lake, and thresholds weren't exceeded. But similar scenarios — for instance if terrorists poured poison into water lines — continue to give water companies nightmares. Fish or water fleas are often used as natural alarm systems, but this is hardly optimal. Drinking water undergoes extensive laboratory testing at extended intervals. "But these tests only find things that are specifically being looked for," says Dr. Heike Barlag, Head of the Biosensors team at Siemens Corporate Technology (CT) in Erlangen, Germany. Neurotoxins or pesticides that are no longer registered are not on the analysis list.

This is why Siemens biosensor chemists and a group headed by Prof. Maximilian Fleischer at Siemens CT in Munich are exploring new approaches to pollutant detection. The researchers have developed three sensor systems that can be used for effective monitoring of air and water. All three systems use biological components for detection and are mutually complementary.

For example, a system called SiequaSAFE, which was developed by Barlag's team in collaboration with several water utilities, functions as a warning system in the event of a terrorist attack. At the heart of the system is a sensor that duplicates the crucial metabolic process performed by acetylcholinesterase (AChE), an enzyme that functions as an extremely fast catalyst. AChE breaks down the messenger substance that, in animals, transmits signals from nerve cells to muscles. Substances that inhibit the enzyme, such as the chemical weapons Sarin and Tabun or the banned insecticide E605, are highly toxic. "If a substance such as Sarin interferes with this enzyme, then it is a good indication that something very dangerous is in the water," says Barlag. However, the initial concern is not so much the identification of the substance, as the ability to instantaneously sound a warning.

The challenge for Siemens chemists was to convert the enzyme inhibition test — an established laboratory procedure — into a fully automated system. The prototype is roughly the size of a printer and has multiple connections for thin tubes through which water samples and solutions are conveyed to a sensor chip. "We found a form of AChE whose cleavage product can be detected electrochemically," explains Barlag. SiequaSAFE begins by pumping the water sample across the chip. It then provides the AChE with a substance to which it can cleave. As long as the AChE is intact, it breaks down this substance. But if it has been exposed to a poison, it stops working and no decomposition products are formed. The sensor uses the flow at an electrode to determine the amount of these products.

The activity of a control enzyme is also monitored. SiequaSAFE sounds an alarm only if this enzyme is working properly and AChE is not. "But even if SiequaSAFE does encounter a dangerous substance, it is not disabled," stresses Barlag. The system regenerates automatically by flushing the chip and replacing the enzyme. SiequaSAFE is extremely sensitive, detecting the toxin E605 in amounts of less than one millionth of a gram per liter. A tenth of a gram is deadly to humans. Many more applications will be possible in the future, however. "Heavy metals, phenols, and blue-green algae toxins are suitable candidates for enzyme inhibition tests," says Barlag.

Mobile Laboratory Barlag's team is working not only on SiequaSAFE, which can continuously monitor the safety of a drinking water system, but also on a portable laboratory system that can identify a large number of pollutants and roughly determine their amounts — within half an hour.

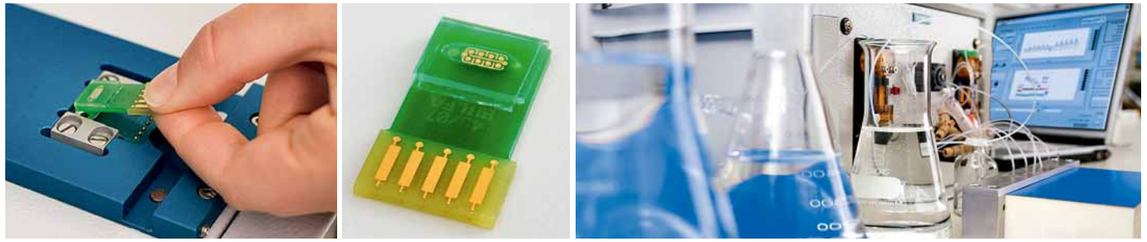
That's what team member Peter Paulicka is working on. As part of a project funded by the German Federal Ministry of Education and Research, Paulicka and others have developed a semiautomatic device called AquaSENS. The device uses an immunological test to detect small molecules such as hormones, antibiotics, and pesticides, as well as much larger bacteria — in a tiny water sample. Detection is based on the ability of the body's own antibodies to recognize foreign substances by the presence of characteristic constituents called antigens.

AquaSENS finds hormones, antibiotics, pesticides, and bacteria in the smallest of water samples.

The antibodies for up to 25 substances are located on a chip on a removable card. When a water sample is pumped across the chip, target substances bind with the specific antibodies on the chip. This leads to another reaction, the products of which are detected electrically. "The smallest currents here are in the range of a few trillionths of an ampere," says Paulicka about the system's performance.

The major advantage of AquaSENS is that this antibody-antigen reaction takes place on an electronic chip. "Expensive optical laboratory systems are now used for most immunological analyses, and they have to be operated by experts," says Paulicka. AquaSENS, on the other hand, is a robust device the size of a laptop computer that delivers relatively rapid results at the push of a button. AquaSENS detects pesticides such as atrazine in concentrations of just a few millionths of a gram per liter, which is very close to the threshold allowed by law. "It's optimal for rapid screening," says Paulicka. "It isn't intended to replace high-precision labs, but simply to test pollutant concentrations quickly and easily on site."

The mobile device could be helpful during field deployments by international organizations, for example. And it can also capture microbes. "Bacteria detection is a central task in water quality monitoring," says Paulicka. This typically requires time-consuming preparation of bacteria cultures. The laws governing drinking water are strict. "No more than 100 colony-forming units of *legionella* are permitted in 100 milliliters of drinking water, which also must be completely free of coliform bacteria," Although AquaSENS still has not yet achieved that level of sensitivity, it is getting closer. One project partner, for instance, is developing a filtration method that fishes bacteria out of water and concentrates them. When fully developed, AquaSENS could take provide routine monitoring in drinking water systems. "In Munich, for example, 45 samples are drawn from water lines every other day and tested in a laboratory for *legionella*," says Paulicka. "But with AquaSENS, the analysis could be performed right at the site."



The heart of the SiequaSAFE water testing system is an enzyme on a chip that is destroyed if a dangerous substance is in the water.

Living Detectors Prof. Fleischer and Dr. Evamaria Stütz of Siemens Corporate Technology in Munich are working on animal-cell-based sensors for AquaSENS and SiequaSAFE. Although unable to identify individual substances, the sensors respond to a broad spectrum of materials that could be dangerous to health or the environment. These include heavy metals, pesticides, ozone and nitrogen oxides, as well as alcohol, nicotine, and drug residues. The principle behind the sensors is that they measure changes in cellular metabolism.

Siemens researchers have taken an analysis unit designed by Rostock, Germany-based Bionas for use in the pharmaceutical sector and are currently modifying the device for environmental analysis. The device uses silicon chips covered with living cell cultures as its sensors. The condition of the cells is monitored by observing three vital signs: The system measures their physical shape, oxygen consumption, and the pH of their waste products. If one or more of these variables change, the chip-based cells may well be under stress. The cell cultures are available commercially and originate from various organisms. Dr. Stütz discovered that muscle cells from rats are particularly well suited for wastewater analyses because they react with great sensitively to pollutants, are long-lived, and undergo genetic changes only slowly. She is also experimenting with a cell line that was isolated from the pulmonary tissue of hamsters as well as with human liver carcinoma cells.

"We want to find suitable cell lines for various applications, including air analyses," says Stütz. "That's challenging because living cell cultures must be flushed with an aqueous culture media." Initial experiments in which gases are blown into the cell nutrient solution are already underway.

Siemens researchers are also optimizing the Bionas system for automatic long-term measurements. "Being able to use an existing system has given us an advantage over the competition, who have to develop everything from scratch," says Fleischer. Plans call for practical tests based on use of living cells as environmental sensors to take place before the end of 2010 with water companies in Germany's Ruhr region.

Fleischer sees a broad range of potential applications, for instance in monitoring of sewage treatment plants and industrial wastewater. Cellular sensors could measure air and water quality in green buildings and provide warnings in the event of a chemical attack at an airport.

Ideally, Fleischer would like to convert entire organisms into sensors. "Lichen could monitor air quality at busy intersections, for example," he says about his idea. The biologists on his team think that's quite utopian given that no one has succeeded so far in having an entire community grow as a culture on a chip. But it's exactly challenges like these that inspire successful inventors.

Ute Kehse

Clean Water — a Challenge for Humanity

Some 71 percent of the earth's surface is covered with water. However, only a little less than 3 percent of this is fresh water, and most of that is contained in glaciers and snow. Moreover, the fresh water that is freely available is also distributed very unequally. In fact, 60 percent of the world's usable reserves of drinking water are located in only ten countries. According to the World Health Organization (WHO), some one billion people — two-thirds of them in Asia — still do not have access to clean drinking water. In Africa, 42 percent of the sub-Saharan population is forced to live with a water supply that is insufficient. China and India will also be facing serious water shortages by 2025. It will take investment of at least $10 billion per year to achieve the UN Millennium Development Goal of cutting in half the proportion of the global population with insufficient access to clean drinking water by 2015.

Around 80 percent of infectious diseases worldwide are caused by contaminated drinking water. WHO reports that 1.8 million people die each year due to diarrhea diseases; 90 percent of these people are children under the age of five, most of them in developing countries. In India alone, around 1,000 children die from such diseases every day. The causes here include sewage water containing human or animal fecal matter that seeps into groundwater or wells through rotting pipes. These days, a whole range of organisms are used as standard indicators worldwide to determine whether water is contaminated. Efforts to identify contaminated water focus on the intestinal bacteria *Escherichia coli*, or the identification of the total number of heterotrophic bacteria in water samples. The challenge with drinking water analysis is that it requires detecting a small number of organisms in a large volume of water. Traditional procedures, which are simple but also time-consuming, involve the cultivation of individual cells of *E.coli* and *enterococcus* bacteria, which are then allowed to grow into visible colonies. Their presence is then determined by counting the colonies that have developed. Methods that make use of molecular biological techniques already employed for medical diagnoses would speed up the process. These would have to be adapted for use with drinking water analyses, however. In the so-called PCR procedure, for example, short *E.coli*-specific sections of DNA are duplicated. A fluorescent dye that integrates itself into the DNA makes the synthesized DNA fragments visible.

Drinking water can be purified through different procedures that can also be combined with one another. Conventional methods utilize activated carbon, chlorine, ozone, and membrane filter systems, among others. Another possibility is to kill germs with high-energy UV radiation.

According to UNESCO, Finland has the best-quality water in the world, and is followed here by Canada and New Zealand. The index used to determine this ranking takes into account various factors such as the amount and quality of fresh water (especially groundwater), sewage treatment effectiveness, and compliance with environmental laws. Indicators used in the calculations include "dissolved oxygen," "suspended solids," "phosphorous," and "permeability." According to the German Association of Energy and Water Industries, however, an objective ranking should also include heavy metals and nitrogen content.

The development of water treatment techniques has been shaped primarily by Germany, Austria, and the U.S., whereby their stringent regulations are also frequently adopted by other European countries. The European limit for nitrates, for example, is 50 mg/liter — but in the U.S. it's only 10 mg/liter. Still, experts don't always agree on the permitted concentrations for every substance. Whereas the EPA in the U.S. sets a limit of 30 micrograms (µg) per liter for uranium, the WHO recommends no more than 15 µg and Germany's Federal Environment Agency recommends only 10 µg. Lead pipes are a problem as well, especially in buildings constructed before 1950. In areas with soft water, the use of such pipes can lead to high concentrations of lead. Regular ingestion of small amounts of lead by young children can damage the process of blood formation and the development of their nervous systems. The EU, for its part, plans to revise its drinking water directive by 2013, at which time the limit for lead will be lowered from the current 25 µg/liter to 10 µg/liter.

Sylvia Trage

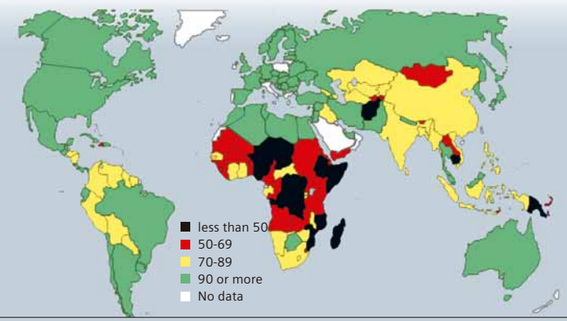
Different Limits for Pollutants

Chemical parameters	WHO Guidelines for drinking water quality 2006	EU Drinking water directive 98/83/EC 1998	Germany Drinking water ordinance 2001
	[mg/l]	[mg/l]	[mg/l]
Benzene	0.01	0.001	0.0001
Nitrate	50	50	50
Mercury	0.006	0.001	0.001
Arsenic	0.01	0.01	0.01
Lead	0.01	0.01 (prov. value until 12/25/2013: 0.025)	0.01 (prov. value until 11/30/2013: 0.025)
Cadmium	0.003	0.005	0.005
Nickel	0.07	0.02	0.02
Nitrite	0.2	0.5	0.5
Aluminum	0.2 resp. 0.1	0.2	0.2
Iron		0.2	0.2
Tritium		100 Bq/l (radioactive)	100 Bq/l

Source: Lenntech, WHO, EU, German Health Authority

Water Is Becoming Scarce in Africa and Asia

Percentage of population with access to clean drinking water



Source: UNFPA, State of World Population 2007

The UN and the World Bank fear that conflicts over access to fresh water will arise in Africa and Asia, as most climate forecasts predict that global warming will result in a further deterioration of water supplies in these regions.

Cameras that combine thermal and video images can identify otherwise invisible sources of danger. CT researchers (right) check the functions of an RFID chip designed to detect trucks carrying hazardous freight.

Danger Made Visible

A truck with a defective engine, faulty brakes, or hazardous freight can trigger an inferno in a tunnel. Siemens researchers are investigating how to use RFID technology, video analysis, and thermal imaging cameras to spot vehicles that are at risk.

The driver of the tanker truck doesn't know that he's heading for disaster. He's unaware that the braking system on one of his rear wheels is blocking and beginning to glow red hot. There's a tunnel coming — in three kilometers — but the potential catastrophe doesn't have a chance to unfold thanks to newly developed safety systems that have already detected the rolling time bomb and triggered an alarm in the tunnel operator's control center. Here, staff switch the lights at the tunnel entrance to red, and flashing hazard signs redirect the driver in order to defuse the dangerous situation.

This scenario is still a future vision. Nevertheless, a research project known as SKRIBT — (German acronym for "Protection of Critical Bridges and Tunnels on Roads") — which is being conducted by scientists at Siemens Corporate Technology (CT) and its Mobility Division, is moving closer to making this vision a reality. Ten partners from government agencies, industry, and research institutes are participating in a three-year project, which is being funded by the German Ministry of Education and Research. The aim is to make critical road segments safer. "Tunnels and bridges are the most important components of the road network," says Dr. Frank Heimbecher, project coordinator at Germany's Federal Highway Research Institute, which initiated the SKRIBT project. "If they get damaged, the consequences can be economically devastating."

Most major accidents in tunnels involve defective trucks — situations in which tires blow, brakes overheat, or engines fail in a manner that triggers a fire. That's why Alla Heidenreich, infrastructure project manager at Siemens CT, has been working with her team since 2008 on two safety systems that can identify defective trucks and those transporting hazardous materials — before they enter a tunnel. The researchers, who are from Munich and Princeton, New Jersey (USA), came up with the idea of combining video images with thermal imaging technology. This enables them to determine if certain vehicle components are overheating. The system works as follows: A video processing program linked to surveillance cameras identifies a passing truck and converts a segmented two-dimensional image of it into a 3D model with using newly-developed algorithms. The program is then able to recognize components susceptible to fire, such as wheels, brakes and axles.

The thermal image of the truck, which is recorded using an infrared camera, is linked with the 3D image, after which an analysis program searches for anomalies that could indicate defects. It does this using knowledge gained from models that provide information on things such as how hot one axle may get in relation to the others. Because normal video cameras need expensive external lighting at night, Siemens researchers are working on yet another idea. "Our next step will be to study possibilities for the exclusive use of infrared images to identify potentially dangerous situations with tires, brakes, and axles," says Dr. Andreas Hutter, an expert in realtime image processing. "If we succeed, we'll be able to significantly reduce costs."

Hazardous material transports pose an even greater problem, especially if it's not clear what type of cargo is being shipped. Some materials like gasoline may only be transported by truck through certain tunnels. Up until now, there has been no automated system for monitoring compliance with such rules. Trucks today are in fact required to carry orange stickers bearing coded information on how dangerous their freight is and which categories of tunnels they may pass through. However, video cameras can not decipher these labels when visibility is poor or the labels are covered with dirt. Radio Frequency Identification (RFID) transponders would thus offer a major benefit here.

Transmission-Enabled Stickers. If experts at CT have their way, trucks will soon also be equipped with hazardous material labels containing a small RFID chip that can be read via radio and that also holds all information about what the truck is carrying. "That would significantly increase the accuracy of the monitoring system," says Heidenreich. Such a system would function roughly as follows. When a truck passes a reading point approximately three kilometers before a tunnel, its cargo data would be registered by the RFID system and forwarded to a control center. Only one truck transporting hazardous materials would be permitted in the tunnel at a time. Should an accident occur, firefighters would tackle the blaze using precisely the right extinguishing agent. Any truck attempting to enter a tunnel with prohibited freight would be stopped by a red light in front of the entrance.

The CT team is particularly proud of its newly developed RFID transponder system's ability to meet extremely high demands. The chip can transmit its signal to the unit's reading device over a distance of around 50 meters — and send the data at least twice within two seconds. "Conventional passive radio chips without a built-in energy source have a range of only six meters," says Daniel Evers, an RFID expert at CT. "That's why we use an active chip that has a built-in battery and transmits in the high-frequency range of 2.45 gigahertz. To ensure the battery lasts as long as possible, the transmitter in the transponder sleeps until it's woken by a radio pulse issued by the reading device at the checkpoint." Evers also points out that the RFID data cannot be intercepted or falsified. To ensure this is the case, Siemens researchers employ an encryption technique they previously developed for passive RFID chips (see *Pictures of the Future,* Spring 2009, p.45). "Previous solutions needed too much energy," says Hermann Seuschek, an IT security expert at CT. "However, our cryptochip is so energy efficient that the transponder can run for at least three years without needing a replacement battery."

Research activities will be followed by road tests in mid-2010, when Siemens researchers will install truck detection system components at the Aubinger Tunnel near Munich. Plans call for the tunnel safety system to be tested until February 2011. "Up until now, activities have focused on improving safety within the tunnel," says Heidenreich. "But in the future, we're going to be able to detect and prevent danger before a vehicle gets there. Video, RFID, and infrared technologies will play a key role in this process."

■ *Rolf Sterbak*

In Brief

■ Researchers are pushing deeper into the nano worlds of cells, proteins and genes. To this end, technologies are being developed that will make diagnoses faster, more reliable, and less expensive. Siemens researchers are, for example, working on a portable system that could instantly test a drop of blood for the presence of a range of diseases. (p. 62, 66)

■ In an interview, Dr. Charles M. Lieber of Harvard University states that in perhaps five years it will be possible to locate tiny sensor systems underneath a person's skin, where they would continuously check his or her blood for biomarkers of diseases such as cancer or flu. (p. 65)

■ Having the right kind of diagnostics is essential when combating cancer. Siemens is combining 3D X-ray images from computer tomographs with positron emission tomography images used in nuclear medicine. Result: doctors can more quickly and effectively determine the size and location of dangerous tumors. (p. 68)

■ Infrared light can be used to discover molecules and thus optimize processes. Siemens experts are using infrared spectroscopy to help regulate coal-fired power plants more precisely and prevent failure in biogas fermenters. (p. 70)

■ ESA employs earth observation satellites to gather data about the interrelationships between volcanic eruptions, earthquakes, and climate change. Siemens is developing special test systems to ensure the huge volumes of data gathered by satellites make it securely to earth. (p. 72)

■ Time-consuming lab tests are currently required in order to detect pollutants in water and air. Siemens researchers have developed several sensor systems that detect dangerous substances such as pathogens and pollutants quickly and directly on site. (p. 74)

■ Trucks with defective engines and brakes could trigger an inferno in a tunnel, as could trucks transporting hazardous freight. Siemens researchers plan to use RFID technology, video analyses, and thermal imaging cameras to identify at-risk vehicles and thus prevent disasters from occurring. (p. 78)

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Zeolite granules rapidly adsorb moisture from dishes and release heat, thus reducing a dishwasher's electricity demand.

Drier Dishes

Drying with zeolite minerals is helping a new generation of dishwashers from Bosch und Siemens Hausgeräte make big energy savings.

The grayish granules feel like a handful of puffed rice. Blow a breath of moist air over them, however, and they quickly become painfully hot. "That's adsorption heat," says Michael Rosenbauer, Head of Dishwasher Development at BSH Bosch und Siemens Hausgeräte (home appliances) in Dillingen, Germany. This heat is generated when the microporous granules trap water molecules in their tiny pores. The unusual material they are made of is an aluminum silicate zeolite that is easily recycled. When placed in a container on the floor of one of BSH's latest generation of dishwashers with "speedMatic" functionality, 1.15 kilograms of these granules adsorb the moisture from drying dishes. A demonstration dishwasher in the BSH lab in Dillingen shows just how rapidly this occurs. Operating in a continuous cycle, the machine wets dishes and then dries them in just two minutes. Even damp patches at the bottom of cups or the drops that always stick to plastic containers evaporate in seconds due to the warm air generated by the heat from the zeolite granules.

Rosenbauer says that the original idea came during a presentation at the Bavarian Center for Applied Energy Research (ZAE) in Garching, near Munich. This nonprofit association, which is funded by collaborations between industry and higher education, had organized a demonstration for developers from all of BSH's product groups. All in all, this spawned 39 ideas, but the Dillingen team was the first to come up with a product. In 2008, 250 pilot-production dishwashers were sent to testers in many locations, without any reference to the special functionality. "The response was immediate. People were amazed by how dry the dishes were," Rosenbauer recalls.

Energy Recycling. At present, no other manufacturer anywhere has anything to rival the zeolite system — and that is unlikely to change for the time being. BSH has filed some 30 patents, ZAE has supported the research, and engineers in Dillingen have protected both the idea of zeolite drying and its implementation.

The system consists of the zeolite container and a heating mechanism. A fan blows damp air over the zeolite granules and hot, dry air back into the dishwasher chamber. This reduces moisture content from 100 to 10 percent. In the process, the granules retain up to 200 grams of water — enough to remove every last drop from the dishes. To remove the water, heating coils then heat the zeolite to a temperature of 240 ° Celsius.

Although this process consumes energy, speedMatic dishwashers use around 20 percent less electricity as compared with conventional models from the highest energy-efficiency category according to German consumer watchdog "Stiftung Warentest." Because water that has been adsorbed is not driven out of the zeolite granules until the next washing cycle, the hot, damp air thus generated can be used to moisten and warm dirty dishes. Part of the heat energy consumed for this purpose is later recouped and used for the drying process — in the form of energy released when water molecules are adsorbed in the tiny pores of the granules. At the same time, the machine's low water consumption — 10 instead of 14 liters per cycle — sets a new record. In recognition of this innovative development, BSH developers have been presented with the Climate and Environment Innovation Award from Germany's Environment Minister.

The speedMatic innovation also offers environmental benefits. If all German households with dishwashers rated at over 1.3 kilowatt-hours (kWh) per cycle were replaced by 0.83 kWh speedMatic models, CO_2 emissions would fall by 1.2 million metric tons a year.

A life cycle assessment by BSH indicates that although production of the new dishwashers requires four to six percent more energy than for older models, the environmental impact of such factors is negligible because a zeolite dishwasher uses one-fifth less energy during its operating life, which is responsible for 95 percent of its environmental impact. Consumers benefit too. At an electricity price of 0.19 Euros per kWh, the additional cost of purchase can be recouped within an average service lifetime of 13 years — or even earlier if power prices continue to rise. ■ Bernd Müller

Whether it's the Russian high-speed Sapsan train or major offshore wind parks — Siemens is helping to finance complex green infrastructure projects.

Green Financing

Environmental investments often require a complex financing plan. Siemens Financial Services is ideally suited for such projects, as it can carry out feasibility studies, provide capital, and bring the right partners to the table.

Efficient, environmentally-friendly technologies are on the march. According to Booz Allan Hamilton, a consulting firm, some €27 trillion needs to be invested in the expansion of water, electricity, and transport infrastructure over the next 25 years. Siemens, with its Environmental Portfolio, acts as a technology partner in many infrastructure projects. However, the company's role is much broader than that. Specifically, its own Siemens Financial Services (SFS) division helps get projects moving, takes over financial planning, brings the right partners together, and even financially participates in major projects via its Siemens Project Ventures (SPV) subsidiary.

SPV was involved in Siemens' acquisition of a stake in the Israeli company Arava Power (p. 11), a PV development firm established in 2006 with the goal of commercially utilizing solar power in Israel for the first time. The company needed an international partner and thus began negotiating with SPV in February 2009. Just six months later, the two companies signed an agreement under which Siemens acquired a $15 million stake in Arava Power. "The chemistry between Arava's owners and Siemens was great from the start," says Klaus Kolof, who is responsible for Renewable Energy at SPV. But that was only the first hurdle. Arava still had to negotiate with Israeli authorities regarding the price of future green electricity. After all, solar power had never been fed into the Israeli grid before. Finally, the price was fixed at the end of 2009. "That made it possible for us to achieve further milestones," says Kolof. The two partners are now establishing a project company that will build the first solar facility at the Ketura Kibbutz, between the Dead Sea and the Red Sea. It's maximum output will be 4.9 megawatts. Siemens is not only providing technical expertise and components, but also managing the project as its general contractor.

Four Gigawatts of Wind Power. The fact that Siemens invests its own capital is important for many customers that commission major infrastructure projects — particularly in the wake of the financial crisis. SFS currently has investments totaling some €7 billion, around €1.4 billion of which is accounted for by technologies from the Siemens Environmental Portfolio. The UK also wants to significantly reduce its CO_2 emissions. For example, by 2020, the British government plans to cover around 25 percent of its electricity needs through nine offshore wind parks. These facilities are currently in the planning stage. Siemens is involved in several projects here, the largest of which is a wind park with a planned output of four gigawatts that will be built near Hornsea in Yorkshire county. Together with the firm Mainstream Renewable Power, Siemens has established the Smart Wind project company to develop the wind park.

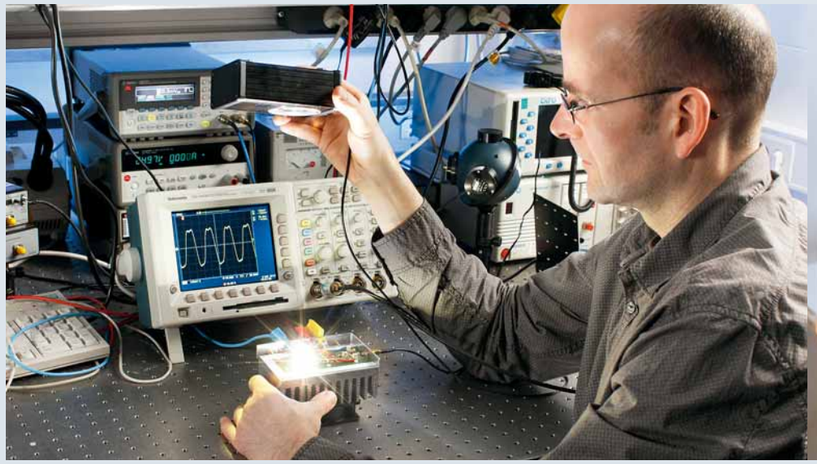
Each partner is providing half the start-up capital. "And that means we're financing half of the required preparation measures," Kolof explains. Construction is scheduled to begin in 2014 — but studies will first have to be carried out to determine the impact of the new facility on the environment, ocean floor, and fish populations. Developers will also be measuring how much wind blows at which time and from which directions in order to determine the park's optimal location. They will also have to determine if shipping routes need to be altered. Kolof estimates it will cost around €19

billion to build the wind park. Siemens' share of the contract will likely be some €6 billion. Once completed, the facility, which will produce enough electricity for around 3,000,000 households, will be sold to an energy supply company.

Siemens is also helping to finance the Lincs offshore wind park project, which will begin this summer off the east coast of England. To this end, SPV and Danish energy supply company DONG Energy have acquired a stake in British energy firm Centrica. The resulting joint venture has already financed half of the €55 million development costs incurred to date, and will acquire a 50 percent interest in the project in return. "Now, we're getting ready to implement Lincs with the help of the project financing market," says Roger C. Ernst, SPV's director at the joint venture. This means the project team is now searching for banks and investors interested in financing some of the €830 million construction costs. The fact that Siemens is also making a significant contribution makes the search easier. "The credit market situation isn't as bad as it was at the beginning of the financial crisis," says Ernst. The Lincs wind park is to go online in just over two years, when its maximum output of 270 megawatts will meet the annual electricity demand of around 200,000 households.

The injection of its own capital is just one of the many financial instruments available to SFS. For example, Siemens built and installed 130 wind turbines for the Windy Point wind park in the U.S. state of Washington. These turbines supply some 90,000 households with green electricity. SFS provided a $178 million line of credit for this project, which was carried out by Cannon Power Corporation, one of the leading wind energy companies in the U.S. Other options for supporting green investment projects include leasing schemes and energy performance contracting. Here, the capital investment is paid back in installments from the savings made thanks to lower energy bills.

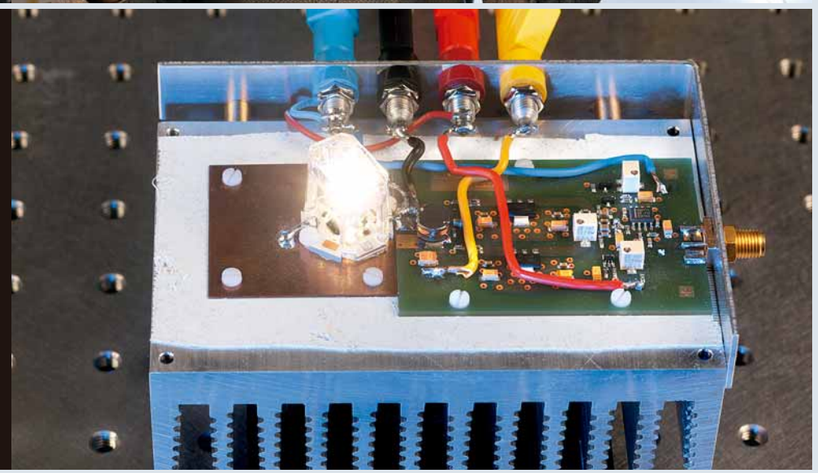
Sustainable investment also includes financing transportation projects such as one involving the new high-speed Sapsan train. This Siemens train — a Velaro adapted to meet Russian climate conditions — has been operating between Moscow and St. Petersburg since December 2009. With a top speed of 250 kilometers per hour, the train shortens the trip by around 45 minutes, and is thus tempting passengers to switch from planes to the train. After years of negotiations, SFS was selected to provide the €318 million needed to finance the new fleet of eight high-speed trains. Siemens was also awarded a 30-year maintenance contract. ■ *Katrin Nikolaus*



By modulating white LED light, Siemens researchers in Berlin were able to set a record for digital data transfer — 500 megabits per second over up to five meters.

Welcome to the Digital Age

The international Delphi study 2030 underscores the importance of information and communication technologies (ICT). As part of the study, 550 experts from around the world evaluated key developments, challenges, trends, and opportunities associated with ICT.



The experts from around the world who participated in the "Prospects and Opportunities of Information and Communication Technologies (ICT) and Media — International Delphi Study 2030" all agree that the triumphal march of ICT will continue. The reasons for this include the increasing number of components that can be put on microchips, continually expanding memory capacities, ongoing improvements to the performance capability of microprocessors and associated software, and the fact that prices will fall in the future, even as performance increases.

Delphi experts predict that ICT will be shaping our entire lives in just ten years. That's because the digitization of all private and professional realms will continue as the Internet in particular offers new applications, functionalities, and services. Moreover, increasing global competition, major global challenges such as climate change, and demographic developments will all stimulate ICT innovations. As part of the 2009 Delphi study, which was funded in part by Germany's Economics Ministry, some 550 ICT experts worldwide were asked to describe the most important trends in their fields between now and 2030.

Some Key Findings:

➔ Powerful communication networks will improve the overall economy. Comprehensive stationary broadband coverage with glass fiber connections and data transfer rates of 100 megabits per second or more will become the global standard. This development will proceed at different speeds in different regions, whereby the pioneers will be Asian nations, the U.S, the UK, France, and Germany.

➔ Future ICT trends will include the "Internet of Things" — a system in which items of daily use will be digitally linked and will autonomously exchange information. Here, we will also see embedded systems operating as intelligent networked processors in aircraft and machine architectures. These systems will be able to learn from — and communicate with — other intelligent systems on their own.

➔ It will also be necessary to establish high-performance communication networks that ensure permanent Internet connections between stationary computers and mobile terminals to create decentralized globally distributed resources on the Web (cloud computing). In place of powerful stationary PCs, Internet service providers will provide users with computing power, memory, programs, and network broadband as required. Some 70 percent of the experts surveyed believe that accessing computer performance in the cloud will become a normal activity by 2024.

➔ The European Union has set itself the goal of increasing the share of power provided by renewable energy sources from the current seven percent to 20 percent by 2020. However, to efficiently exploit renewable energy and guarantee supply it will be necessary to modernize energy systems through the introduction of innovative ICT solutions such as the smart grid. Experts therefore believe that ICT must be introduced to energy systems by 2020 at the latest. ICT in sectors such as transportation, telematics, energy, and intelligent building systems could also help to significantly reduce CO_2 emissions before 2020.

➔ The dynamic development of ICT will primarily impact the key German sectors of automobile production, automation systems, mechanical engineering, energy, and health care by serving as a growth accelerator and innovation driver. Just under two thirds of the experts on Germany reported that ICT value added in the automotive industry will likely increase from its present level of between 20 and 30 percent to 50 percent by 2024. This growth will include the expansion of in-vehicle Internet as well as car-to-car networking. ICT will also play a key role in electric mobility — for example, when it comes to establishing smart electricity grids.

The study was published by the Münchner Kreis, a renowned association of ICT experts in Germany, as well as by the European Center for Information and Communication Technologies (EICT), Deutsche Telekom AG, and TNS Infratest. Siemens also worked extensively on the study, which it considers to be of particular interest to the company. "ICT forms the basis of most of our products, systems, and solutions — among other things, in the automation, health care, and energy sectors," says Prof. Dr. Hartmut Raffler, who played a key role in managing the study at Siemens. Raffler also says the development of "green ICT" will be especially important in the future. Such technologies will help conserve energy — for example, in energy-efficient buildings that are intelligently managed and controlled with ICT systems. The devices in such buildings could return surplus energy to the grid without threatening its stability.

An Internet of Energy. Raffer predicts the future will also bring an "Internet of energy" containing many network nodes that intelligently link participants in the energy system. Participants will include households, industrial consumers, energy supply and storage companies, electric vehicles, and electronic marketplaces. ICT and the energy system will then merge into a unit in which energy can flow in any desired direction. Corporate Technology is working intensively on the development of solutions for the Internet of energy (see *Pictures of the Future*, Fall 2009, p. 14).

According to Raffler, the international study's assessment of many key technologies makes it particularly valuable. "The global perspective of the study's experts enables us to better estimate exactly when certain innovations might be successful on specific markets," he says. Delphi experts also concluded that open innovation is essential if Europe is to compete with the U.S. and eastern Asia in the innovation realm. "We must open our companies and let in expert knowledge from the outside," Raffler says. "Open innovation is already well under way at Siemens, and we're transforming ourselves from a company whose philosophy is 'the lab is our world' into one that takes the view that 'the world is our lab.'" ■ *Nikola Wohllaib*

Highlights

2020

The concept of open innovation was first conceived about 20 years ago. Today it's an essential aspect of the work being done in research laboratories all over the world. Open Innovative is a company that specializes in development projects of all kinds. Managing director Diego is showing Johannes Quistorp how the company performs even the most complex tasks with the help of its knowledge network and the Internet.

Brazil 2020: A Brazilian company develops complex solutions for corporate customers all over the world. In its operations it combines the advantages of a gigantic global knowledge network with those of virtual space. That saves time and money and minimizes risk. A look at IT specialist Johannes Quistorp's first day on the job.

Unlimited Wisdom

Welcome to Open Innovative! I'm Diego, the Managing Director." A taxi has just deposited me at the gates of a slightly dilapidated beach house, and I can hardly believe my eyes. I'm a recent graduate of an interdisciplinary program in IT and engineering in Bremen, Germany, and not long ago I applied for a job with the global market leader in the area of open innovation (OI) in the city of Niterói in Brazil. To my amazement, I immediately got the job. Even in this virtual age it's still good form to show up in person for a job, so I've flown to Brazil — partly because this country has always fascinated me.

I don't know what I expected the headquarters of a global market leader to look like, but this beach house is a disappointment. Nor did I imagine I would be meeting a man dressed in a Hawaiian shirt, shorts, and flip-flops, but there he is, slap-slapping his way toward me. Am I really in the right place? I did check the address on the card several times, didn't I? — But I'm brought back to the here and now when the man calls out, "You must be Johannes, right?"

I can only nod at this point, but Diego has already started to tell me about his company: "Open Innovative provides companies in every sector with research partnerships and development solutions of every kind — but of course you already know that. To achieve our aims, all we need are some smart employees, storage space, and computing power in the cloud — in other words, in virtual space." I begin to blush. It seems as if my new boss is reading my mind.

Diego leads me to a wing of the villa and places his palm against a security panel. The

door opens and we enter a room with a round table standing in the center. "This is our showroom," explains Diego. He presses a button, which causes a three-dimensional hologram to rise up out of the table. The hologram shows a strange structure that seems to be a confused tangle of connected points and lines. "This is our trump card," Diego tells me proudly. "It's our gigantic knowledge network. Each of these tens of thousands of points stands for an amateur inventor, a scientist or a complete research institute that has registered on our Internet platform and will make its knowledge available upon request. The countless lines show how all of these points are communicating with one another. The center of the structure is our company, because this is where all the communications ultimately meet."

"What's actually new about that?" I interject. "Internet service providers have been applying this principle for years." Diego nods in agreement. "You're right, but our services go far beyond those offered by other OI providers. We don't just help our customers to find individual solutions for various small problems. We also offer them the option of having us develop complete solutions of every kind for them." He makes a steering movement and a camera that's hidden somewhere obviously interprets it correctly, as the hologram of a virtual laboratory immediately appears. "I'll show you a current example," says Diego. "The United Nations has commissioned us to take models of eco-cities — in other words, plans for sustainable urban development with customized infrastructures — and to transfer them to virtual space in a way that is true to life. Then we have to harmonize their individual elements, such as transportation, water supply, and building technology, with one another down to the smallest detail and optimize their efficiency. Urban growth and environmental protection should go hand in hand."

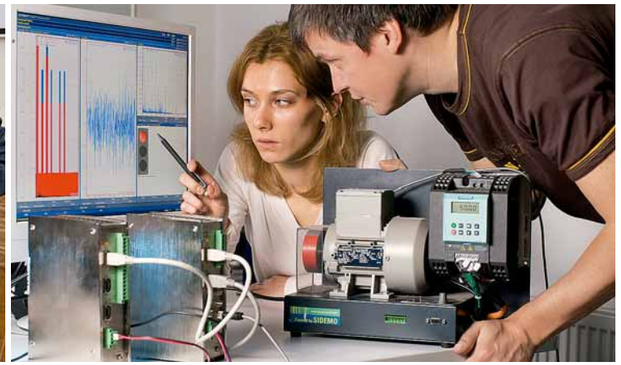
Diego once again makes a hand movement that resembles turning a page in a book, and the hologram shows some new details. "As with every commission, the customer sent us detailed requirements, including the maximum costs for materials and operation. We fed these figures into our knowledge network — including the amount of the award that will be granted for the best solutions. At that point we opened up a virtual laboratory on the Internet, as we do for every one of our projects. Depending on the complexity of the order and the knowledge they can contribute, individual Open Innovators who have registered with us can then log into these virtual labs, no matter where they are located. Our innovators can get the virtual components they need for their work from an online database of products and processing techniques. This is where we also store information about the customer's requirements. In the case of eco-cities, this information includes 3D models of individual infrastructure elements, including prices, the weather parameters of various regions, and the green requirements that must be fulfilled by construction materials. Using this information, our researchers can build up true-to-life models of everything in virtual space within a few weeks, test it, and optimize it."

It's clear to me how enthusiastic Diego is about these processes. "A particular highlight of this project was the infrastructure we created for the eco-cities," he continues. "We had to integrate large and small power plants, renewable energies, electric automobiles, storage devices for heat and cold, smart buildings, and thousands of electric meters. Then we had to simulate consumer behavior in the region and connect the system up with further new solutions that we had developed in secondary projects."

He points to parts of the hologram. "For example, major research institutes in Russia contributed their latest synthesis gas turbines, and a U.S. university had just developed a highly efficient method of CO_2 separation for this type of turbine. A brilliant architect from Madagascar suggested to us how we could use captured greenhouse gas to boost harvests in the agricultural areas he had built into his green high-rises. As you see, these are all very complex aspects that we have to optimize through the interaction of our worldwide experts. To make sure all these interactions proceed smoothly and that creativity and productivity go hand in hand, we need our administrators. And that's exactly the job we want you to do. As part of a virtual team, you can of course do your work on any computer anywhere in the world."

Diego notices that I can hardly wait to start my new job, and he decides to slow down my enthusiasm just a bit. "We're going to start you off on an easy project. A hospital operator is looking for a university to work with on a pilot project involving knowledge databases for cardiovascular diseases. So we're going to launch an ideas competition in which universities can submit their concepts to our network. You're going to coordinate that project."

Diego then adds with a smile, "But first, as your new boss I have to find out if you know how to surf." I look at him in amazement. He laughs and points to the wall at the other end of the room. "I don't mean surfing the Internet!" he exclaims. "Grab a surfboard — we're off to the beach!" ■ *Sebastian Webel*



As Siemens strengthens its portfolio for the long term with some 1,000 cooperative projects a year, the company and its partners at universities around the world gain insights from each other's fields of expertise.

Tapping New Worlds of Ideas

Potentially, game-changing innovations are everywhere. They are hidden in the minds of employees and customers and in projects at universities and research institutes. Tapping these sources is something employers are doing to an ever increasing extent. As they do so, they are opening the doors of their labs, exchanging ideas with external partners, and creating a world of synergies.

Henry Ford was a technology pioneer. He founded one of the most successful automobile companies and was the first to introduce assembly line production, which revolutionized manufacturing industries. Despite his capacity for invention, though, Ford was for the most part unable to develop his ideas alone.

And he recognized this. One of his most famous statements, in fact, was an assertion that "coming together is a beginning; keeping together is progress; working together is success." He took his idea for the assembly line, for instance, from the conveyor belt used in Chicago slaughterhouses, which required each worker to perform only a few tasks. Ford expanded on this idea for his own purposes, and the rest, as they say, is history.

Today "working together" is still an effective way to accelerate the development of new technologies. And this is especially true for companies whose business success depends on innovations. Such companies often have to rely on the expertise of others, particularly when the work in question involves the latest findings in basic or applied research.

And naturally, this is true of Siemens as well. Every year the company enters into over 1,000 cooperative projects with universities, research institutes, and industrial partners in an effort to strengthen its portfolio of innovations for the long term.

In the Energy Sector, for example, Siemens is developing the technology for carbon dioxide capture in power plants, and is striving to make it ready for commercial use in collaboration with energy suppliers in Germany and Finland and well-known research institutes in the Netherlands (see p. 111).

At the same time, Siemens is testing the integration of electric cars into the power grid with several companies, as well as Denmark Technical University (DTU) in Copenhagen. Here, the objective is to get electric cars hooked up to sockets as soon as possible so they can be used as a storage medium for fluctuating quantities of wind-generated electric power (see p. 92).

Meanwhile, in the healthcare sector, Siemens is working with partners to develop new types of phase-contrast X-ray systems that can render a large variety of soft tissues in minute detail — an improvement that makes diagnoses more precise (see p. 90).

At Siemens Corporate Technology (CT) a specialized department focuses on the vital interface between the company and its university collaborators. The department coordinates the work carried out with partners, including activity parameters. "Together with our strategic project partners, we want to move innovations forward," explains Department Head Dr. Natascha Eckert. "Our principal task in that regard is to work with the Siemens Sectors and Corporate Technology to constantly identify new opportunities and forms of collaboration with universities."

The University as Partner. Siemens thus forges links worldwide with top universities, for example by entering into strategic partnerships with them. The aim is to pursue research together, encourage talent, and establish networks. With this in mind, Siemens has set up so-called "Centers of Knowledge Interchange" (CKIs) on the campuses of a number of universities (see *Pictures of the Future*, Fall 2006, p. 66). "Each CKI is supervised by a Siemens-paid key account manager at the university," says Eckert. "This person coordinates cooperative work locally, identifies partners, organizes workshops, and nominates students for Siemens programs for scholars." Siemens currently operates eight CKIs, which are located at Munich Technical University, Berlin Technical University, and the RWTH Aachen in Germany; at DTU in Copenhagen; at Tsinghua University in Beijing and Tongji University in Shanghai; as well as in the U.S. at the Massachusetts Institute of Technology (MIT) in Boston, and the University of California, Berkeley.

CKIs reflect the technologies and markets that have a promising future for Siemens," says Eckert. In addition to its expertise in renewable energies research, DTU, for example, is also engaged in research with Siemens focused on membrane technologies for water treatment (see p. 95). Munich Technical University contributes its expertise in the field of health care technology for the development of phase-contrast X-ray systems. And scientists at the prestigious Tongji University in Shanghai are working with Siemens on the development of "eco-city" models. It is hoped that these models will help to reconcile the extraordinarily rapid growth of Chinese cities with environmental protection needs (see p. 104).

Of course, these cooperative projects benefit not just Siemens but also its partners. Scien-

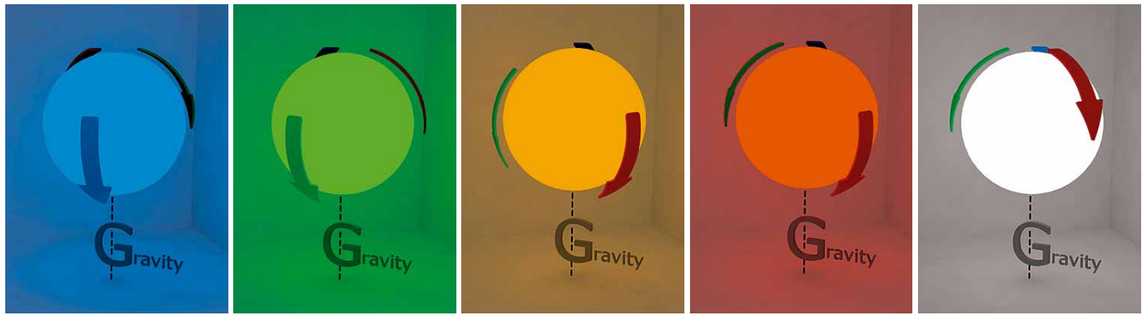
tists working on CKI projects benefit from exposure to issues of practical interest to industry, thus allowing them to go beyond purely academic research. What is more, it's not at uncommon for young scientists at partner institutions to find jobs at Siemens later on.

The Internet as Research Platform. In addition to cooperative projects, there is another way for companies such as Siemens to broaden their research horizons: a paradigm known as "open innovation" (OI). "In contrast to a classic research partnership with a framework agreement, in this case the developer searching for a solution calls for bids via the Internet and thereby integrates external problem-solvers, and sometimes foreign ones, into its innovation process," explains Prof. Frank Piller, an innovation management expert at RWTH Aachen (see p. 89), a prestigious technical university in northwestern Germany. This strategy of open innovation is already being implemented in various ways by many different companies — including Siemens.

One type of open innovation is known as the "innovation jam." Web-based, and usually in-house, these moderated discussions with hundreds or even thousands of participants are designed to find and evaluate new ideas. "Toward the end of 2009 we set up a jam, where we asked our employees in what ways future IT and communications technologies such as cloud computing could change the way Siemens does business," says CT researcher Dr. Thomas Lackner, who is responsible for open innovation issues at Siemens. "Thanks to roughly 1,000 contributions from those who took part, we were able to develop some initial concepts for responding to these evolving trends."

Siemens is making use of OI methods in research as well. When faced with particularly tricky problems, Siemens researchers sometimes turn to "e-brokers," who team up with external problem-solvers. In such cases, developers publicly describe their problem on an e-broker website, such as NineSigma or yet2com, and offer a cash reward for the best solution. And that solution can come from a large IT company in India or from an amateur developer in Germany. Approximately half of the problems are successfully solved in this way. So it's not surprising that large companies like BASF, Novartis, and Nestlé are likewise using this method of finding solutions.

In addition, Siemens has developed its own tool to foster networking among employees within the company. "When it comes to the process of finding solutions, our internal Siemens tool, which is called TechnoWeb, more or less corresponds to the e-broker principle," says Lackner. "Put simply, it works like an Internet forum in which any registered employee can post a specific problem. Whether it's a complex technical matter or just a question about how to use Microsoft Word — every user can see and answer these questions. That speeds up the work routines of individual users an awful lot."



Open innovation makes it relatively easy for developers to enhance their potential for innovation. Osram, for example, used an ideas competition to garner over 600 proposals for lighting solutions, as was the case with this chromatic ball.

The Customer as Development Partner. The most widespread method of open innovation, however, is called "crowdsourcing." "In this case, companies outsource their inventiveness, as it were, by getting customers actively involved in the innovation process through networking platforms or idea competitions, for example," says Caroline Rudzinski from Management Zentrum Witten (MZW), which has been dealing with the subject of collective intelligence for some time now and is analyzing the use of open innovation in the business market.

The list of companies now using crowdsourcing is long. In 2008, for example, approximately 4,000 people used a dedicated networking platform to take part in a vote arranged by Japanese noodle maker Acecook to determine which flavors consumers like most. In much the same way, fans of automaker Fiat had a chance to contribute design ideas for the new Fiat 500.

Consumer goods manufacturer Procter & Gamble plans to put special emphasis on customer input through crowdsourcing. Over the long term, the company intends to generate half of all new products by means of customer feedback. "With crowdsourcing, companies can take the needs of customers into account more quickly and react rapidly to dynamic market conditions. That leads in some cases to a huge competitive advantage," says Rudzinski.

Siemens lighting subsidiary Osram has also gained experience in the OI field. In 2009 Osram set up its "LED — Emotionalize your Light" idea competition. The competition gave professional designers and amateurs alike an opportunity to submit, inspect, and discuss their lighting ideas online. The overall goal was to identify practical and affordable lighting solutions that are easy for users to operate and install. Prizes were awarded for the best ideas.

Entries included a floating scallop lamp that provides relaxing hues of light in the bathtub, and the "chromatic ball" (see images above), which uses acceleration sensors to change the color of its light when rotated. "More than 600 ideas were submitted during the competition, and most of them are technically feasible," says Lackner, who is confident that Osram will implement one or more of these ideas in the not-too-distant future.

Despite these successful scenarios, many companies are still reluctant to open up their innovation processes, because they fear a loss of intellectual property or worry that it may not be possible to patent OI products. "But OI takes place entirely within the existing patenting process if the rules are defined properly — such as with a non-disclosure agreement or a waiver of rights," explains Prof. Piller. Nevertheless, he believes that companies will never expose all their expertise to outsiders, in part because of the issue of patent protection. In his opinion, OI will therefore only supplement the classic approach of in-house development instead of replacing it.

OI specialist Lackner is planning to bring about even greater integration of the various open innovation tools at Siemens. The success that Siemens has so far enjoyed with OI makes him confident. In February 2010 the company was ranked second for its knowledge management and its OI activities in the European Most Admired Knowledge Enterprises (MAKE) study by international market research firm Teleos. This marks the sixth time since 2001 that Siemens has been among MAKE's top finalists. Lackner is now considering organizing new idea competitions at Bosch und Siemens Hausgeräte GmbH, Osram, and at universities. Colleges could submit proposals for research projects, and the one with the most promising concept would then be awarded a partnership with Siemens.

"Whereas idea competitions identify the best new ideas, which are later implemented, e-brokers locate solutions that already exist," says Lackner. "This is especially useful in the case of complex technical problems relevant to the Siemens Sectors that work with power plants, industrial facilities, and medical devices."

Lackner hopes to pursue open innovation methods further within Siemens as well, because they provide a vehicle for discussing future trends with large numbers of employees and to also identify the best ideas. Another two-month idea competition is therefore set to start in mid April, and will be dedicated to the topic of sustainability. Says Lackner: "No matter how different the individual OI methods may be, they have one thing in common. They complement traditional research and development by integrating the creativity and expertise of many people into the innovation process. They therefore broaden the R&D horizon in a relatively simple way." ■ *Sebastian Webel*

Open Road to Innovation

Prof. Frank Piller, 40, has held the Chair in Technology and Innovation Management at RWTH Aachen, Germany, since 2007. Prof. Piller received his doctorate in business administration in Würzburg and led the Customer Driven Value Creation research group at Munich's Technical University. Until his appointment in Aachen, he was a Research Fellow at the Sloan School of Management at the Massachusetts Institute of Technology in Boston, Massachusetts.

| Interview

What is open innovation?
Piller: "OI" represents a completely new way to organize the innovation process. Instead of a company relying exclusively on its own R&D capabilities, it calls upon the assistance of external problem-solvers and integrates them into the innovation process. As a result, developers use the outside world to enhance their potential for innovation. In this way, companies acquire expertise and solutions without huge expenditures. This applies to B2B as well as to consumer products. Companies use OI to ensure that their products meet the needs of customers, thereby lowering the risk of flops. They specifically ask what customers want, or they might even actively include them in the development of a product — for instance with traditional idea competitions.

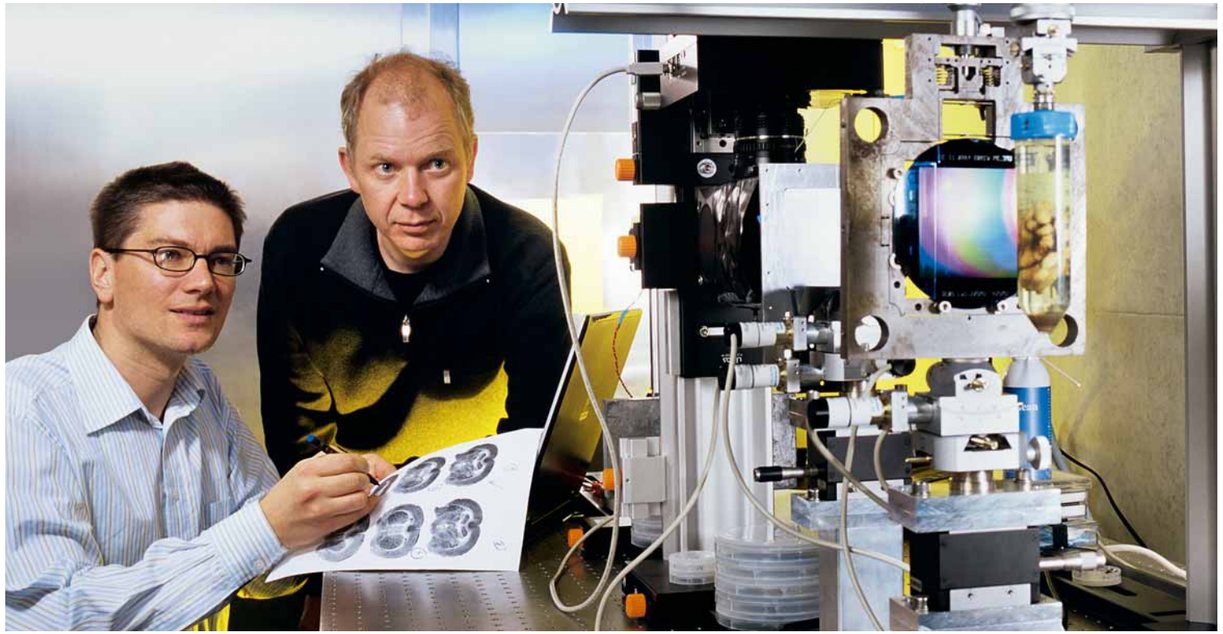
Doesn't OI endanger the intellectual property rights of the developer?
Piller: OI operates within the existing patenting process as long as the rules of the procedure are properly defined, such as with non-disclosure agreements or waivers of rights. But companies aren't the only ones to have these concerns. Today most amateur inventors are glad to be actively involved in the development of a product, in exchange for waiving rights. But over time, they will become more assertive, and a company will then have to allow them to enjoy a share in the success of a product.

Who practices open innovation?
Piller: Often it's companies that lack a large corporation's development capacity. But big companies have discovered OI too. Hewlett Packard (HP), for example, runs its own OI platform on the web — the "Idea Lab." With its "Emotionalize your Light" idea competition, Osram generated new design ideas for lamps and created a best practice in Germany. But even if used internally, OI can represent a great opportunity, especially for companies that operate worldwide and have lots of in-house expertise — like Siemens. In this case there aren't any problems with confidentiality or patents because everything stays within the company. Researchers from a wide variety of departments who might otherwise never meet can use OI to pool their knowledge and quite easily create synergy effects. At present, only a few companies are making use of this OI potential in a systematic way.

Can OI replace the traditional in-house approach to development?
Piller: No, OI will complement the traditional approach by offering very efficient development alternatives. It will probably take several years before it becomes firmly embedded in innovation processes. It's the same as with many new approaches to management — they're discussed with great enthusiasm and then not implemented on a broad basis for five or ten years.

■ *Interview by Sebastian Webel*

Franz Pfeiffer (left, above) uses a new radiography technique to create images with greater detail than conventional X-ray systems allow — as the photos of a fish and a Kinder surprise egg show (right).



Soft Tissues Revealed

They're used every day in hospitals, but X-ray images don't really offer the kind of detail needed to determine the size and structure of a tumor. With a new technique called "phase-contrast X-ray imaging," however, this may be about to change.

An experienced radiographer can read much more from the gray tones of an X-ray image than can a lay person. But it can be difficult for even a trained eye to determine the exact size and structure of a tumor. This information, however, is vital for selecting the right treatment. In a joint project established in 2008 with the support of Germany's Federal Ministry of Education and Research (BMBF), researchers from Siemens, the University of Erlangen-Nürnberg, the Institute of Technology in Karlsruhe, and the Technical University of Munich (TUM) are now investigating a promising new imaging method known as "phase-contrast X-ray imaging."

Unlike conventional radiography, which is based on the absorption of X-rays, this technique could reveal various types of soft tissue such as muscles and tendons, all in high contrast. Conventional radiography exploits the fact that bone and tissue absorb X-rays to differing degrees. An X-ray image of the head, for example, will clearly reveal the bones of the skull, which absorb a lot of radiation, but not much of the brain, which shows up as just a uniform patch of gray. With higher soft tissue contrast, however, individual areas can be clearly distinguished, including any tissue abnormalities — such as a tumor. The technique could therefore reveal the size and position of a lesion at an early stage, enabling doctors to determine the right treatment, including the precise dosage of radiation therapy. The same applies to mammograms. Here, too, the new technique could improve the contrast of blurry images of breast tissue.

This improved performance is based on the fact that phase-contrast imaging not only measures X-ray absorption, but also shifts in the phase of the waves. Like visible light, X-rays can be regarded as both particles and waves. Whereas pure absorption-based radiography records whether X-rays penetrate anatomy or not, phase-contrast imaging measures the effect that passing through bodily tissue has on their phase — in other words, how much the (X-ray) waveform is shifted with respect to its original position. The same principle makes air bubbles visible in water, for instance, due to the different refractive indices of the two media. This phase shift is very revealing because it varies depending on the nature of the tissue through which the radiation is refracted. This effect is very small, though, and must be amplified.

However, until recently this was impossible with conventional X-ray systems. The first approaches to this problem emerged over 20 years ago and involved the use of special crystal optics. The method only works with monochromatic radiation, however, like that generated by an expensive synchrotron source. The difference between the radiation produced by this type of particle accelerator and that from a conventional X-ray source is similar to the difference between laser light and an incandescent light bulb. The waves of light emitted by a laser oscillate exactly in time with one another — that is, they are perfectly in phase. In similar fashion, the X-ray light from a synchrotron is almost completely synchronous. By contrast, the X-ray sources used in hospitals produce too much interference, because they radiate a spectrum of wavelengths in all directions. This is why the scientific world declared in 2004 that phase-contrast imaging was impossible with conventional X-ray sources.

But scientists hadn't reckoned with physicist Franz Pfeiffer, Professor of Biomedical Physics at the TUM. Back in 2004, Prof. Pfeiffer was researching at the Paul Scherrer Institute in Switzerland, where he went on to publish his revolutionary findings in 2006. Pfeiffer also used synchrotron radiation for his initial research, but in conjunction with a Talbot-Lau interferometer, a piece of equipment primarily found in atomic physics rather than X-ray physics. His groundbreaking idea was to also use the interferometer with a normal X-ray tube. His first phase-contrast images showed a fish at an unprecedented level of precision.

Pfeiffer's Talbot-Lau interferometer consists of three gratings made of silicon. These look like small plates with slits cut into them at intervals of only a few micrometers. The first grating's slits are filled with gold. It is placed between the X-ray source and the object under examination, and its job is to make the chaotic radiation emitted by the X-ray source as synchronous as possible. The gold absorbs the X-rays, while silicon lets them pass through, resulting in a large number of quasi-coherent X-ray waves. When these waves strike tissue, they alter their phase. The second grating consists purely of silicon. Its job is to recombine the individual partial waves — a process known to specialists as interference.

At the same time, the part of the radiation that passes through the silicon undergoes an additional —and in this instance exactly known — phase shift. This is what makes it possible for the phase information contained in the X-rays to be deciphered by means of the third grating. Like the first grating, the third one consists of silicon and gold. To measure wave intensity, this grating is moved relative to the second grating, and a detector records the signals. The measured values are compared to measurements made without the object. The difference between the two is the phase contrast, and it is visible in the image as levels of gray.

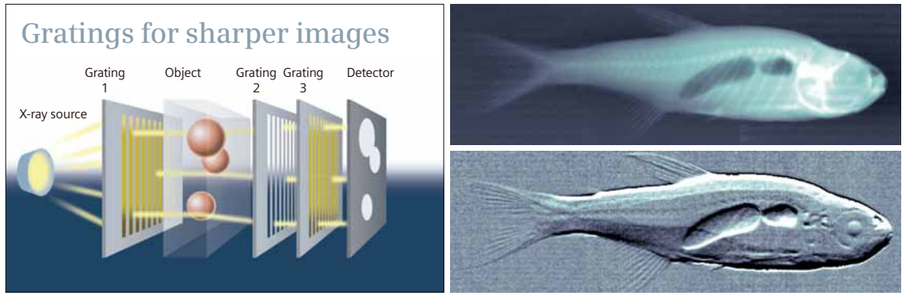
> In 2004, experts declared that phase-contrast imaging was impossible — but Pfeiffer proved them wrong.

In 2006, shortly after Pfeiffer had published his image of a fish, he started working with Siemens. His initial encounter occurred at a trade fair for X-ray systems. Siemens researchers, including Dr. Eckhard Hempel, at that time with the company's Healthcare Sector, immediately recognized the potential of Pfeiffer's development. The remaining partners came on board in 2008, the year the project was launched. "Integrating phase-contrast X-ray imaging in a conventional X-ray system for human diagnostics was a radical idea — and it still is," says Hempel. "But we succeeded in showing that it works. And that's why we won in the BMBF Innovation Competition for the Advancement of Medical Technology."

Low Radiation. The project's goal is an instrument that will seamlessly integrate into everyday hospital procedures. To do that, it must be no larger than a conventional system and must not exceed the time or cost of today's examinations. With this in mind, the Karlsruhe Institute of Technology is enhancing the gratings, and the University of Erlangen-Nürnberg is improving the detectors. Siemens researchers, meanwhile, are working with Pfeiffer's team on integrating the interferometer into an X-ray system. The demands placed on the components pose special challenges. Medical imaging requires the use of high-energy X-rays, so the gratings' slits have to be finer than those in Pfeiffer's system — in this case, no more than 2.5 micrometers across. Similarly, the gaps between the gratings, X-ray source, and detector could be freely modified in Pfeiffer's original setup. In the new system, all these components will have to fit into less space.

The detectors will also have to be adapted to the new specifications. As with a digital camera, the images from the new X-ray system are made up of pixels. The more radiation and the greater the number of pixels, the better the image quality. In the interest of patients, however, radiation dosage must be minimized. Finding the optimal combination here is the job of researchers led by Prof. Gisela Anton of the University of Erlangen-Nürnberg. They aim to improve the detector and the parameters of the grating structure so that the best image can be achieved with the least possible radiation exposure.

The project is scheduled for completion in 2012, but that won't be the end of the research. Unlike absorption radiography, which can draw on many years of experience, the field of phase-contrast X-ray imaging is largely unexplored. "That's what's so fascinating," says Anton. "There's so much to investigate." For her and the other scientists, the biggest motivation is knowing the benefit that this new technique will bring to doctors and patients alike. For as soon as phase-contrast imaging works in clinical practice — and none of the partners sees any reason to doubt this — it will likely open up a host of new diagnostic possibilities. ■ *Helen Sedlmeier*



There's still a long road ahead before electric cars like the eRuf Stormster (below) can recharge on wind-generated electricity. Siemens and Danish company Lithium Balance are helping the vision become a reality (right).

All Charged Up

Major cooperative projects are paving the way for the launch of electric vehicles. Experts from industry and universities are creating the technological basis for linking vehicles to the power grid. In fact, field tests are now under way, especially in Denmark and Germany. One key objective is to use electric cars as energy storage units that can compensate for fluctuations in wind power.

As recently as five years ago, the idea that hundreds of thousands of electric cars could be on the road in Europe by 2020 was considered a futuristic scenario. Hardly anyone believed that the idea of driving with electricity could be implemented so quickly, and on such a grand scale. Times have changed, however, and work on readying electric cars for everyday use is proceeding at full speed. At the same time, some components of their energy source — the power grid — are being completely redefined (see *Pictures of the Future,* Fall 2009, p. 44). Two European regions in particular are leading the way to the future of electric mobility — Denmark and Germany's Harz region in the country's middle. Both already obtain a large portion of their electricity from renewable sources, especially wind. In Denmark, the figure is 20 percent; in the Harz, wind, biogas and solar facilities cover 50 percent of energy needs. As a result, both regions often face the same problem: too much wind energy.

When strong wind causes turbines to really get moving, they can actually meet more than 100 percent of each region's electricity demand. To prevent the grid from overloading, wind facilities in Harz are shut down — much to the annoyance of their operators. Danish energy suppliers, however, are legally required to use the excess wind power, which they pass on to their European neighbors. What's more, they have to pay transmission fees for the privilege. And the problem could get worse, since the share of electricity generated by wind power is increasing in both the Harz and Denmark. The latter hopes to have around 50 percent of its average electricity demand covered by wind by 2025.

Electric vehicles could help solve the problem by acting as a virtual surplus electricity storage system. Specifically, thousands of electric cars would recharge their batteries when winds are strong, primarily at night. Conversely, during periods of calm, they could resupply the grid at higher prices. It's a great idea — but can it work? For example, how can electric cars and the power grid communicate reliably? How can vehicles be recharged quickly and safely? And how is everyone to be billed? Two major cooperative projects in Denmark and the Harz are seeking answers to these questions with the help of Siemens experts.

One project is headquartered at the Risø research center at the Technical University of Denmark (DTU), not far from the famous Viking Ship Museum in Roskilde. The center houses wind turbines, solar photovoltaic systems, a transformer station, and a vanadium-ion liquid battery the size of a shipping container. Here, the energy consumers are electric heating units in the center's office buildings, hybrid cars, and several small batteries that simulate additional vehicles. The research center thus has a miniature power grid that can be used to test the interaction between various components.

Risø is home to Denmark's EDISON ("Electrical vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks) project, the world's first major effort for bringing a pool of vehicles to power outlets. Practical testing will begin in 2011 on the island of Bornholm. "We're focusing mostly on the question of how electric vehicles can be charged quickly, safely, and efficiently," says Sven Holthusen, who is responsible for the EDISON project at Siemens' Energy Sector. Holthusen and his colleagues analyze, for example, how a vehicle can be recharged at different types of charging stations or how a large number of batteries can be recharged simultaneously.

Holthusen knows that electric cars will become truly attractive to consumers only when they can travel long distances and be recharged within a few minutes. Electric cars these days are normally charged at an 11 kilowatt (kW) outlet. A typical battery with a 25-kilowatt-hour (kWh) storage capacity thus takes more than two hours to fully recharge. Increasing the charging power would lower the charging time. That's why Holthusen's team of researchers is developing 120 kW technology, which reduces the charging time to just a few minutes. However, with charging currents of up to 300 amperes and 400 volts of alternating current (a.c.), the load is equivalent to powering nearly 20 households.

"Heat generation during recharging with a.c. is one of the biggest challenges at the moment," explains Holthusen, who is testing charge controllers that would be installed in vehicles as well as those that would be part of charging stations. Onboard controllers offer the benefit of not having to be integrated into the power pump, which reduces infrastructure costs. Such controllers also ensure that each vehicle optimally controls the charging process in line with its battery's requirements. External controllers, on the other hand, are better at dissipating heat, thus enabling higher charging currents.

> Siemens researchers are working on a 120 kW system for recharging electric vehicles in just a few minutes.

No one knows which charging technology will gain the upper hand. That's why Siemens is developing different technologies in parallel in its Inside Car and Outside Car electric mobility teams. The teams develop and test components for vehicles and grid technologies. Holthusen is also looking at direct current (DC), since it allows batteries to be charged without a controller. "However, DC is more dangerous, mainly because of the arcing that occurs in the event of a short circuit. Commonly used AC fuses cannot be used for protection in such a situation." Holthusen is thus working on new, safe approaches for DC supply.

Along with the DTU and Siemens, EDISON project partners include IBM, which is developing the software infrastructure for linking decentralized components, the Eurisco development firm, and energy suppliers Dong Energy and Østkraft. The latter are mainly interested in practical solutions for feeding wind power into the net; Østkraft is also organizing a field test on Bornholm. With wind energy continuing to expand worldwide, Holthusen and his colleagues believe all the technologies they're working on have good chances of market success. In the Outside Car area alone, they estimate that global demand for electronic components capable of expanding the power grid and charging infrastructure will total over ten billion euros by 2020.

The German government is funding the expansion of electric mobility in eight regions. In Munich, Siemens is participating in a pilot project with BMW and the local municipal utility (SWM). Here, BMW plans to expand its trial fleet of "Mini-E" electric vehicles to at least 40, Siemens is providing technology for the next-generation charging infrastructure — including fast charging — and SWM is supplying "green" electricity. Siemens has also launched a project in Berlin in which electric vehicles are being used on a daily basis as company cars. The project includes six electric smart models provided by Daimler, which can "fill up" at 20 charging stations at the main Siemens locations in Berlin. Siemens has its own medium and low-voltage network here, which can charge or discharge the cars.

Fast Charging. The Harz.EE-Mobility project has 15 partners. They include several research institutes and universities, public utilities, pow-

er grid operator E.ON Avacon, Deutsche Bahn, Siemens, and mobile radio company Vodafone. Together, these partners are paving the way for future electric mobility in the Harz region. The project seeks to identify ways of making recharging convenient, intelligent, and reliable. The partners have already installed the first power pumps not only in the Harz but also in Copenhagen, Denmark, where vehicles from the EDISON project also recharge. EDISON and Harz.EE-Mobility thus complement one another and share results. Whereas the EDISON partners focus mainly on power electronics and fast charging technology, the Harz project is concentrating on the charging process and vehicle-grid communication.

"The most important thing for users is that charging should be fast and simple," says Dr. Jörg Heuer, who is responsible for the Harz project at Siemens Corporate Technology. Achieving this goal will require automatic communication between the vehicle and power pump. Europe now has a standardized connector that includes not only a charging cable capable of handling up to 44 kW but also a data-exchange channel. The power pump uses a communication protocol to determine when a vehicle is ready for charging. Conversely, the pump tells the vehicle how much charging power it can provide.

An additional communication channel for automated payment or the transfer of other vehicle data can also be activated. "If a large number of vehicles recharge simultaneously in a parking garage, we could have a local overload," says Heuer. "That's why vehicles need to be able to communicate and coordinate their requirements." Siemens is therefore working with many companies — including RWE, EDF, Better Place, BMW, Daimler, Renault, Toyota, Honda, and Ford — on international ISO/IEC standardization of a communication protocol. Such a protocol would make it possible for power pumps and vehicles from all automakers to exchange data via the pump's cable or a wireless link. The protocol is to include a system for multi-stage vehicle authentication, which would prevent misuse and electricity theft. Heuer also serves as a consultant in various standardization bodies.

> Without coordination, the simultaneous recharging of many vehicles could overload local grids.

Vodafone is involved in the Harz.EE-Mobility project because charging at various stations resembles cell phone roaming between different wireless providers. Given that the future billing process might therefore be similar, Vodafone is contributing its experience with movement profiles. After all, it's relatively easy to find out where a cell phone is and where it goes when it's on. "In our project, we want to study the extent to which movement profiles of electric vehicles can reveal information about potential demand for electricity at places like park-and-ride lots or parking garages," says Heuer. "The grid needs to be capable of reacting should demand rapidly increase at any of these locations." In 2010, some 30 Audi A2 models retrofitted as electric vehicles will hit the road in Harz and surrounding regions and cities that are also participating in the project. Project staff will use the cars to act out various scenarios. For example, they will simulate peak demand during simultaneous charging at the Magdeburg railway station parking garage. Deutsche Bahn, which operates car-sharing fleets, is very interested in the results.

Intelligent Grid. "When you include all the wind turbines, biogas and solar energy facilities, small power plants, and cars, our project will link around 2,000 electrical units," says Heuer. "There's never been a project that big before." With the help of communication solutions that align supply and demand, it may even be possible to increase the share of eco-friendly electricity involved to more than 50-percent by adding locally-produced energy from renewable sources. That energy would then no longer have to be exported. "With such a large number of electricity producers and consumers involved, it isn't practical to establish an overriding control center like the traditional ones used in centralized networks and major power plants," says Heuer. In other words, nothing will work without intelligent communication technologies and predictive algorithms. Researchers are particularly interested in how the grid will behave when electric cars link up and disconnect. To this end, project staff are developing mathematical rules that use the principles of probability theory to predict when, where, and how many vehicles will require electricity.

To make recharging easier, the project consortium includes experts in user-friendliness. "Drivers will have to choose between a maximum of only three or four charging modes," Heuer says. In fact, two modes — "Charge at Maximum Speed" and "Charge at Minimum Cost" — might be all that's necessary. Use of the charge pump will be automatically billed via cell phone. Harz.EE-Mobility will reach cruising speed in 2011. That's when the last of the test's electric cars will hit the road to demonstrate that recharging is as easy as filling up today. ■ *Tim Schröder*

At the Risø research center, scientists from the Technical University of Denmark and Siemens are testing how electric cars, power grids, and renewable energy generation systems can operate in harmony.

Dr. Dieter Wegener, CTO of Siemens Industry Solutions (left), and experts at the Danish Technical University discuss how endocrine disruptors in water can be neutralized.

Taking Aim at Pollutants

Before long, oxidation systems will be used to destroy pesticides, hormones, and antibiotics in drinking water. To this end, Siemens experts are developing efficient, energy-saving solutions in collaboration with researchers at the DTU in Copenhagen.

No one really knows how dangerous they are. They flow with waste water out of plastics factories, or pass into sewage pipes when toilets are flushed. The intractable chemicals in question even survive bacteria in sewage treatment plants. They are called "endocrine disruptors," and these long-lived compounds are suspected of having an effect on the hormonal systems of humans. They include plant pesticides, active agents in birth control pills, and chemicals from the synthetic resins industry. Some of them can cause cancer, while others are believed to cause male fish to turn into female fish.

Because they cannot be destroyed with conventional biological sewage treatment technology, they accumulate in the environment. To get rid of them, heavier weaponry is needed: hydrogen peroxide or ozone, for example, which form aggressive radicals and thereby decompose the contaminant molecules into harmless constituents. There are currently only a few reference systems on the market that are designed to attack endocrine disruptors with oxygen.

The technology that decomposes these molecules is called "Advanced Oxidation Process" (AOP). It uses ultraviolet lamps for radical formation. Although contaminants are effectively decomposed, the process uses a great deal of power. In addition, elaborate post-treatment steps with activated carbon are required to remove extra chemicals and by-products.

Experts from Siemens Water Technologies in Günzburg, Germany, are now developing a much more efficient and economical system. To achieve their goals, they are working with specialists at the Technical University of Denmark (DTU) in Copenhagen. Chemist Henrik Rasmus Andersen's team has been researching AOP units for years and has developed first-rate analytical procedures for detecting mere micrograms of endocrine disruptors or antibiotics in water. The team is now working with Siemens on a new reaction chamber that will be more efficient than comparable systems. Because radicals are extremely short-lived, the flows in the system — the fluid dynamics — have a considerable influence on the cleansing effect of the chamber. The geometry of the chamber must therefore be designed accordingly. Ultimately, the objective is to optimize the system as a whole, so that the best result can be achieved while using only small amounts of chemicals and energy.

Reliable Partners. It is no coincidence that the Germans and the Danes have chosen to work together on this project. The DTU is one of eight outstanding international universities with which Siemens maintains close research partnerships. Several years ago, Siemens set up a CKI program (Center of Knowledge Interchange) to foster such relationships, which are based on a common framework agreement with the universities in question (p. 86). The DTU, which has been a leader in the development of environmental technology for many years, has been a CKI university since 2006.

"With the CKI program, we try to achieve loyal, long-term cooperation giving rise to many individual joint research projects," says Dr. Dieter Wegener, chief technology officer of Siemens Industry Solutions. For a long time, companies in the industrial sector were cautious when it came to working with external partners; they were worried about the effects of transferring knowledge to outsiders. Siemens has liberated itself from this fear. "If you want to make big advances in development and you're aiming for radical innovations, you have to rely on the expertise of universities," says Wegener. In addition to technical expertise, another key to success is personal rapport. This can be cultivated in the CKIs, which are designed to last many years.

"First, we met with experts at Siemens to discuss which fields of technology we can best cooperate in," says Henrik Søndergaard from the DTU, who oversees the cooperative projects at the university as CKI manager. "That resulted in projects like AOP systems technology,

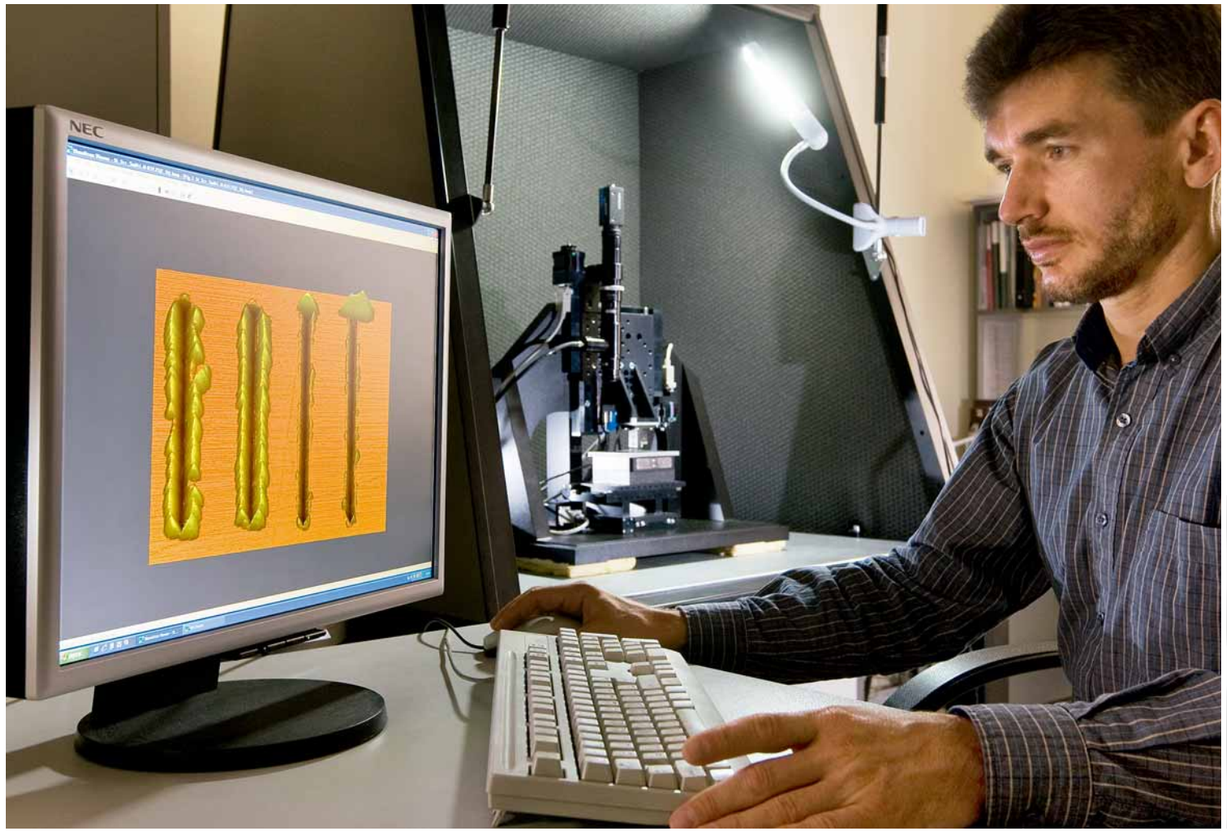
and the EDISON project, which is studying how electric cars can interact with the power grid" (p. 92). In another example, experts from Industry Solutions and Siemens Corporate Technology have worked with the DTU and Berlin's Technical University to develop the "Eco Care Matrix" — a new assessment methodology that identifies the economic and ecological value of green products and solutions.

For water technology experts at Siemens, the CKI partnerships have many benefits. "We can fall back on experts that we don't have inside the company," says Klaus Andre, a research director in Günzburg. "We also meet young scientists who could work for Siemens after their studies." With regard to AOP development, one shouldn't forget that DTU has expensive analytical equipment, such as mass spectrometers. "Endocrine disruptors have been the subject of detailed study for about ten years — particularly since the technology became available to detect these substances relatively quickly and easily," says Andre's colleague Cosima Sichel, a process engineer.

The U.S. — especially California — Germany and the EU are promising markets for AOP technology, because awareness of the issue is already widespread. "Hormones and antibiotics are mostly expelled by human beings and end up in the water," says Sichel. In the case of antibiotics, it is thought that they can lead to the development of resistant infectious germs. And hormonally-active substances are consumed by human beings in drinking water. At present, ecotoxicologists do not yet know exactly what effects that may have. Prudence would therefore dictate that endocrine disruptors should be removed from drinking water.

The AOP system that is currently being developed with the DTU for market launch within three years is expected to solve this dilemma. It is suitable for drinking water purification at water works. In the chemical and pharmaceutical industry, it can process contaminated effluents before they are discharged into the primary waste water stream. And in the microelectronics industry, it can produce ultra-pure water to clean sensitive components.

Systems of different sizes will be used, depending on the application. A simple system for drinking water purification will supply about 200 cubic meters of water per hour. It is still difficult to estimate the size of the future market, says Andre. "The AOP systems will be used on a large scale as soon as they are mandated by law." There are few such regulations in effect now, Andre adds. But the potential is huge. In Germany alone, there are around 10,000 sewage treatment plants and over 6,000 water supply companies. *Tim Schröder*



CT Russia's cooperative projects with universities set the tone for innovations, such as development of a nanostructured bismuth telluride coating for frictionless bearings.

Siemens researchers are working with partners in Russia to develop new technologies. On tap are nanoparticles in an aluminum metal matrix that improve the hardness and strength of alloys, refinements in thermoelectric components that hold the promise of generating electricity from waste heat, and software that learns as it monitors production.

Building Networks of Innovative Ideas

The city of Troitsk near Moscow has an exciting past. It was one of the science centers whose existence the Soviet Union wanted to conceal. The research conducted here in nuclear engineering and materials research was top-notch. The city's Technological Institute for Superhard and Novel Carbon Materials (TISNCM) has since attained official status. It continues to be a world leader — but today it is part of a worldwide network that also includes Siemens.

One of the most important areas of research in Troitsk is the development of materials that are expected to make power generation and transmission more efficient. "Materials research in nanotechnology is very attractive from a financial point of view," says Professor Vladimir Blank, head of the TISNCM. "For example, we are incorporating carbon nanoparticles in an aluminum-metal matrix to improve the hardness and strength of alloys while retaining their very good electrical and thermal properties."

One to one-and-a-half percent by weight of fullerenes, as these new particles are known, is enough to obtain the material properties that Blank is seeking. Fullerenes are molecules that contain 60 carbon atoms (C_{60}) and resemble soccer balls. What makes them so suitable for novel materials is their high mechanical strength at a low weight.

"The new nanostructured aluminum composites are almost three times as hard as normal composites but substantially lighter in weight," says Siemens Corporate Technology (CT) project manager Dr. Denis Saraev. This supermetal composite is particularly well suited for enhancing the performance of compressors, turbochargers, and motors.

Power cables made of nanostructured aluminum composites could one day replace cables made of pure aluminum. The new cables would have the same electrical properties while being thinner, thus saving material and costs, in particular when compared to expensive copper cables. TISNCM researchers produce the new material using a specially hardened planetary mill. Aluminum and C_{60} are milled in an argon atmosphere to the size of nanoparticles, with the powders combining during the process to form the new material. Blank expects that the development of aluminum material with fullerenes specifically for use in superconducting cables will soon be completed. Such cables could provide benefits in magnetic resonance imaging systems and compact motors, for example.

In a nearby lab, Siemens and TISNCM researchers are working on the refinement of materials, but this time the subject is so-called thermoelectric components. These are electrically conductive substances that can either generate an electric voltage and from that an electric current when a temperature difference is established at two locations, or generate thermal energy when a voltage is applied. The scientists have combined the thermoelectric reference material bismuth telluride with fullerenes. "We think that we will be able to generate a power output of about 50 watts from a 10 cm x 10 cm thermoelectric device with a temperature difference of 100 degrees Celsius," says Saraev.

Such a development would enable many types of devices to generate electricity from their waste heat, thus substantially reducing their energy costs. For example, thermoelectric power generators could use not only the waste heat from gas turbines or steel mills, but also from the processors in computers or automobile engines and batteries — the latter could, for example, supply power for cooling and for information, navigation, and entertainment electronics. Devices equipped with this technology could also help to reduce the use of gases in refrigerators and freezers that are harmful to the climate — and quite incidentally to also reduce associated noise, because the technology is silent. The researchers have already reached a key milestone. "We have improved the thermoelectric 'goodness factor' by 20 percent with our nanostructured bismuth telluride," says Saraev, "and that is currently tops worldwide."

A Cushion of Air. Meanwhile in Moscow, about 30 kilometers away, Siemens is involved in another partnership. There, a CT team headed by Dr. Viacheslav Schuchkin is working with Dr. Alexander Vikulov from the Institute of Mechanics at Lomonosov Moscow State University on turbomachines mounted on air bearings that can replace conventional high-maintenance oil bearings in small turbines and compressors. Turbomachines rotating at speeds of up to 180,000 revolutions per minute can be used for such things as gasoline or diesel engines or in the oil industry for the treatment of wastewater with compressed air.

To produce maintenance-free bearings, the researchers designed extremely thin Teflon-coated lamellae. "At roughly 15,000 revolutions per minute, the lamellae reach the speed at which they lift off from the rotor's axle by

several thousandths of a millimeter," says Schuchkin. "An extremely thin cushion of air forms between the bearing and the lamellae, thus allowing the turbine to run with essentially zero resistance. At that point it is maintenance-free." In order to accomplish this, the researchers had to compute not only the optimal lamella size, but also the best angle of deflection and the ideal arrangement of the lamellae. In the future, it should be possible to apply this development to larger turbines as well.

Siemens Corporate Technology Russia is also active in the field of integrated gasification combined cycle (IGCC) power plants (see p. 109). For instance, a team of CT researchers headed by Dr. Stepan Polikhov is hoping to use a new turbine technology to increase the efficiency of IGCC plants with carbon capture from today's 30 percent to between 40 and 45 percent. Researchers at the Moscow Engineering Physics Institute (MEPhI) are providing substantial support. Synthesis gas — a mixture of carbon monoxide and hydrogen — is used as the fuel.

"The goal is to reduce carbon dioxide emissions of such turbines burning a gas mixture to the level of power plants fired with natural gas, while reducing the costs of CO_2 capture," says Polikhov. Coal-fired power plants equipped with this technology would then be as clean as natural gas-fired power plants. The technical challenges are substantial, however. Synthesis gas contains large amounts of hydrogen, which causes flashback, flickering, or spontaneous ignition, all of which make it more difficult to achieve combustion that is as complete as possible and thus environmentally friendly. To address this problem, Polikhov and Professor Sergey Gubin from the MEPhI are working on a simulation of the gas turbine combustion process that incorporates critical parameters such as gas flow rates, gas mixture ratios, combustion chamber pressures, and combustion speed. Such simulations allow researchers to derive a burner design that is optimized for a specific gas mixture. Successful tests of a mixed-gas burner in a real combustion chamber have already been carried out.

Researchers are developing technologies designed to boost the efficiency of IGCC power plants by about 15%.

Intelligent Operating System. Siemens maintains successful research partnerships with Russian institutions in St. Petersburg as well as in Moscow. At the St. Petersburg State Polytechnical University, CT researcher Bernhard Lang is working with Professor Dimitrii Arseniev and Professor Vyacheslav Potekhin — both specialists in distributed intelligent systems — to develop new software solutions. The goal of this collaboration is to develop self-managing learning software that monitors the operation of production plants. The software is being designed to automatically recognize and report failures before they occur. It should also monitor the quality of each production step, continuously checking against data provided by a planning system to ensure that production is always in line with orders, the supply chain and current market prices.

All available data are input once into the learning system. For a metals plant, for example, this would comprise data on hundreds of production parameters such as temperature, pressure, quantity, and material composition, as well as the optimal combination of these data. The system not only autonomously monitors production and detects impending faults, but can intervene to prevent them.

Learning systems can be universally deployed. They have been in use since 2008 to monitor the gearboxes of Siemens wind power plants and the level of St. Petersburg's Neva River. Such systems can be used to provide continuous tracking of river levels and early warning in the event of danger.

An example is the "Urban Flood" project, an international research study funded by the European Commission to increase the reliability of forecasts and further improve the monitoring of rivers and lakes so that we can increase people's security even during periods of extended, heavy rains," explains Corporate Technology's Lang. The study will examine annual precipitation and wind over the Gulf of Finland with a view to providing early warning. Intelligent warning systems will also be used to protect London and Amsterdam.

"Since the establishment of Siemens Corporate Technology in Russia in 2005, collaboration between Siemens and top Russian universities has had many successes," says Dr. Martin Gitsels, head of CT Russia. "They range from solutions for shortening development times for gas-insulated high-voltage switches to smart software for monitoring wind turbines. I am convinced that the skills of our Russian partners will enable us to soon develop additional innovations in areas such as coal gasification, high-speed turbines, and the integrated factory." *Harald Hassenmüller*

Andrey Bartenev (center) shows Martin Gitsels, head of CT Russia, experiments with a gas burner (left). Researchers are also working on maintenance-free bearings and fault analysis software.

Open Innovation as a Success Factor

For years, companies have been working closely with external partners. For example, through joint projects with universities, they gain access to the latest findings from pure and applied research, which can be used by their internal research and development organizations. Open Innovation (OI), however, goes one step further and integrates external problem-solvers into the innovation process – a methodology that is also taking place at Siemens (p. 86). In this case, a company's R&D department is no longer its only source of innovation; customers, suppliers, other companies, and online communities also play a part in the development process.

As global competition intensifies, development and product cycles become shorter and shorter, thus driving up the risks of innovation and thereby the associated costs. One of the prime objectives of OI is thus to cut the time it takes to introduce new products and services — and to thoroughly canvass customer opinion in order to slash the number of products that flop.

IBM and consumer goods corporation Procter & Gamble (P&G) were among the first enterprises to open their innovation processes several years ago. P&G, for example, operates its own "Connect + Develop" website, where customers can submit ideas and help to solve concrete problems. This process led to the creation of the "Swiffer" duster, for example. In 2004, 35 percent of new products from P&G resulted from external sources. The company's aim is to increase this figure to 50 percent. By 2006, productivity at R&D had improved by around 60 percent and the product success rate had doubled. At the same time, investment in R&D had fallen from 5.8 to 3.4 percent of sales.

Alongside its managers, researchers, and development engineers, a company's most important source of ideas is its own customers. This is the finding of a study conducted by Grant Thornton International. Almost half of all respondents in the Asia Pacific region said customers were an important source of innovation, compared to 40 percent in Western Europe, and 35 percent in the U.S. Moreover, a significant proportion of respondents worldwide identified open innovation as successful and a strategy that they will continue to adopt. At 35 percent, agreement with this claim was highest in Western Europe, compared to 30 percent in North America, the original home of open innovation.

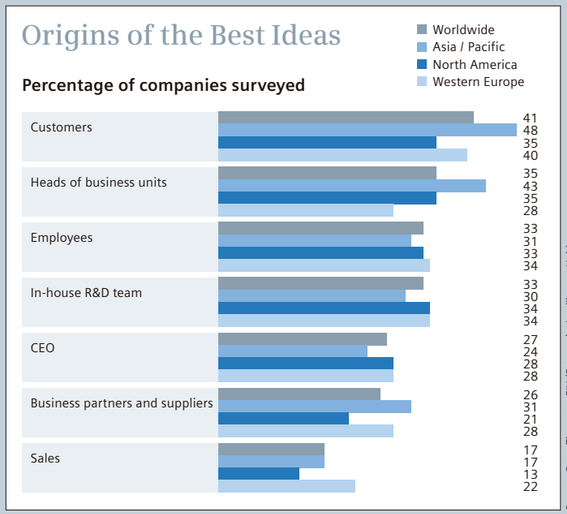
One OI pioneer, U.S. company Threadless, develops all of its products on the basis of customer suggestions. In fact, the Threadless community generates around 1,000 ideas a week. If a T-shirt design is actually printed, the creator of the design receives $2,000. And if an Internet survey demonstrates that a T-shirt is particularly popular, its designer can earn up to $20,000.

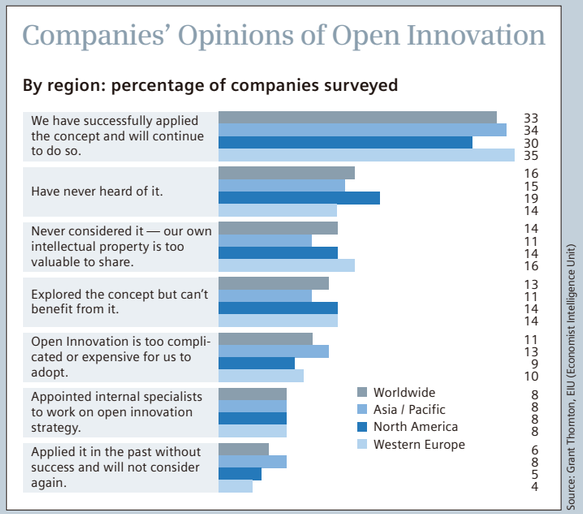
Another type of OI is to commission an external service provider. Such companies have built up a global network of experts and can command substantial fees of anything up to $1 million for taking on a specific research problem.

A prime example of this is the U.S. open innovation company InnoCentive and its online platform InnoCentive Challenge. The company was launched in 2001 and now mobilizes over 180,000 challenge-solvers worldwide. To date, this community has been able to solve 400 of the some 900 challenges posed by 150 companies around the world. Forrester Research investigated the financial impact of this technique in a study based on SCA, a Swedish hygiene group. According to its findings, queries to the expert InnoCentive network generated average yields of 74 percent and paid back the initial investment in under three months.

Nevertheless, a lot of companies are still uneasy with OI when it comes to intellectual property rights. The 550 experts surveyed in the international Delphi Study 2030 ("The Future Prospects and Viability of Information and Communication Technology and the Media") identify an inadequate culture of innovation and data-protection issues as the biggest hurdles to OI in the corporate world. At the same time, the majority of respondents said that OI as a new R&D paradigm would greatly increase in significance by 2024 at the latest and enhance the efficiency of innovation processes.

Nikola Wohllaib





Ahmed Shuja (above) and Praveen Medis (center) have developed the world's brightest LED source (left). Rated at 15,000 lumens, it not only outshines metal halide lamps, but uses 60 percent less energy.

From Concepts to Companies

Siemens' Technology-to-Business Centers are providing support to a range of young companies. On tap are energy-stingy LEDs capable of outshining metal halide lamps, PV panels that use one tenth the silicon of conventional models, battery-powered vehicle detection systems that last ten years, and an ultra-efficient transmission.

Light emitting diodes (LEDs) have a reputation for running cool. Touch one and all you'll feel is a serene glow. But just try and pack dozens of them together in a tight space and they'll get so hot that they can burn out within seconds. Now, however, Progressive Cooling, a startup company funded by Siemens' Berkeley, California-based Technology-to-Business Center (TTB), has developed a solution that makes it possible to pack over 80 of the brightest white LEDs onto a one-square-inch circuit board. The result: A light source significantly brighter yet far more energy efficient than the metal halide or sodium lamps now used to light factories, warehouses, streets and airport runways. "In the U.S. alone there are about 100 million so-called 'high-bay' fixtures in commercial buildings and about 60 million bulb changes per year," explains Progressive Cooling CTO and founder Dr. Ahmed Shuja.

The technology that allows tightly-packed LEDs to keep their cool is a patented micro thermal management engine that contains some 60 million vertically-etched uniform pores per square centimeter on a flat silicon substrate. The technology allows capillary force to efficiently channel heat away from diodes and into a halo of fins that surround Progressive Cooling's light source.

Originally developed at the University of Cincinnati to reduce the cooling requirements for microchips on miniature satellites and subsequently adapted to server farms (see *Pictures of the Future* Spring 2008, page 22), Progressive Cooling's concept has been "re-vectored to the LED market to take advantage of the fact that a totally integrated LED fixture will have significant competitive advantage in the commercial illumination market over traditional metal halide bulbs," says Shuja.

Based on Osram's newest Oslon LED, which can be driven to produce up to 200 lumens, Progressive Cooling's new device delivers some 15,000 lumens over an 80-degree angle from a height of 18 to 30 feet, resulting in an ideal 30 foot candles on the work surface. "To put that in perspective," says Progressive Cooling Senior Scientist Dr. Praveen Medis, "a 100-Watt incandescent bulb typically produces 1,200 lumens. So what we are saying is that we have packed the equivalent of twelve100-watt bulbs into a flat one-square-inch device, making it the brightest LED source in the world."

In addition, the device cuts energy demand by 60 percent compared to conventional metal halide lamps, and, thanks to the fact that it can be addressed wirelessly and dimmed from zero to 100 percent, its power demand can be reduced by an additional 20 to 25 percent in response to changing lighting requirements.

Reduced maintenance costs are another major advantage. While metal halide lights typically last 12 to 18 months, Progressive Cooling's device is rated to last five years and has been designed to screw into an existing mount. "That's a key feature," says Shuja, "because changing high-bay lights at a height of 18 feet requires a scissor jack and two experienced workers." Plans call for Progressive Cooling to begin seeding the market with its mercury-free LED product this year.

Banyan: Focus on the Sun. Probably the biggest barrier facing widespread implementation of photovoltaic energy is the high cost of silicon panels. With this in mind, five former graduate students of the University of California at Berkeley and Stanford University have formed Banyan Energy, a company whose patented technology and proprietary intellectual property promise to reduce the area of silicon photovoltaic material in a standard module by 90 percent while producing the same amount of power as a conventional module. What's more, the inventors calculate that the cost of production facilities for such modules will be 75 percent lower than for today's facilities.

Funded by an investor group led by Siemens, the company has been selected by the U.S. Department of Energy for a technology development subcontract and is already working with the U.S. National Renewable Energy Laboratory. "Siemens TTB not only invested in us from the start," says Banyan CEO Shondip Ghosh, "they really drove the process and did the due diligence." Adds Ayman Fawaz, PhD, Director of Venture Technology at TTB Berkeley, "We are helping Banyan demonstrate that their technology is viable. The next step will be to see if Siemens' solar organization will adopt the technology." Simply put, Banyan's concept is to replace expensive silicon cell material with economical optics. Ghosh explains that while many other companies have attempted to adapt clumsy magnification systems to PV panels, Banyan's "aggregated total internal reflection" concept uses a sheet of optical elements that is only 1 cm thick.

"The energy falling on the optics is aggregated and delivered to a focal area, which is where the photovoltaic material is located. The key is that the collection process is performed by the optical layer rather than by the silicon cells," says Ghosh.

> The brightest LED source worldwide, the device packs the equivalent of twelve 100-watt bulbs on one square inch.

Since the technology can be integrated into the standard dimensions of current PV panels, it offers numerous downstream advantages, including identical shipping, handling, installation, and cleaning requirements. But perhaps its greatest advantage is that it reduces the capital expenditure of manufacturing the panels themselves. Today, such panels are covered with silicon wafers. The wafers are sliced from ingots and then processed and mounted. "To build a conventional fabrication facility with a

Banyan CEO Shondip Gosh measures the efficiency (left) and response to different angles (right) of an optically-based photovoltaic module in a device that duplicates sunlight.

gigawatt worth of annual production capacity, you would have to spend about $1.2 billion," says Ghosh. "But with our system you can shrink your plant size for the ingot, wafer and cell steps by a factor of ten. As a result, a gigawatt facility would now cost only about $300 million. So we can significantly reduce the capex for manufacturing, which means that for every dollar such a company invests, they can build four times the production capacity as they otherwise would."

Banyan is particularly interested in entering the market for large field installations that are designed for tracking the sun – an application that maximizes the yield from its unique optics. "Installations that track the sun produce about 25 percent more energy than static installations," says Ghosh. "This more than offsets the added cost of tracking systems. What's more," he adds, "the growth rate in large field installations is twice the rate of the rest of industry." The world market for solar panels is now at five gigawatts per year and rising rapidly.

Sensys: A Startup Hits the Road Running. Two of the hard facts of modern life are that traffic congestion is rising but road capacity is not. In order to make the best of this situation, Sensys, a mature startup with close ties to Siemens, which is headquartered in Berkeley, California, has developed a unique magnetic sensor technology that helps road authorities continuously and reliably detect traffic levels in real time.

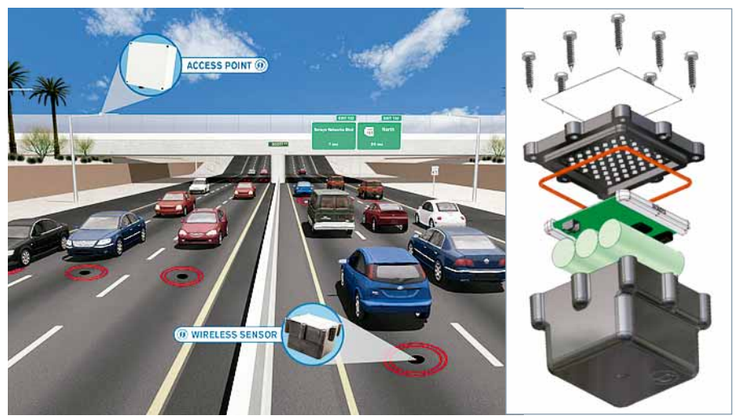
At the heart of the company's sensor is the ability to extend the lifespan of three AA batteries to ten years. "That is essential, because once the device is in the pavement, it is difficult to access," explains CEO Amine Haoui, PhD. Adds Sensys Vice President for Marketing Floyd Williams, "In terms of low power sensing and battery life, I don't think there is another application anywhere that comes close to what we have achieved."

The key to such extended battery life is, in principle, disarmingly straightforward. Most of the sensor circuitry is technically asleep 99 percent of the time. But each time a vehicle passes, thus disturbing the earth's magnetic field, the sensor wakes up, wirelessly transmits a packet of information to an access device, and goes back to sleep. Two sensors are embedded in each lane, and over eight sensor-equipped lanes can communicate with the same access point. Typically mounted on a lighting mast, the access device, which includes a mini Linux computer outfitted with a radio receiver and transmitter, relays speed, traffic volume and density information via the Internet or Ethernet to a centralized location. The data can be used by highway authorities to optimize roadway planning and performance through signal optimization, ramp metering or road pricing. In the near future it may also be used to provide real-time information for maps and automotive navigation systems.

Unlike inductive loops that are stretched across roads, either on the surface or in the pavement and which are prone to break at the weakest point in a line, Sensys wireless sensors are point devices that are buried beneath the road surface, are weatherproof, sterile, and maintenance free.

In view of the fact that Sensys vehicle detection systems are very cost effective when compared with inductive loops, governments around the world are installing the systems. Caltrans, the California Department of Transportation, has deployed 800 Sensys traffic monitoring stations on California freeways. And in Melbourne, Australia, a 75-km stretch of freeway has been equipped with groups of the sensors at 500-meter intervals. The sensors are used to control ramp meters and lane speed gantries. "The local transportation authority has shown that the system reduces the number of accidents, increases safety and improves freeway throughput by about 30 percent. So it is a dramatic improvement, especially when you consider the total cost of a multi-lane freeway," says Haoui.

Siemens, which provided Sensys' first source of finance through the TTB, is now integrating the company's wireless sensor with its family of traffic light controllers. The first such combined controller-sensor system is now being installed in Minneapolis, Minnesota. "This will be a very advanced adaptive signal system that will use an algorithm called SCOOT to optimize traffic performance around the city's new stadium," says Haoui. "With SCOOT, our sensors collect data at each intersection and feed it to a Siemens centralized system that creates a web of optimized traffic lights. If a city were to replace all its traditional time-of-day signal timing with such a system, it could expect a 20 to 30 percent improvement in traffic flow efficiency and a corresponding reduction in vehicle-caused emissions."

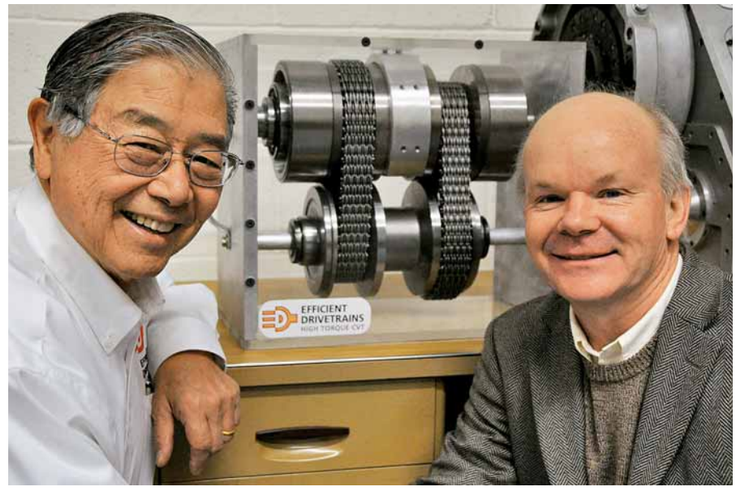


Thanks to an advanced sleep mode, Sensys traffic detection devices work for ten years on three AA batteries.

EDI: More Power for Hybrid Vehicles. Prof. Andy Frank's laboratory in Dixon, California looks a lot like the kind of place you'd take your car for a tune up. But the people who are driving in for service are not looking for spark plugs or an oil change, but rather to get an entire industry on the road. Otherwise known as "the father of the plug-in hybrid electric vehicle" (see *Pictures of the Future*, Spring 2008, page 22) Frank, who is Director of Hybrid Vehicle Research at the University of California-Davis and founder of Efficient Drivetrains, Inc. (EDI), has put together a test vehicle whose fuel economy is 80 percent better than that of a comparable conventional vehicle. It is also capable of operating all-electrically for about 70 km without using any liquid fuel. "As a result," says Frank, "with gasoline priced at roughly $3.00 per gallon and electricity at about 10 cents per kilowatt-hour, a typical user would pay about 75 cents per gallon-equivalent when operating our vehicle electrically."

Behind EDI's results is a continuously variable transmission (CVT) protected by multiple patents that is smaller, lighter, and considerably more efficient – 96 percent – than any other CVT or automatic transmission. Part of the reason for this is that EDI's CVT uses only 60 parts, compared to up to 2000 parts in a conventional 7 to 8 speed transmission; the other is that it is based on a patented chain from a European partner that transfers power with extreme efficiency from the motor (be it electric or conventional) to the rest of the drive train.

"An average automatic or manual transmission will have five to seven speeds," says Frank. "But ours has an infinite number of gearing ratios." He explains that this is particularly important for hybrid vehicles "because electric motors are designed to operate at high torques and speeds. But by adding a transmission, you expand the torque-speed range, meaning that the motor can operate at maximum efficiency across a much wider spectrum of load conditions."



Prof. Andrew Frank (left) and Jörg Ferchau have developed a continuous variable transmission based on a patented chain. Using only 60 parts, the transmission is ideal for electric motors.

Working closely with Siemens' Technology-to-Business Center in Berkeley and with Siemens' Drive Technologies Division, EDI has steadily harmonized its transmission to become an integral part of a drivetrain for hybrid and electric vehicles that can be easily scaled up or down in size depending on a manufacturer's requirements.

"We expect that our collective research will result in a Siemens electric motor and EDI continuous variable transmission that can be sold as one, integrated package," says EDI CEO Joerg Ferchau. "We estimate that our package will cost one third less than a motor and a conventional transmission in hybrids and electric vehicles."

Although applicable to the automotive market, EDI's technology is initially being focused on the needs of the light- medium- and heavy-duty hybrid commercial vehicle market, which includes everything from delivery trucks and airport shuttle vans to hybrid buses and excavators. "Our CVT is rated at 220 kW, which makes it one of the biggest around. But it can easily be scaled up to 1,000 kW," says Frank. ■ *Arthur F. Pease*

TTB China: Affordable LEDs

Most consumers are comfortable with the look and feel of incandescent bulbs, but would like them to consume much less power. Light emitting diodes (LEDs) placed inside a conventionally-shaped bulb could offer a solution. With a view to eventually providing an affordable product along these lines for the vast Chinese market, Siemens' Technology-to-Business Center (TTB) in Shanghai has extended its "outside-in-innovation" strategy to include potential suppliers. Traditionally, outside technologies are spun in to Siemens business units. The new idea is to spin-in external technologies to suppliers. "By doing this, we believe we can overcome any technology gaps while leveraging the cost-innovation strength of local suppliers to accelerate the launch of a Siemens product with the right performance at the right price," explains Shih-Ping Liou, who heads TTB China. Concretely, TTB China is working with Siemens' Osram lighting subsidiary's procurement and R&D organizations to create a consumer LED product in China that can be made for about 25 percent less than Osram's current offering. "To help Osram accomplish this, TTB scrutinized the technology of five short-listed suppliers. Specifically, we looked at the connections between what Siemens wants to achieve and what the short-listed suppliers can offer," says Liou. "We then looked for external technologies and worked with Osram's R&D people in the Asia-Pacific region to come up with new design options to balance performance with cost." The next step, he says, "will be to optimize the new designs and spin the final blueprints to the selected supplier."

Prof. Wu Zhiqiang uses a model of the Shanghai Expo site to explain to his students how tailored infrastructures can dramatically improve a city's sustainability.

China's Model Future

China's cities are bursting at the seams — to the detriment of the environment. Shanghai's Tongji University and Siemens are working together to develop Eco-City Models that link environmental protection measures to urban growth.

Looking down at the city of Shanghai from an upper floor of Tongji University's Science Building gives you a good idea of what urbanization is all about. The campus is surrounded by countless gray concrete structures huddled together. Giant excavation pits bring to mind the houses that were torn down because they were too small to accommodate the masses streaming into the city. This dreary area could definitely use a little sunlight, but even when the sun shines you can't see it because of the smog. The view from the top of the building also includes the Yangpu District, which has 18,000 residents per square kilometer — the highest population density in Shanghai. By comparison, Berlin's population density is only one fifth of that.

"Urbanization is a great challenge for China," says Professor Wu Zhiqiang, Assistant President of Tongji University and head of the University's College of Architecture and Urban Planning (CAUP). "In the last 30 years alone, the proportion of the population living in China's cities has risen from 19 percent to about 50 percent, which corresponds to 400 million people moving into urban areas." The resulting increase in demand for housing, energy, and industrial products has made China the world's biggest producer of CO_2 emissions today.

"And the urbanization process has only just begun," says Wu, who expects China's urban population to double over the next 30 years. "We're therefore going to need completely new infrastructure concepts that address the requirements of both a growing urban population and environmental protection. This especially applies to new cities in China, which are literally springing up from the ground to accommodate the 13 million people moving into urban areas each year."

Individual lifelines. With this in mind, in 2002 Wu launched the Eco-City Model project, which aims to develop complete infrastructure models for individual districts and entire cities. These models must provide answers to a crucial question. How can we meet huge urban energy demands, improve efficiency and quality of life, and at the same time dramatically reduce urban energy consumption, and thus emissions, from the levels common in large cities today? "Each city has its own specific needs," says Wu. "For example, requirements vary on the basis of different climate conditions throughout our huge country."

In the first phase of the project, Wu analyzed the needs of different types of cities. Since 2007 he has been studying how these needs can be addressed with technology, which is why he's brought Siemens in as a partner. This is not the first time Siemens has worked with Tongji University. Shanghai college, which has around 55,000 students, is one of eight Siemens Centers of Knowledge Interchange (CKI) around the world. Siemens has entered into strategic partnerships with CKIs in order to conduct joint research, promote talented individuals, and establish networks. "With its virtually unique worldwide expertise in technological infrastructures, Siemens is the ideal partner for us in the Eco-City project," Wu explains. Siemens also benefits from the partnership, as Dr. Meng Fanchen, General Manager of Siemens in Shanghai, points out. "When we provide Professor Wu's team with technological support, we also learn a great deal about the future requirements of the Chinese market and how to prepare for them."

The next step in the partnership will be to develop Eco-City Model master plans that help to make new entities such as satellite cities as self-sufficient, environmentally neutral and pleasant to live in as possible. The master plans will include intelligent building management systems and the use of renewable energy sources such as wind, solar, and hydro power, depending on the region. Efficient water treatment facilities and extensive public transport systems — areas where Siemens already offers solutions — will also be part of the picture. At the same time, the models need to be cost-efficient and, even more importantly, reproducible. What Tongji and Siemens want is clear: to ensure that these models, which are already eagerly awaited by urban planners and government officials, are ready as soon as possible. This can't be done overnight, but it's extremely important. China has already shown that it appreciates the work Wu is doing. He has been appointed Chief Planner for Expo 2010 in Shanghai. ■ *Sebastian Webel*

The Fruits of Collaboration

A university-industrial collaborative project has found that sheet silicate nanoparticles in a generator's insulation can improve power plant performance.

Virtually any improvement that enhances the efficiency of a power plant is good for business and the environment. That is particularly true when it comes to optimizing the performance of downstream generators, which are responsible for converting the rotational energy of a plant's turbines into electrical power. To this end, in 2007 Siemens teamed up with the Universities of Bayreuth, Freiburg, and Dortmund as well as with industry partners Infineon Technologies AG, cable manufacturer Leoni AG, and Nanoresins AG, a supplier of nanoparticles. The joint project, which has the support of Germany's Federal Ministry of Education and Research, is known as "Nanotechnology in Insulation Systems for Innovative Electrical Applications" — or NanoIso for short.

The basic idea behind the project is simple. When an existing power plant is being retrofitted with more powerful turbines, it would also make good technological sense to install a larger generator — were it not for the complexity and cost of this procedure. However, there is an alternative. By swapping the electrical conductors inside the generator for ones that can carry more current, the generator's output can be increased without having to replace the entire installation. Even so, this solution is not without complications. A generator consists of a rotor and a stator. The rotor is a current-carrying bar magnet that is turned by the turbine; the stator consists of coils made of copper bars, which surround the rotor. The rotational movement of the rotor induces an electrical voltage in the stator, which causes an electric current to flow.

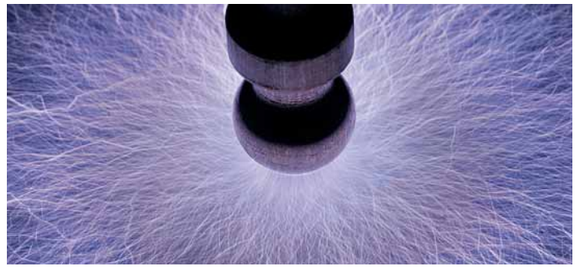
If the copper bars in the coils are to carry more power, they must be made thicker. However, as there is no additional space available within the generator housing, this means that the layer of insulation coating the copper bars must be made thinner. This, in turn, means that the insulation must provide much better protection against disruptive discharges — which is precisely the aim of NanoIso. By developing new insulation materials containing nanoparticles, it is possible to make the insulation thinner and thereby increase the efficiency of existing generators.

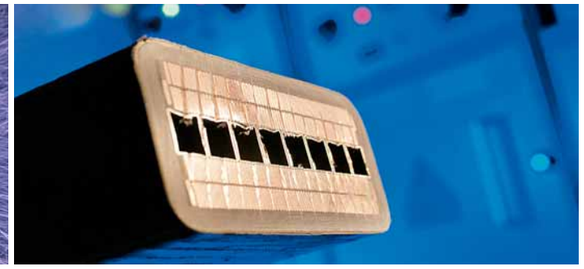
Greater Resistance to Erosion. The rotation of the rotor inside the generator results in potential differences of as much as 27,000 volts between the copper bars of the stator windings. This can cause the air to ionize, leading to partial discharges in the form of small lightning flashes that destroy the insulation. The result is so-called erosion channels, which eat through the material and can lead to shorting. The current method of preventing this is to incorporate mica in the plastic insulation material. Tiny scales of this mineral — some five micrometers thick and several millimeters in length — block the path of the erosion channels, so that it takes longer for them to reach the metal. But because of the mica, the layer of insulation has to be several centimeters thick — valuable space that could be occupied by thicker copper windings.

In addition to mica, researchers on the NanoIso project have also incorporated particles of sheet silicates just one nanometer thick into the insulation. These were developed in cooperation with the University of Freiburg. Because of their huge surface area in relation to their volume, these nanoparticles offer greater resistance to erosion channels. "Laboratory tests show that the nanoparticles improve resistance against partial discharges by as much as a factor of ten," explains Dr. Peter Gröppel from Siemens Corporate Technology.

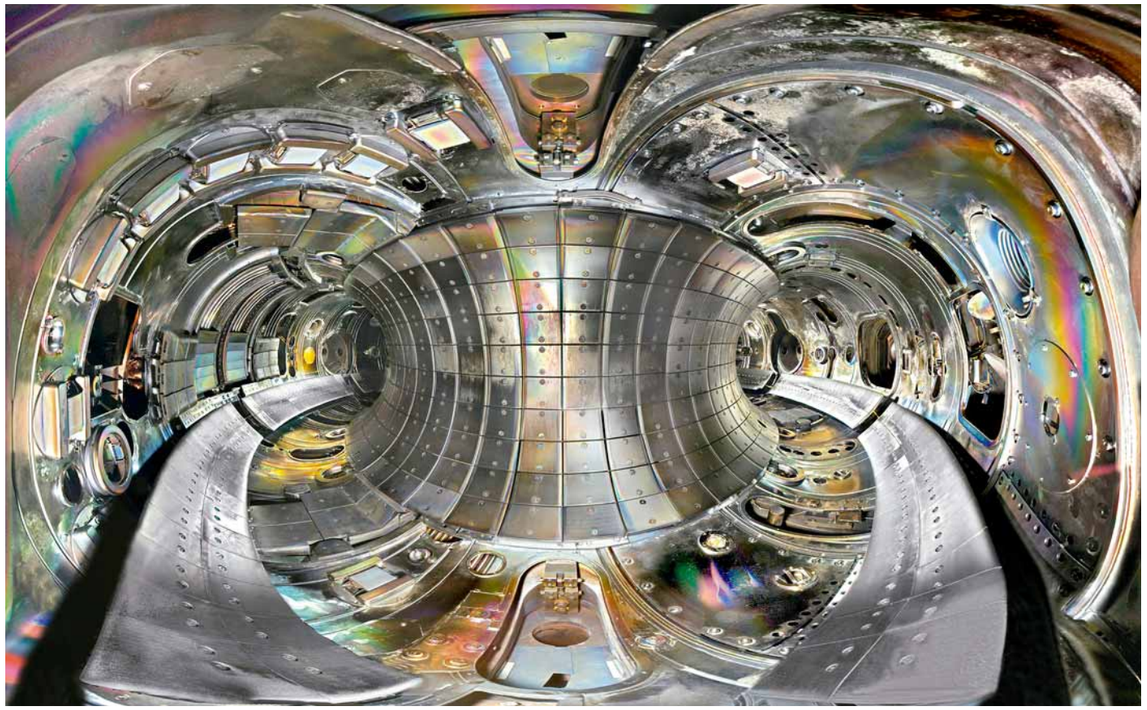
As good as all of this sounds, hurdles still remain. Scientists in Freiburg are investigating possible interactions between the nanoparticles and the plastic insulating material. Researchers from the University of Dortmund are testing the service life of the new insulation. And a team in Bayreuth, Germany is looking at how best to process the nanoparticles. Meanwhile, Siemens is responsible for collating all this new information. The ultimate aim is to develop an insulation material that meets the full range of industrial requirements, including that of being quick and easy to manufacture. The next step toward a more efficient generator will be to install copper conductors fitted with the new insulation.

The resulting generator will be provided by power company RWE. In the future, when one of RWE's power plants needs to be upgraded, the generator will be fitted with the new technology instead of being replaced at great expense. "We don't know exactly which power plant this will be," Gröppel explains. But he's confident that in a few years the knowledge gained from this joint research project should be helping to make power plants operate more energy-efficiently. ■ *Helen Sedlmeier*





Normally, discharges in a power plant generator destroy layers of its insulation. Incorporating nanoparticles in the insulator (cross-section, right) improves its resistance by a factor of ten.



Researchers are experimenting with a fusion reactor known as a tokamak to revolutionize energy generation. The resulting knowledge has already yielded improved materials for turbine blades.

Here Comes the Sun

By 2030, researchers expect to build a fusion reactor demonstration plant that produces more energy than it consumes. If successful, fusion power will provide a nearly inexhaustible and CO_2-free source of energy. Related developments in materials research are driving improvements in many Siemens technologies.

Nuclear fusion is pure solar energy. Deep within a star, the atomic nuclei of light elements fuse, generating vast amounts of energy in the process. For a long time now, scientists have wanted to use such fusion power here on earth, because it promises to provide us with a virtually inexhaustible source of clean energy. The raw materials (water and lithium) for fusion power are available in practically unlimited amounts. Fusion energy does not emit CO_2 into the atmosphere and — unlike nuclear fission plants, which split heavy atomic nuclei — fusion does not produce highly radioactive waste that remains hazardous for thousands of years. The interior walls of a fusion reactor become only slightly radioactive after being bombarded by fast particles. After about 100 years, the radiation level declines to such an extent that all of the material can either be recycled or disposed of.

All fusion power plant concepts are based on fusing the hydrogen isotopes deuterium and tritium. The tritium, a rare substance, is produced by bombarding widely available lithium with fast neutrons that are created during the fusion reactions. Deuterium is produced from water. The plan is not without its problems, however. Because atomic nuclei have a positive charge and repel one another, they have to collide with one another very quickly for fusion to take place.

The difficulty is to heat a gas to a temperature of more than 100 million degrees Celsius and to keep the resulting hot plasma compacted long enough. Whereas researchers in the 1970s were still optimistic about the prospects of fusion power, they eventually realized that the plasma is extremely unstable and reacts negatively to even minimal disruptions. According to Prof. Günther Hasinger, Director of the Max Planck Institute for Plasma Physics (IPP) in Garching near Munich, Germany, this problem has now been overcome. "Plasma physics has come a long way in the past few decades through bigger experiments, for one thing, but also because supercomputers can simulate plasma processes," he says. "I think most of the difficulties have been solved and the focus is now on creating optimal reactor designs and operating scenarios."

The goal is to have two large-scale facilities generate more energy than is fed into them (see box). If the reactors are a success, these experiments will lead to the construction of commercial power plants by 2050. Is this too late to help reduce global CO_2 emissions? Hasinger doesn't think so. "The transformation of our energy generation systems will be one of the biggest tasks of the century," he says. "All the scenarios for the development of energy consumption, the availability of fossil fuels, and the necessary reduction of harmful greenhouse gas emissions show that far greater efforts will be required in the second half of the century than in the period up to 2050. If we manage to exploit fusion power by mid-century, it will come at just the right time to make a big difference."

Hot Synergies. Because fusion power involves technologies from a broad spectrum of fields, industrial companies are monitoring associated research efforts with great interest. One of these efforts is the search for suitable materials for the fusion reactor wall. Although a magnetic field keeps the hot plasma at a safe distance, the "cooler" outer areas of the plasma are channeled toward the reactor floor in order to clean it. Researchers estimate that certain plasma states could cause the temperature of the wall interior to rise to over 2,000 degrees Celsius, which few substances are capable of withstanding. In addition, the huge amount of heat generated by the deceleration of neutrons from a fusion reaction must not impair the mechanical stability of the reactor shell.

Siemens' Energy Sector is looking for heat-resistant materials for its turbine blades, which are covered with ceramic insulation material that allows them to operate reliably even at 1,300 degrees Celsius. Although such blades are far from reaching their melting point at that temperature, their rapid rotation causes centrifugal forces to affect them as heat levels rise. Over time, these forces can cause blades to actually stretch.

On the other hand, because the efficiency of a gas and steam turbine power plant increases by about one percentage point for every 100 degree Celsius rise in temperature, engineers are constantly investigating technologies that make higher temperatures possible, explains Dr. Stefan Lampenscherf, who researches heat-resistant materials at Siemens Corporate Technology (CT). Such an increase in efficiency would enable a 400 megawatt power plant to save one million euros in fuel costs per year. The tungsten alloys that are being developed for fusion reactors could, for example, allow the turbines to work reliably at up to 1,800 degrees Celsius.

CT is working with IPP and the Technical University of Munich to identify such dual-use technologies and analyze their cost-effectiveness. Dr. Thomas Hamacher from IPP is also interested in this research. "We have to design fusion power plants in such a way that they fit into as many different energy scenarios as possible," he says. "Due to the increasing importance of renewable energies, they will have to be very flexible, which means that many components will be subject to cyclical changes in thermal load. We now have to take a closer look at the technological and financial costs this will entail."

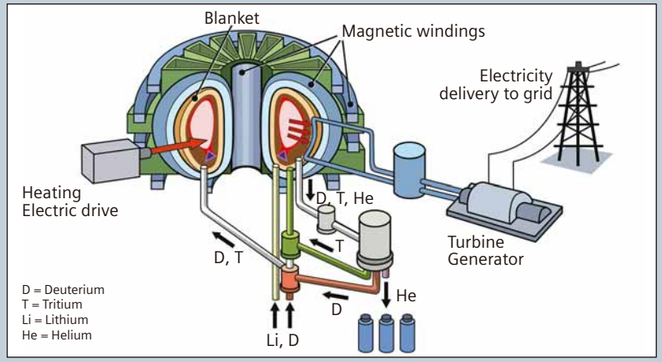
Siemens is also interested in work being done with superconducting magnets for fusion reactors. When such magnets are cooled to very low temperatures, they consume almost no electricity and can generate very powerful magnetic fields. Siemens Healthcare therefore uses them in many of its magnetic resonance tomographs to improve image resolution. Medical technology could benefit from research in high-temperature superconductors, which consume much less energy for cooling than conventional superconductors, and from techniques for the precise management of magnetic fields.

Prof. Hubertus von Dewitz from CT has great expectations regarding fusion research. "Take the Apollo space project," he says. "Putting a man on the moon took us a big step forward. Through massive investments in microelectronics, for example, space travel created the basis for today's communications technology. The development of fusion energy is a far bigger task than the moon flight. It should be energetically promoted, if only to achieve such technological leaps." German Chancellor Angela Merkel also believes it's worthwhile to invest in nuclear fusion and is seeking to foster international collaboration. Merkel, who is a physicist herself, visited the IPP site in Greifswald in early February to learn about the current state of research. ■ *Christine Rüth*

What's the Status of Fusion Research?

The National Ignition Facility in Livermore, California, the world's largest laser, was dedicated in 2009. Since then, measurements, including calibration and laser focusing, have been conducted. This summer (2010), the facility will begin experiments. For a few billionths of a second, the laser will generate a flash of 500 terawatts — over 100 times the output of all power plants worldwide — concentrated on a BB-sized droplet of hydrogen fuel. The flash will compress the droplet to such an extent that it will create a plasma in which a fusion reaction will occur. Researchers hope that in about two years they will achieve their first fusion reaction in which more energy is generated than is pumped in by lasers. However, to operate a fusion power plant they will have to develop lasers that flash five to ten times per second instead of once every few hours, as is currently the case.

Meanwhile, the International Thermonuclear Experimental Reactor (ITER) is being built in Cadarache in southern France. The facility, which is scheduled to enter service in 2018, is based on the most advanced type of fusion reactor, which is known as a tokamak. The plasma generated in this ring-shaped reactor is enveloped by powerful magnetic fields. The plasma is heated up by the electricity induced by a magnetic field, as well as by powerful microwave systems and high-energy particles. In the late 1990s the European JET tokamak used this technology to regain over 60 percent of the energy expended. It is hoped that ITER will be the first fusion reactor to generate more energy than it consumes — with a target of ten times the energy input, or around 500 megawatts. By 2026 this complex experiment will have progressed so far that researchers will be able to test their theory. This will be followed around 2030 by the construction of the first demonstration power plant.



An Oasis of Education

Through King Abdullah University of Science and Technology (KAUST), Saudi Arabia intends to secure its future as a high-tech research venue. Siemens has co-founded an industrial collaboration program at KAUST to spur research throughout the region.

Research at KAUST is providing new insights that will promote the development of green technologies — with help from Siemens.

In September 2009 the world gained another elite university when King Abdullah University of Science and Technology (KAUST) opened its doors to graduate students 80 kilometers north of Jeddah in Saudi Arabia. Covering 36 square kilometers along the Red Sea, the rambling university campus provides students with ideal learning conditions, including state-of-the-art labs for 11 courses of study. Researchers at the university can use one of the world's fastest supercomputers — the Shaheen, which operates at 222 teraflops per second. Students live in fully air-conditioned dorms that include cafeterias, shops, and sports facilities.

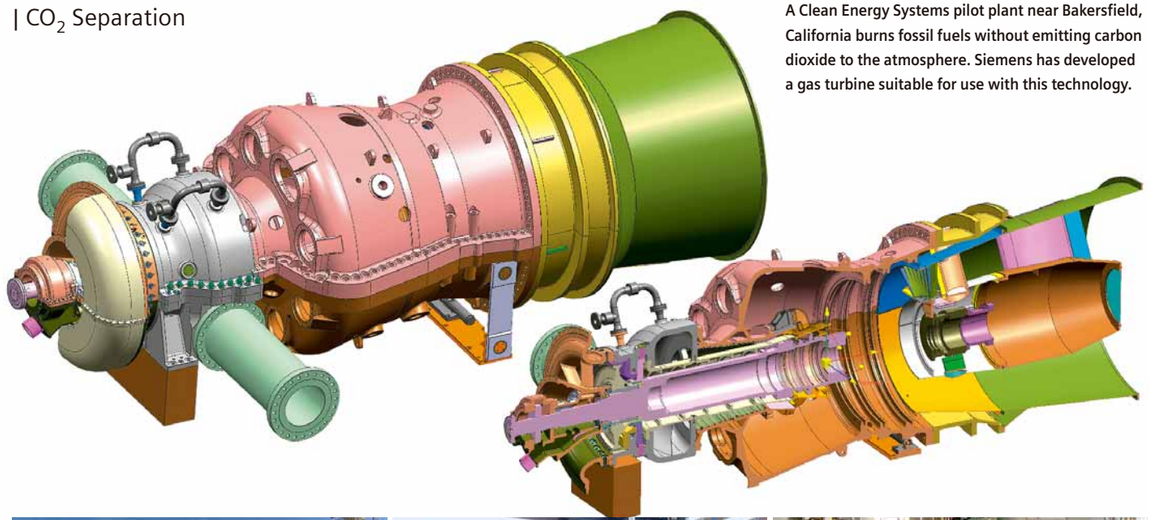
KAUST, which still has room for more students, initially began its operations with approximately 70 professors, who had previously worked at various universities and research institutes around the world. Around 2,000 graduate and postgraduate students will soon begin to conduct their research projects under the supervision of a staff of 220 professors. The young scientists come from all over the world, and only 15 percent of the openings for students are reserved for Saudi nationals. KAUST is also the first educational institution in Saudi Arabia at which men and women are permitted to work together.

The academic programs offered by the new university include Environmental Science and Engineering, Material Science and Engineering, Bioscience, and Applied Mathematics and Computational Sciences. "KAUST offers exactly those subjects that will help us to develop sustainable solutions for green technologies," said Prof. Hermann Requardt, Chief Technology Officer and CEO of Siemens Healthcare, at the signing ceremony for a partnership agreement. Siemens is one of the founding members of the KAUST Industrial Collaboration Program (KICP), which will in the future promote industrial research partnerships in the region and worldwide. Like Siemens, the other KICP members, such as Boeing and General Electric, have operated in Saudi Arabia for many years. In addition to KICP, KAUST is also involved in various projects conducted by a research network that consists of renowned universities such as Stanford in California, Cambridge in the UK, and the Technical University of Munich in Germany.

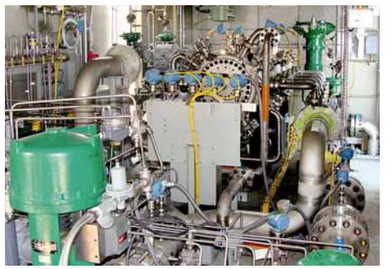
Strong Commitment. The new university provides its industrial partners with access to the research being conducted on its campus. "Siemens will regularly take part in workshops and conferences that address topics that our researchers are working on," announced Erich Kaeser, CEO of Siemens Middle East. Further benefits from the partnership between Siemens and KAUST include a continuous exchange of information between the faculty members, access to research programs, and contact to the best young scientists in the region. In this way, Siemens plans to further intensify its 75-year involvement in Saudi Arabia, which covers the Industry, Energy, and Healthcare Sectors.

Siemens is already taking part in many infrastructure projects in Saudi Arabia, for example, and almost all of the hospitals in the country use Siemens equipment. The company is currently planning to build a state-of-the-art power plant with an output of 900 megawatts. The plant will be equipped with flue-gas desulfurization technology and will treat around 880,000 cubic meters of drinking water per day for the cities of Jeddah, Mecca, and Taif. Siemens also offers training programs to many young Saudis and helps the government prepare young women for skilled professions.

Young people who wish to study at KAUST can apply after obtaining a bachelor's or comparable degree. The tuition fees of about $60,000 per year correspond to those of other elite universities. However, a foundation established by the king of Saudi Arabia provides scholarships for many students, including some from abroad. The Saudi royal house has invested about $12.5 billion in the new university, and regards this as an important step toward making the country less dependent on oil. Other Arab countries have taken a similar approach, with the huge Education City in Qatar, for example, offering an academic program in cooperation with several U.S. universities, while the famous Sorbonne University in Paris has established a branch facility in the Emirate of Abu Dhabi. ■ *Katrin Nikolaus*



A Clean Energy Systems pilot plant near Bakersfield, California burns fossil fuels without emitting carbon dioxide to the atmosphere. Siemens has developed a gas turbine suitable for use with this technology.



Underground Economy

Developing economical technologies for separating the carbon dioxide produced by coal-fired power plants from other gases is a burning issue. Working with international research partners, Siemens is now studying how CO_2 can be safely exploited.

North of Los Angeles, near Bakersfield, California, is a pilot plant full of rocket technology. Rudi Beichel, the space pioneer with German roots who helped the U.S. to reach the moon, worked there on the development of rocket engines for a long time. He was nearly 80 years old — an age at which most of his colleagues had retired — when he accepted a new challenge and set out to develop a fossil-fuel power plant that generates electricity with practically zero emissions.

In 1993, six years before his death at 86, Beichel established the Clean Energy Systems (CES) company. Today the company's work is bearing fruit. CES has developed a combustion chamber that can burn an extremely wide variety of fuels for a 50-megawatt (MW) test power plant. What makes this plant special is the fact that it emits no carbon dioxide (CO_2) or other exhaust gases into the atmosphere. It is one of the first zero-emission plants in the world — and the largest of its kind. The company's innovative technology has piqued the interest of Siemens. "We worked on similar ideas in the 1990s," says Frank Bevc, Director of Technology Policy and Research Programs at Siemens Energy in Orlando, Florida. "We were impressed by how Clean Energy Systems has implemented its ideas."

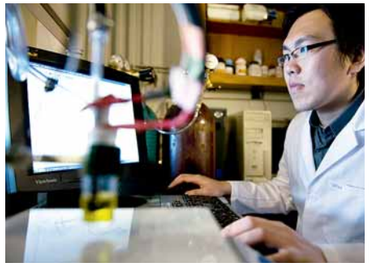
The central innovation from CES is its "direct oxyfuel process." Whereas natural gas requires little pretreatment, coal, coke, and biomass must first be converted into a gas and then cleansed of sulfur or ammonia compounds. The resulting gas is then fed into a combustion chamber where pure oxygen rather than air is used for combustion. The advantage of this is that the nitrogen that constitutes three quarters of the air does not have to be passed through the combustion process, and only oxygen, hydrogen, and hydrocarbons such as methane are burned in the combustion chamber. The flue gas produced by this process is composed mainly of carbon dioxide and water vapor.

Pilot plants built by power producers Vattenfall and E.ON in the Lusatia region of eastern Germany and in Ratcliff, UK, respectively, have also recently begun burning coal with oxygen, but in these cases the flue gas is recirculated into the combustion process to increase the level of CO_2 and to control the temperature (see *Pictures of the Future,* Spring 2008, p. 36). CES, on the other hand, uses water for cooling, as well as higher pressure, which in turn results in higher efficiency for electricity generation. In the CES plant, a heat

exchanger is used to cool the hot flue gas after it has passed through the turbine. The water vapor condenses out of the flue gas as it cools, leaving behind the CO_2, which can then be drawn off. In this way, more than 99 percent of the carbon dioxide can be prevented from entering the atmosphere.

CES's 50 MW plant is too small to generate electricity commercially, according to Keith Pronske, President and CEO of CES. "But the plant is already industrially attractive to anyone who has natural gas available as a fuel and needs carbon dioxide for the extraction of gas or oil from the ground," says Pronske. He points out that liquefied carbon dioxide from such a plant can be pumped into oil-bearing layers of rock to increase pressure and extract oil from old wells.

What is it about CES's technology that intrigues Siemens? "The company's innovative combustion chamber is an excellent complement to our turbine expertise," says Bevc.



Siemens is working with experts at MIT on methods for scrubbing CO_2 out of plower plant flue gas.

Working closely with CES, and with financial support from the U.S. Department of Energy, in 2006 Engineers from Siemens Energy in Florida began development of a 200 MW power plant based on combustion with oxygen. Siemens is contributing an innovative gas turbine design to the project.

The gas turbine must be able to withstand a hot and moist environment that is normally the domain of steam turbines. The dense gas stream has a pressure of 15 bars, a temperature of roughly 1,200 degrees Celsius, and is comprised of 80 percent water vapor and 20 percent CO_2.

A vintage Siemens SGT 900 gas turbine has been specially adapted for such conditions, and the efforts of its developers are paying off in the form of high efficiency. Because the temperature of the stream entering the turbine is very high for such a moist, high-pressure environment, the plant's efficiency is over 40 percent with natural gas and over 30 percent with gasified coal. These are modest numbers compared to the efficiency of a modern coal-fired power plant, which without carbon dioxide separation, is over 40 percent. However, Siemens hopes to exceed these values with its next generation of turbines, which are scheduled to be introduced in 2015. The new turbines should have an efficiency of roughly 50 percent for natural gas and 40 percent for coal.

Carbon Dioxide Laundry. This isn't the only approach to the separation of carbon dioxide that Siemens is pursuing. In addition to the oxyfuel method, the company is pressing forward with development of so-called IGCC (integrated gasification combined cycle) plants. These installations use entrained flow bed gasification and scrubbing processes to separate greenhouse gases from fuel gas prior to combustion (pre-combustion carbon capture). IGCC technology is now so mature that it can be deployed on an industrial scale. Siemens is also currently working to develop an efficient and environmentally-friendly post-combustion carbon capture process based on amino acid salts, which can even be retrofitted to meet the requirements of existing fossil-fueled power plants (see p. 111).

"Despite our internal development work, we are always on the lookout for partners such as Clean Energy Systems that can help us to further advance our CO_2 separation technologies," says Robert Shannon of Siemens Energy in Florida. "We're also interested in experimental, potentially revolutionary research approaches."

Siemens found one such development at the Massachusetts Institute of Technology (MIT), which has been chosen by Siemens as a Center for Knowledge Interchange (CKI). CKIs are special universities with which the company has signed close framework and research contracts. Chemical Engineering Professor T. Alan Hatton and Howard Herzog, an MIT specialist in carbon dioxide sequestration, told Siemens about a method by which CO_2 can be removed from a flue gas stream at a potentially low energy cost, which makes the technique extremely economical. A cooperation project on the topic commenced in 2008.

The basic idea behind this partnership can be summed up as follows: Most separation methods remove carbon dioxide from flue gas by using special scrubbing liquids, which are later heated. The process is effective, but it is also very energy-intensive. Hatton's idea is to pass the flue gas through special salts rather than scrubbing agents. Unlike known scrubbing agents, the salts have a melting point of less than 100 degrees Celsius. They absorb CO_2 in the liquid state and release it again when they are induced by an electromagnetic field to change to a semicrystalline solid state.

> The CES process can capture 99 percent of the carbon dioxide produced in the plant.

"This could reduce the energy consumption associated with carbon dioxide separation by 50 or even 75 percent," says Hatton's research partner, Dr. Thomas Hammer of Siemens Corporate Technology (CT) in Erlangen, Germany. "However," he adds, "with this brand new method, we can't expect a commercial application for at least ten years." The quantities with which the MIT and Siemens researchers are working in the laboratory are modest at the moment. "No more than a thimblefull," says Hatton.

CO_2 Goes Underground. If carbon dioxide separation is successful, the gas will still need to be disposed of permanently. CES, for example, has already found one way to do this. The fact that it could be easily reconfigured to suit the company's needs is not the only reason that CES purchased the Bakersfield power plant. The plant is also strategically located over rock strata that can hold billions of tons of trapped CO_2. That's enough to store centuries worth of the CO_2 produced each year by the planned 200 MW power plant. Another option is to sell the separated CO_2 — for example, to the operators of depleted oil fields in the surrounding area, who would pump the CO_2 deep below the surface to increase oil extraction rates. ■ *Hubertus Breuer*

Siemens and E.ON are testing a scrubbing technique for CO_2 separation at the CCS pilot facility near Hanau. Their goal is to integrate the technique into power plant processes.

The latter is particularly advantageous because it requires only the retrofitting of existing power plants, and is thus an attractive option for plant operators. Because Siemens already has a laboratory facility and extensive experience in flue gas scrubbing operations, the company is a sought-after partner when it comes to cooperation projects for optimizing CO_2 capture systems.

E.ON and Siemens: A Perfect Match. A CCS pilot facility has been operating in Block 5 of the Staudinger hard-coal power plant near Hanau just west of Frankfurt, Germany since September 2009. E.ON will be testing a new CO_2 scrubbing technology there in cooperation with Siemens until the end of 2010.

"Siemens' experience in this area is twofold," says E.ON's Head of Research, Bernhard Fischer. "It's got the required engineering and power plant construction expertise as well as valuable knowledge in the field of process development for the chemical industry." As an energy supply company, E.ON is a specialist in the planning and operation of fossil fuel-fired power plants. "Our work with Siemens is perfect for successfully refining CCS techniques and integrating them into the power plant process," says Fischer.

Siemens initially developed its new CO_2 scrubbing technique in a laboratory facility at the Höchst Industrial Park near Frankfurt am Main. In principle, the method — a common one for treating gas in the chemical industry — involves exposing CO_2 to an aqueous scrubbing

Scrubbing Agent is a Winner

A new scrubbing agent now being tested by Siemens will soon be used to separate carbon dioxide from power plant flue gases, thereby setting the stage for safe sequestration. Based on the use of amino acid salts, which are biodegradable, reusable, non toxic and non flammable, the technique uses less power than competing systems.

When it comes to scrubbing carbon dioxide (CO_2) from power plant flue gas emissions, amino acid salt is the powder of choice. Its use enables the capture of more than 90 percent of CO_2. As a result, the scrubbing agent is currently being tested at a pilot facility near Hanau, Germany. The tests are being conducted by Siemens in cooperation with the E.ON power company as one of several cooperative projects involving carbon capture and storage (CCS).

Experts predict that without CCS it will be almost impossible to achieve the 20 percent CO_2 reduction target set by the European Union for 2020 (relative to the base year 1990). This goal poses a dilemma in a situation where demand for energy is rising, thus putting pressure on utilities to respond quickly by burning more coal.

Power plant operators will therefore need to build facilities that emit low levels of CO_2. Indeed, the EU has stipulated that CCS systems must be ready to enter service by 2020. With this in mid, three avenues offer hope for a solution: coal gasification, oxygen combustion (oxyfuel technique), and the separation of CO_2 from flue gas after combustion (*see Pictures of the Future*, Spring 2008, p.36).

Siemens' CCS development activities are focusing on coal gasification and CO_2 separation.

agent that binds to the gas. To this end, Siemens equipped the Staudinger power plant with a 35-meter-high absorber tower through which a portion of the flue gas is passed.

The tower is packed with structured metal that is exposed to the detergent solution and the gas in a process that captures more than 90 percent of the CO_2 present in the flue gas. The CO_2-saturated solution is then steam-heated in a 20 meter-tall desorber tower until the CO_2 once again emerges as a gas. Two things are essential here: a scrubbing agent that is as environmentally friendly as possible and a cleaning process that uses as little energy as possible. Conventional chemical absorption methods utilize monoethanolamine (MEA). Siemens' technique, on the other hand, employs environmentally-friendly amino acid salts in an aqueous solution. In addition to being easily biodegradable, they are not flammable or toxic. What's more, the salts do not require high temperatures for CO_2 capture, and once the desorption process is completed, nearly all of the dissolved salt can be reintroduced into the cycle.

"Amino acid salts are ideal CO_2 capture agents," says Dr. Tobias Jockenhövel, who is responsible for the project at Siemens in Erlangen. CO_2 scrubbing with amino acid salts consumes less energy than other CCS techniques. "We were able to lower our energy requirement from four gigajoules to 2.7 gigajoules per ton of CO_2, which led to a significant cost reduction," Jockenhövel reports.

With prices ranging from €10 to €20 per ton of CO_2, pollution rights are still relatively inexpensive; but with costs expected to rise above €40, it will pay off for power plant operators to separate, transport, and store CO_2. Conventional monoethanolamine-based CCS techniques lead to an efficiency loss of 11 percent at an 800-megawatt hard-coal plant; the comparative figure with the Siemens method is only nine percent.

Ideal for Finland. State-of-the-art power plants burn coal at an efficiency of 47 percent. "It is therefore already possible to use our technology to operate power plants with low CO_2 emissions at an efficiency of 38 percent," says Fischer. That figure corresponds to the average efficiency of existing coal-fired plants in Europe.

The current goal, however, is to further improve the chemical properties of the scrubbing agent and the efficiency of the scrubbing process. At present, the test facility near Hanau can process one ton of carbon dioxide per day, which is one ten-thousandth the volume of flue gas produced in Block 5. Plans call for the technique to advance by 2011 to a point where Siemens will be able to build a large demonstration facility that will begin operating in 2015 and be able to separate the CO_2 produced by an entire power plant block.

To ensure optimal operation, technicians must continually measure parameters such as the CO_2 and SO_2 content of flue gas (left, center), as well as flue gas volume flows (right).

Power plant operators in Finland are also impressed by Siemens' CCS technology, which will be used at the Meri Pori power station in the western part of the country. In October 2009 the plant's operators — Fortum and Teollisuuden Voima (TVO) — selected Siemens Energy from among ten companies to build a CCS demonstration facility by 2015.

"Siemens' technology seemed particularly promising to us," says project manager Mikko Iso-Tryykäri, "especially because it's environmentally friendly and has already been tested at a power plant."

The project offers Siemens the opportunity to operate its scrubbing system on a commercial scale at the 565 MW plant, initially by treating about half of the flue gas produced there. The partnership with Siemens will also enable Fortum and TVO to implement one of Europe's biggest CCS projects. Specifically, the two plant operators plan to retrofit their facility and test the transport and storage of CO_2 in the North Sea together with other companies (see box).

Separating CO_2 from Gas Plant Emissions. Natural gas is a much more climate-friendly fuel than coal, which is why combined-cycle power plants enjoy great popularity. Nevertheless, these plants also produce CO_2, albeit to a lesser degree. Siemens is therefore studying ways to adapt its scrubbing technique to combined-cycle facilities on behalf of Norway's Statkraft power company.

But there's a catch: Combined-cycle power plants produce oxygen-rich flue gas, which attacks every kind of detergent. "In view of this, we have modified our technology and now know that it we can also achieve good efficiencies at combined-cycle facilities," says Jockenhövel. "Efficiency losses in our lab tests are well below eight percent."

The process for CO_2 separation with amino acid salts is fairly advanced, but both the scrubbing substance and the process as a whole need to be further refined if they are to be employed on a commercial scale. Such a large-scale application is the goal of a partnership launched by Siemens with the TNO research institute in the Netherlands in the summer of 2009.

By studying scrubbing techniques that use diverse chemical substances, TNO has discovered that amino acid salts offer a particularly promising option. TNO's contribution to the partnership is its knowledge of amino acid salts other than those tested by Siemens. Since 2008 TNO has been operating a pilot facility at a coal-fired power plant in Rotterdam, the Netherlands. The plant is similar in size to the one in Hanau.

"Siemens is an ideal partner, and our cooperation has been very successful," says René Peters, who manages CCS projects at TNO. "TNO provides its expertise in chemicals technology, while Siemens is contributing the knowledge it has gained from its development and implementation of power plant processes," Jockenhövel adds. Siemens now plans to improve the processes in cooperation with its Dutch partner. The next step will involve testing the refined processes at the Staudinger plant. In the mid term, Siemens plans to build a demo facility for a power plant block by 2014. This could provide conclusive evidence that some powders can scrub flue gas clean.

Jeanne Rubner

Is There Enough Storage Capacity?

European coal-fired power plants emit around 880 grams of CO_2 per kilowatt-hour of electricity produced (*see Pictures of the Future*, Spring 2008, p.34). That leads to annual emissions of 350 million tons in Germany alone. The earth and the sea are the biggest natural storehouses of CO_2, so it makes sense to use them to store the gas. To date, the most extensive attempt to store CO_2 beneath the ocean floor is being made by Norway's Statoil at the Sleipner gas platform off the country's south coast. Here, CO_2 is liquefied and pressed via a pipeline into a layer of sandstone 800 meters deep. The porous stone absorbs CO_2 like a sponge, and the hard rock layers above serve as a cap. After ten years of observation and the storage of around ten million tons of CO_2, researchers have concluded that the gas has been securely retained. Another storage option is offered by underground reservoirs such as empty oil and gas reservoirs, layers of coal whose mining is unprofitable, and extremely deep rock layers through which saltwater flows. Since 2008, a group led by the German Research Center for Geosciences in Potsdam has pumped some 60,000 tons of CO_2 into porous sandstone 700 meters below the ground in Ketzin in the German state of Brandenburg. The project's scientists have closely monitored how the gas has spread throughout the rock layers. However, there are still questions regarding several aspects of CO_2 storage. For example, the cost estimates for transporting the gas and storing it underground range from 40 to several hundred euros per ton. It's also not clear how much capacity is available underground. Currently known capacity in Germany would be filled in 40 to 130 years, according to estimates made by the Federal Environment Agency. Still, it's likely that sufficient capacity is available worldwide. According to Statoil, the rock formation under the Sleipner platform is several hundred kilometers long, 150 km wide, and 250 meters thick, and could hold 600 billion tons of CO_2. That alone would be sufficient to store the CO_2 produced by all European power plants currently on line from now untill the end of their lifespans.

In Brief

■ Companies have to respond flexibly to the needs of today's dynamic market. In addition to creating research partnerships, they have to engage in open innovation — i.e. open their labs and share their knowledge with the outside world. This results in global synergies that bring cost benefits, improvements in innovation, and other competitive advantages. (p. 86, 89)

■ Major cooperation projects are paving the way for electric vehicles. A major focus here is linking vehicles with the power grid. Key players in Denmark and the Harz region of Germany are striving to plug electric cars into power sockets so that the cars can serve as storage units for offsetting wind power fluctuations. (p. 92)

■ Founded in 2005, CT Russia quickly made a name for itself in the fields of materials science, energy conversion, and software engineering. Much of this success is due to the many research partnerships that CT has formed with some leading Russian research institutes and universities. (p. 96)

■ The Siemens Technology-to-Business Centers (TTB) provide funding and expert advice to start-up companies. The most popular ventures are projects involving technologies that save energy and improve our quality of life. (p. 100)

■ Saving energy and improving our quality of life is the goal of a partnership with Tongji University in Shanghai. Siemens is working with Tongji to develop Eco City Models that will enable urban growth and environmental protection to proceed hand in hand in the future. (p. 104)

■ Energy generation by means of nuclear fusion would be sustainable and conserve resources. While working on fusion power plants, scientists are also developing technologies — in areas such as materials research — that will enable other industries to progress. (p. 106)

■ Coal-fired power plants will remain the key to electricity production for the foreseeable future, although their CO_2 emissions will have to be cut. Together with international research partners, Siemens is looking at ways of separating and using CO_2 for commercial use. (p. 109, 111)

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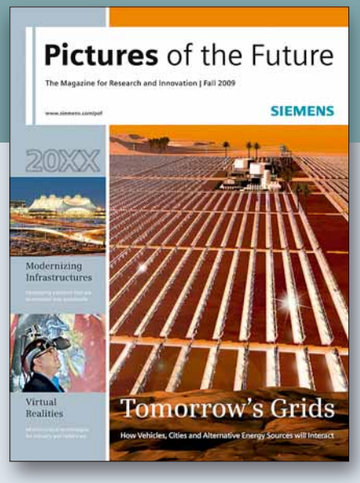

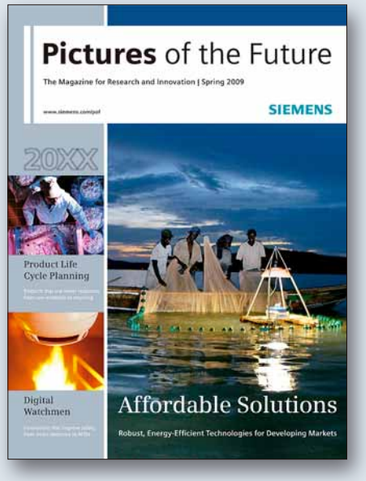

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Preview

Sustainable Mobility

Almost seven billion people live on our planet, and every year they are joined by approximately 80 million more — that's equivalent to the entire population of Germany. The world is also becoming increasingly integrated by means of transportation networks, as well as via electric and data highways. In order to ensure that the climate and the environment are not overly burdened by this increase in mobility, scientists are working to develop technologies capable of guiding the growing traffic volumes as efficiently and sustainably as possible. The technologies involved include energy-efficient local transport systems, high-speed trains, innovative drive systems for ocean liners, and new solutions for electric vehicles.

Emerging Markets on the Move

Many emerging markets are no longer sleeping giants. More and more of them are making good use of their human, material, and knowledge resources on the world market. For example, China, India, and Singapore not only boast booming exports but are also forging ahead thanks to their own technological developments and achievements in R&D. Brazil is also moving forward, in part because it will be hosting the World Cup soccer championship in 2014 and the Olympic Games in 2016. These and other success stories have one thing in common: state-of-the-art technologies and solutions that are helping to sustainably increase prosperity and quality of life.

Demographic Challenge

In many countries, the population as a whole is not only growing but also aging — and both of these trends are having a tremendous impact on society. For example, average worldwide per capita healthcare expenditures for people over 75 are five times higher than those for people aged 25 to 34. Many diseases primarily affect older people. With a view to improving efficiency and reducing healthcare costs, Siemens is therefore conducting research designed to maximize early detection, diagnosis and treatment of a broad range of diseases. Other areas of research and development associated with solving the challenges of demographic change are technologies that enable people to live self sufficiently as long as possible. These range from mobility solutions that offer a high degree of comfort to new device-operating concepts, robotic assistance, and smart systems for the home.

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