Pictures of the Future

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Modernizing Infrastructures
Developing solutions that are economical and sustainable

Virtual Realities
Mission-critical technologies for industry and healthcare

Tomorrow’s Grids
How Vehicles, Cities and Alternative Energy Sources will Interact
The New Age of Electricity

Wolfgang Ohlem is CEO of the Energy Sector and a member of the Managing Board of Siemens AG.

Cover: By 2050, electricity generated as solar thermal plants and wind farms in Africa and the Middle East is expected to cover 15 to 20 percent of Europe's energy needs. That's the goal of the Desertec Industrial Initiative. A founding member and technology partner of the initiative, Siemens can offer a range of solutions.

Tomorrow's Power Grids

10 Scenario 2030
12 Trends
16 Offshore Wind
19 Solar Energy
22 Interview with Hans Müller-Steinhagen
24 HVDC Transmission
28 VDC Conversion
31 Energy Storage
34 Networking
36 Smart Meters
38 Interview with Dan Arvizu
40 Virtual Power Plants
42 Facts and Forecasts
44 Electromobility
46 From Wind to Wheels

Modernizing Infrastructures

50 Scenario 2025
52 Trends
55 Water Networks
56 Power Plant Upgrades
59 Hospitals
60 Universities
62 Steel Plants
64 Steel Production
66 Airports
68 Radar Sensors
71 Facts and Forecasts
72 Istanbul

Virtual Realities

100 Interview with Jaron Lanier
A virtual reality pioneer on the potential of VR technology and its influence on human dignity in cyberspace.

110 Section 2: Science Express

116 Contents

T he second half of the 19th century was an age of pioneers. In 1866 Werner von Siemens discovered the dynamo-electric principle, and thus the most economical method of generating electricity. In the late 1870s, Thomas A. Edison resolved to bring light to every household by means of his incandescent bulb. George Westinghouse and Nikola Tesla conducted experiments with alternating current. Oskar von Miller was the first to transmit large amounts of electricity over a distance of 17.5 kilometers. And Werner von Siemens realized that electricity "will result in countless devices in homes and factories that will make life easier." Many of these devices were promptly developed by von Siemens himself. They included the first electric train, the electric coach—a forerunner of the electric car and the streetcar—and the first electric elevator. Broad electrification began around 1890. Today—120 years later—we are on the threshold of the second pioneering age of electrotechnology, as this issue of Pictures of the Future illustrates. In the future, electricity will become the dominant energy choice. This development is being driven primarily by the realization that it takes only a few hours to reduce greenhouse gas emissions in order to counter climate change. How this goal will be achieved will be the subject of the U.N. Climate Change Conference, which will take place in Copenhagen in December 2009. Electric energy holds the key to achieving this goal, because it can be produced, transmitted and used in environmentally-friendly ways. In short, it’s ideal for a transition toward an economy based on carbon-free energy. All of the technologies need to make this happen are available—they only need to be implemented. For example, efficiency can be boosted at every link of the energy conversion chain, from power plants (p. 56) and energy transmission (p. 24) to use in buildings (p. 34, 60), industrial facilities (p. 62), and transportation (p. 44, 78). The amount of electricity generated via CO2-free methods will vastly increase. According to calculations by the International Energy Agency and Siemens, by 2030 energy generated with wind will have increased 13-fold and we will be producing 140 times more power from solar sources than at present. One especially promising example is the Desertec concept, which focuses on solar power plants in North Africa and the Middle East. An industrial consortium was recently formed to plan and implement this idea (p. 19). More and more wind turbines are also being built on land and at sea (p. 16). In both cases, large amounts of electricity must be transmitted over long distances with minimal losses. And this is where high-voltage direct-current transmission comes in. In China, Siemens is building the world’s most powerful electricity high-way, which will transmit 5,000 megawatts of electricity from hydroelectric power plants in the interior across 1,400 kilometers to cities on the coast, with only minimal losses (p. 24). However, the wind and the sun don’t provide electricity exactly when it’s needed. That means it has to be stored somehow. The likely future boom in electric vehicles could prove useful here (p. 44). Aside from their green credentials, these vehicles could serve as mobile energy storage units—and enable their owners to make some cash. For example, they could recharge their vehicles at night with cheap power and sell this electricity in the daytime for top prices. Just a few hundred thousand electric vehicles in the power grid would be enough to provide more balancing power than Germany currently needs to cover peaks in demand. To make such a system work we need smart electric meters—for cars as well as other small energy generators and consumers (p. 36)—plus smart technology to manage it (p. 12). Thanks to sophisticated information, communication, and sensor technology, these grids will make electricity consumption more transparent and manageable, thus helping to save energy. Here too, Siemens has all the necessary solutions in its portfolio. Making power networks smarter has been our core business activity for decades. The worldwide market for smart grid technologies can be addressed by Siemens alone between today and 2014 amounts to some €30 billion. It’s an enormous growth market—that are the markets for renewable energy sources, power transmission, and electromobility. All of them taken together will be key factors in the new age of electricity.
Pictures of the Future

Gout Minus Ouch

According to a study at Vancouver General Hospital, doctors could use computed tomography (CT) in the future to diagnose gout much more reliably than is the case with the joint puncture method that is currently in use. Siemens dual-energy computed tomography (DECT) scanner enables a noninvasive examination, which quickly and accurately localizes small deposits of uric acid and marks them in color on a CT image. What makes this possible is a CT system that simultaneously uses two X-ray tubes to scan the patient with two beams that have different energy levels. Uric acid crystals appear red in the images, while bones and calcium appear as grayish blue.

Although gout is the most common inflammatory joint disease, it is nevertheless difficult to diagnose, since there are other diseases such as arthritis that have similar symptoms. A diagnosis can be confirmed only by verifying the presence of uric acid — a procedure that requires fluid to be withdrawn from a joint with a needle. This can be difficult and painful when the joints are inflamed. Doctors taking part in the study reported finding more gout-affected sites per patient using DECT than with the conventional examination. The scientists also achieved significantly better detection of gout in the elbow, foot, ankle and knee with DECT than with the puncture method.

Turbo Dishwasher

Special minerals that release heat make the drying cycle of the Siemens speedMatic dishwasher faster and more efficient. Zeolites, silicate minerals with a large surface area and internal voids, heat up as they absorb water and then give off the heat. At 50 degrees Celsius, for example, the dishwasher completes its standard program around 15 minutes faster than conventional models. The speedMatic is thus the fastest dishwasher in the highest efficiency class (AAA). And thanks to its EnergySave function, the machine consumes roughly 20 percent less electricity than the previous best dishwasher in its class worldwide — a new record.

Laser Navigator

Siemens development is now enabling vehicles to move about autonomously in factory halls and warehouses without the need for additional orientation aids. The system surveys its surroundings using a laser scanner mounted on a swivel motor and prepares a three-dimensional map for navigation. New routes are learned by driving along them only once. Systems used until now have required external navigational aids, such as reflectors, magnets or inductive guide wires.

Bright Ideas

Oxram is turning to open innovation for the development of new lighting solutions. Professional designers and hobby tinkers alike were given the opportunity to spotlight their ideas in the “LED-emotionalize your light” contest. The objective: practical and affordable lighting solutions that are easy for the user to operate and install. There was only one condition. The bright ideas had to use light-emitting diodes (LEDs) and implement them in the form of application scenarios, graphic designs, and technical notes to a website. A community of registered users and a professional jury assessed the ideas and then selected the winners. Around 600 ideas from 95 countries were submitted before the entry period closed at the end of July 2009. A total of €7,000 in prize money was awarded. You can admire the winning designs at www.LED-emotionalize.com.
Nanotube Scanning

X-rays have been produced in exactly the same way for over 100 years. A hot filament in a vacuum tube emits electrons that are accelerated by a high voltage and crashed into an electrode, where they induce the release of X-rays. To get a 3D image of the inside of a human body, the best CT scanners available today are equipped with two X-ray tubes that rotate around the patient roughly 3.5 times a second and then moved in the CT tube. In the future, hundreds of miniature X-ray sources could be permanently installed in a circular tube. They would then be triggered sequentially to achieve virtual rotation times in excess of ten per second. This would enable fast processes such as the distribution of a contrast agent in the blood to be observed with high image quality. In addition, this would be achieved with a lower dose of radiation for the patient (assuming identical image resolutions). It would also be possible to take sharp X-ray images during radiation therapy to destroy tumor tissue. The new X-ray sources are still in an early stage of development, and it will be years before a device for medical applications can realistically be expected. However, use of the technology to scan baggage at airports or in industrial environments could happen much sooner. The most important factor for achieving fast throughput is scanning speed, and the novel scanner is already phenomenally fast.

Andreas Klein Schmidt

Diagnostics for Pets

High-tech diagnostic methods such as magnetic resonance tomography (MRT) have generally been reserved for humans. But Siemens has now developed programs and special miniature coils suitable for use with animals. These new features help to ensure a reliable diagnosis and targeted treatment of illnesses by veterinarians. After reading, MRT devices used primarily for people can also reveal details from inside the bodies of small animals. Until now, veterinarians could only use X-rays or ultrasound to examine their small patients. Unlike people, animals must be anesthetized for an examination. If immobility is the key to a clear diagnostic image. Prior to an examination, the anesthetized animal is secured to the patient table. A blanket protects against hypothermia. / fm

Diodes Do It

In collaboration with Osram, researcher at Siemens Corporate Technology (CT) have developed a relatively low-cost manufacturing process for production of organic photodiodes. A flat-screen X-ray detector produced using the new spraying technology is even performing better in some ways than the detectors used to date. Organic photodiodes are made of organic plastics rather than crystalline semiconductors. Such diodes represent a low-cost alternative for use in future large-area detectors. / na/fm

Red Hot Ideas

Siemens researchers in Moscow simulate flames in gas turbines. They do so to make power plants cleaner and pave the way for turbines that will burn pure hydrogen.

On a dark screen, a hand-rolled wire coil comes into view from the right and begins to glow. A flame shoots up from a small opening on the lower edge of the screen. The flame seems peculiarly unstable, with its bluish light flickering back and forth like an apparition. An unseen experimenter then literally puts the gas, and the flame stands upright. The show ends a few seconds later when Dr. Andrey Bartenev clicks on another window displaying a snapshot of the same flame, but this time as a colorful simulated image. The simulation is remarkably similar to the real flame in the video.

Bartenev, who heads the Energy Technology and Energy Resources department at Siemens Corporate Technology (CT) in Moscow, is delighted. Hardly any other organization on earth can simulate combustion processes in gas turbines as precisely as his ten-member team. When the lab was established in 2005, Bartenev, a secretary, and the Head of CT in Russia, Martin Gitsels, worked alone in an old building behind the Paveletsky train station. Today, the lab has over 50 employees specializing in various disciplines, 23 of whom work at CT in St. Petersburg. The workforce has grown in line with the lab’s success. In the beginning, the lab received orders modeling combustion processes in gas turbines. Only a few of these assignments were commissioned from Germany, where Siemens has much bigger teams that calculate combustion processes and optimal turbine blade shapes. But that quickly changed after information about the skills of Bartenev and his team spread at Siemens’ Energy sector in Erlangen, Germany.

Better PCBs

Siemens researchers have developed a non-tack coating based on chemical nanotechnology that makes it easier to produce printed circuit boards (PCBs). The lotus effect (water repellency) is used on stencils on which the solder paste is printed onto boards, enabling production of solder structures of a few hundred micrometers. The process also enhances the quality of the PCBs and reduces production time as the coated stencils require less cleaning than conventional ones. The coating is already in use. / na/sw
Bartenev, 44, is a physicist who earned quite a reputation between 1987 and 2005 at the Russian Academy of Sciences in Moscow with his work on combustion—his so-called “Fast Processes” in combustion and explosions. He also performed research at RWTH Aachen Uni-
versity, Germany, and MIT in the U.S. The contact he established in Moscow benefit-
ted the Siemens team today. Bartenev’s group now has its hands full, and it is only Russian mod-
edness that keeps him from observing that many gas-turbine burner simulations used at Siemens originate in Moscow.

The team’s main task is to test new burner designs developed by their colleagues in Ger-
many. This involves virtually igniting a burner on a computer and monitoring its flame behavior with regard to various parameters, including gas composition, flow rate, and mixing processes. The results are passed on to de-
developers in Germany, who incorporate them into combustion chamber and turbine designs. The components themselves are not simulated in Moscow. “We just focus on the individual flames,” says Bartenev.

Complex Flame Simulation. When asked if there’s such a thing as an optimal burner or gas mixture, Bartenev shakes his head, ex-
plaining that there are no elegant formulas for burning pure hydrogen to produce water, and that most engineers work on secret projects for the Russ-
ian military.

However, he concedes that otherwise, such simulations require a lot of know-how. Two components are used to develop these algorithms: a software module that calculates reaction kinetics—the chemical reaction process — and a second module for gas dy-
amics, which calculates the dissemination of the gas particles in the combustion chamber. This happens at intervals of a few milliseconds. The latter is a commercial software product. Some stan-
ard software also exists for the first module’s task, but the processes are complex and need too much computing power. Simplifying the methods reduces accuracy, but overly simple calculations of chemical reactions are extremely complex.

When calculating the combustion of syngas — such as that resulting from coal gasification — each calculation step usually involves 16 reaction species and 48 reversible reaction paths, all of which have to be tested against pressure distributions. Oxygen from the air, for exam-
ple, reacts with hydrogen to produce water, with carbon to form carbon monoxide or carbon dioxide, and with nitrogen to produce various nitrogen oxides. “One gas dynamics calculation requires us to make a thousand chemical calculation steps,” says Bartenev. Several months are needed for a complete cal-
culation, even with the fast cluster computer used by the Siemens lab in Moscow, which has 108 processors and 672 gigabytes of RAM and is housed in a highly cooled chamber.

Fortunately, thanks to the Cold War, when Soviet scientists were working intensively on rocket propulsion systems and explosion re-
tear, there’s an expert in Russia for every combustion-related research problem.

So when the CT lab needed help it con-
tacted the Institute for Chemical Kinetics and Combustion in Novosibirsk, which is operated by the Russian Academy of Sciences, a Siemens cooperation partner. Oleg Korgo-
bechin, a professor at the institute, is one of the world’s leading scientists in the field of reac-
tion kinetics. His specialty is simulating com-
plex chemical reactions in the way mathemati-
cians shorten very long formulas into just a few terms. Korgobechin reduced the reaction for syngas combustion from 16 to 13 reaction partners and from 48 to 14 reaction paths without significant loss of final accuracy.

Utilizing Synergies. Siemens researchers also rely on their academic colleagues’ expert-
ise for actual experiments in the lab — be-
cause obtaining approval for commercial experiments in Russia is a long, drawn-out process. Probably the world’s greatest concentra-
tion of combustion and explosion research expertise can be found at the National Research Nuclear University (MEPhI) in south-
ern Moscow.

MEPhI, a mix between a nuclear research center and a university, was established in 1942 and later developed a detonator for the Soviet Union’s first atomic bomb, and today a small research reactor is still operated on its campus. The facility also employs many scien-
tists who work on secret projects for the Russ-
ian military.

Bartenev documents the characteristics of different gas flames for later analyses.

The turbines of the future could burn hydrogen and oxygen to produce pure water—without emissions.

Efforts to stabilize the flame, however, have been complicated by the high reaction speed of hydrogen. The high combustion speed makes it possible to stabilize the hydrogen flame using air, for example. Instead of the pipe with a square cross-section that improves the flame’s stability and reduces nitrogen oxide emissions in the simulation and in the actual experiment, Bartenev’s team has even more ideas about how to stabilize hydrogen flames. One idea, which has already been patented, involves a pipe with a square cross-section that improves the flame’s stability and reduces nitrogen oxide emissions in the simulation and in the actual experiment. The vortex burner reduces nitrogen ox-
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15 High-Altitude Harvest
Siemens is building the world’s largest offshore wind farm on the North Sea off the Danish coast. The rotors are so stable they can withstand hurricanes.

19 African Sunlight for Europe
The goal of the Desertec initiative is to help Europe meet its future energy requirements by supplying solar power from North Africa. The necessary technology exists already today.

24 China’s River of Power
Starting in 2010, hydroelectric plants are to supply energy to megacities in southeast China — with power generated 1,400 kilometers away. An HVDC transmission line from Siemens will transport this environmentally-friendly electricity in the most powerful system of its kind anywhere.

31 Trapping the Wind
In the future, fluctuations in wind power will have to be balanced by storage systems in order to prevent power grids from being overloaded. One option could be gigantic underground hydrogen storage centers.

44 From Wind to Wheels
Electric cars could play a stabilizing role in tomorrow’s power grids, as mobile electricity storage units. Siemens is investigating how vehicles, the grid, and renewable energy sources interact.

**Highlights**

**2030**

**Harvesting electricity in 2030:** A solar thermal power plant in the Moroccan desert covers 100 square kilometers, which makes it the world’s largest installation of its kind. Using HVDC lines, the electricity is transmitted as direct current at 1000 kilovolts to the coast, where it transforms salt water into pure drinking water. From there, it is transmitted across the sea to Europe, where it provides clean power to many countries.

**Morocco in 2030.** Karim works as an engineer in the world’s largest solar thermal power plant, which transmits energy from the desert to faraway Europe. Every evening he takes the time to admire the sunset above the countless rows of parabolic mirrors. But today he’s not doing it alone.

The Electric Caravan

The reflected image of the man walking past the glittering parabolic mirrors is oddly distorted. It wanders like a mirage through the seemingly endless row of mirrors, stops briefly and then continues on its way. There’s not a breath of wind, and even though the sun is now low, the temperature is still over 30 degrees Celsius. Karim is in a hurry, because he doesn’t want to miss the daily evening show. Before the sun sets he wants to reach the hill above the “frying pan” — his colleagues’ name for a huge solar thermal installation in the Moroccan desert.

In the glow of sunset, the level field of countless mirrors is transformed into a sea of red flames. It’s a spectacle Karim has never yet missed in the five years since he was sent here to help manage the world’s biggest solar thermal power plant.

Together with his colleagues, he lives and works in a small settlement on the edge of the installation. With the help of thousands of sensors, solar thermal power experts here monitor the power plant, which covers 100 square kilo-
Karim is a calm and deliberate man. He seldom uses bad language — only in the rare cases when there isn’t enough sugar in his tea or when one of his colleagues has forgotten to “tank up” the off-road, as has just happened.

The electric vehicle wasn’t plugged into an electrical socket — sockets that are supplied with power from the solar thermal installation. Nevertheless, Karim gets into the driver’s seat and presses the starter button. The vehicle’s 150 kilowatt electric motor starts up with a soft, crackling flame. The old man greets him with a traditional “Salam” and motions for him to sit a nomad holding a teapot above the caravan — the electricity travels across distances as great as 3,000 kilometers to European cities or face collapse. As a result, sooner or later, every city government must decide whether to expand its transportation infrastructure or face collapse. The situation with our power grid is similar. Electricity flows on copper “highways” from power plants to centers of demand. Along the way, it passes through various “road networks” that are separated by substations. These facilities function as traffic lights or railroad switches while also adjusting the electricity before forwarding it to the next grid. In the highest voltage alternating current lines, electricity flows at 220 to 380 kilovolts (kV) across hundreds of kilometers from power plants to substations, where the voltage is reduced to 110 kV before the electricity is then fed into the what is called the distribution or high-voltage grid. This grid is used for the general distribution of power to population centers or large industrial sites, where, depending on the region, the voltage is stepped down again to between six and 30 kV for the medium-voltage grid. This is followed by local distribution. Here, substations reduce the voltage to 230 and 400 volts and send the power into the low-voltage grid, which feeds consumers’ outlets.

Needed: Electricity Highways. Until now, electrons have flown relatively smoothly through Europe’s grids, despite the fact that many of the continent’s power lines are now over 40 years old. Gridlock is inevitable, however, as traffic continues to increase. According to the International Energy Agency, the European Union generated roughly 3,600 terawatt hours (TWh) of electricity in 2006. This is expected to reach 4,300 TWh by 2030. In addition, the energy mix is getting more environmentally friendly. In 20 years, some 30 percent of the world’s electricity is expected to come from renewable sources. Today the figure is only 18 percent. But as the percentage of electricity generated by renewables grows, so does the instability of the network. Because eco-friendly electricity is primarily generated by wind farms (see p. 16) much more energy than can be used is pumped into high voltage grid in stormy weather, while supply can’t be guaranteed on calm days.

In addition to being able to accommodate a fluctuating supply of wind-generated electricity, tomorrow’s grids will have to incorporate a growing number of small, regional power producers. “The generation of electricity will become increasingly decentralized, incorporating small solar installations on rooftops, biomass plants, mini cogeneration plants and much more,” says Dr. Michael Weinhold, CTO of the Siemens Energy Sector. “As a result, the previous flow of power from the transmission to the distribution grid will be reversed in part or for periods of time in many regions.” According to Weinhold, our grid infrastructure is not yet prepared for that.

Grid operators and governments agree on how the challenge should be met. In addition to a massive expansion of electricity highways, the grids must undergo a fundamental change. “Right now they are not very intelligent,” says Weinhold. “The level of automation is often a total mystery to utilities. Because it includes hardly any components capable of cognition, such as the actual amount of energy being used by consumers and the condition and efficiency of the line system.

Karim grins. “You’re not too far off the mark. Hussein points to the west, where the sun is dipping beneath the horizon. “And what happens after it gets dark?” he asks. “The power plant is equipped with storage systems that contain the same kind of salt that’s in the pipes,” explains Karim. “This salt stores so much heat that the plant can also produce electricity at night.”

The nomad looks thoughtful. “But what do we need all that electricity for?” he asks. “There’s only dust and gravel here wherever you look, and Casablanca is far away,” Karim responds, adding a gigantic high-voltage overhead line leading northward from the installation through the desert until it is lost from sight. “We use some of the power to change seawater into drinking water,” he says. Hussein nods. This makes sense to him.

Karim likes explaining things to people and is now hitting his stride. “But we also sell a lot of it at good prices to Europeans and to our future neighbors as far away as Japan. That’s why we need all this infrastructure.”

The power plant produces enough electricity to supply all of Morocco. My job is to make sure everything runs smoothly.”

Hussein looks down at the installation, which is starting to glow red in the sunset. “A power plant? I’d say it looks like a work of art created by some crazy European.”

Karim. “You’re not too far off the mark. This technology was in fact developed in Europe. Installations like this one are being built all over North Africa. They’ve been going on for years. The mirrors automatically swivel so that they’re always facing the sun. They capture the sun’s beams and focus them on a pipe that is filled with a special salt. The salt is heated to as much as 600 degrees Celsius and generates steam, which in turn drives a turbine that produces electricity.”

Karim hands Hussein a glass of tea. “What brings you here?” Karim shovels several spoonfuls of sugar into the tea. “Perhaps you are bringing a bit of feedback for the engineers here?” Karim asks, handing Hussein a glass of tea. “What brings you here?” Karim shovels several spoonfuls of sugar into the tea. “Perhaps you are bringing a bit of feedback for the engineers here?”

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According to an Accenture study, up to ten percent of energy disappears from the grid either due to inefficiency or electricity theft without being noticed by power providers. In large cities in some developing nations, as much as 50 percent of electricity disappears this way, and power providers are often unaware of outages—at least until the first complaint is received.

With a view to heading off impending problems, in 2005 the European Union came up with a concept, which it called the “smart grid”—a vision of an intelligent, flexibly controllable electrical generation and distribution infrastructure. “The energy system plus informatics and communications technology all enter into a symbiosis in the smart grid,” says Weinhold. “Not only does this make the grid transparent and thus observable, it also makes it easier to monitor and control.”

Governments and companies are committing large amounts of money to ensure that this vision becomes reality. The U.S. Department of Energy, for instance, has provided roughly $4 billion in subsidies for smart grid projects in the U.S. Germany’s energy utilities are planning to invest roughly $25 billion in smart grid technology by 2020 (see p. 42). Key components for the power grid of the future are already available and have even been installed on a limited basis in some countries. One example is smart meters—intelligent, electronic electric meters (see p. 36).

“Smart metering is a key technology for the smart grid,” says Eckardt Günther, who heads the Smart Grid Competence Center at Siemens Energy in Nuremberg, Germany. “With smart metering, energy providers and consumers can for the first time record in detail where and how much electricity is being used and fed into the grid.” The advantage is obvious: if electricity consumption is precisely recorded, flexible rates can be used to match consumption to supply. This lowers electric bills and CO₂ emissions. In contrast, at present if more electricity is being consumed than was forecast, the production of electricity must be increased. Shedding some light on the distribution grid isn’t the only advantage associated with smart meters. “Smart meters heighten energy use awareness and help to better control the grid,” adds Günther. “In addition, they are a prerequisite for actively participating in electricity markets.”

“Virtual Networks. Another component of the smart grid is the ‘virtual power plant’ (see p. 40). Here, the idea is that small energy producers such as cogeneration plants, wind, solar, hydro or biomass plants, which have previously fed their power into the grid individually and inconsistently, could be connected to form a virtual network. “This would allow them to bundle their power and sell it in a marketplace that is inaccessible to small suppliers,” says Günther. The grid would benefit too. “Consolidated into a virtual power plant and acting as a flexible unit, small plants could make balancing power available and thus help to stabilize the grid,” says Günther. Balancing power is provided in addition to the base load to cover peaks in demand. As this type of power requires power plants that can begin producing energy quickly, the price for a kWh of balancing power is much higher than for a kWh of base load power. Base load power is generally provided by the workhorses of power generation—coal-fired or nuclear power plants that run around the clock. Stability will be crucial to tomorrow’s grid. But intelligent systems alone will not be enough to manage the large amounts of energy provided by the growing numbers of wind farms or solar-thermal power plants. “There is also work to be done on the hardware side,” says Weinhold. “We need to greatly expand the number of power lines, as physics limits the transmission of electrical energy to wires or cables.”

According to the German Energy Agency (DENA) study, some 400 kilometers of high-voltage grid needs to be reinforced and an additional 850 kilometers of lines need to be erected by 2015 simply to transmit the wind energy that will be generated in Germany. Super Grids. The steadily increasing distances between power generation sites and consumers must also be bridged. One element of a solution to this problem could be high-voltage direct current (HVDC) transmission, which is capable of transporting large amounts of electricity across thousands of kilometers with low losses. Siemens is currently building the world’s highest capacity HVDC transmission system in China (p. 24). The system is scheduled to begin transmitting electricity generated at hydroelectric plants with a record-voltage of 800 kV across a distance of 1,400 kilometers by 2010. Weinhold believes that these electricity highways will not only cross borders in the future, but will link entire continents. “We will see the establishment of super grids in regions that can be interconnected across climate and time zones,” he says, adding that this would also be seasonal changes, times of day and geographical features to be used to their optimum benefit. Super grids could be used to transport enormous quantities of solar energy from Northern Africa to Europe, as described in the Desertec project (see p. 19). “Electricity will draw the world together,” predicts Weinhold. In addition to new electricity highways, tomorrow’s grid will need more buffers to stop it from bursting at the seams. Intermediate storage is needed for the excess power fed into the grid by fluctuating energy sources (see p. 31). Traditionally, this has relied on pumped storage power plants, but there is hardly any capacity for further expansion in Central Europe. As a result, wind farms will either have to be shut down to prevent them from overloading the grid during periods of overproduction or producers will have to pay someone to take the electricity.

One future solution could be electric cars, which temporarily store excess energy and later return it to the grid when needed—at a higher price (see p. 44). For example, 200,000 electric cars connected to the grid could make eight gigawatts of power available very quickly. That would be more than is currently required in Germany. As part of the EDISON project, in which Siemens is also participating, testing will begin on the electric cars concept and other solutions in Denmark in 2011. It is abundantly clear to Weinhold that we are moving full speed ahead into a new era. “Just yesterday the big issue was oil, but climate change is moving things in a different direction,” he says. Weinhold believes that we are currently on the threshold of a new electric age. Electricity is increasingly becoming an all-encompassing energy carrier. This is good for the climate, because electricity can be generated ecologically and transmitted very efficiently.

Sebnem Rustischka of Siemens Corporate Technology is also convinced that tomorrow’s grid will have to be smart. As part of the E-DeMa (development and demonstration of locally-produced energy marketplaces) project, which is subsidized by the German federal government, Rustischka is responsible for developing the information and communication interface between smart meters, the system for meter data management, and the electronic marketplace. “Among the things we are investigating is how these digital links need to be configured, i.e. what data should be transmitted and how can we obtain useful information from it,” she explains. The interfaces will connect both private and commercial electricity customers within model regions to an electronic marketplace and link them to energy traders, distribution grid operators, and other participants. The project is scheduled for completion in 2012. Rustischka believes that projects like E-DeMa will boost the smart grid’s prospects. “The technology is available and it works,” she says. “The first large-scale smart grid solutions could become reality by 2015.”
A neon tube lights up the long shaft containing the gearbox, which transforms the rotation of the blades into a generator speed of 1,500 rpm. The generator is hidden at the back and can produce 2.3 megawatts (MW) of electrical power once the wind speed exceeds 12 meters a second — but only if no visitors are present in the nacelle. “When anyone is visiting, the wind turbines are switched off for safety reasons,” says Møller, who heads Offshore Technology at Siemens Wind Power division in Denmark. However, this is small consolation for visitors. Even though you are standing on a secure grid, you can’t help but feel there’s very little between you and the abyss beneath your feet. The North Sea swell is lapping at the foundations 60 meters below. At the same time, the structure sways lightly in the wind — despite its weight of over 300 tons. “It’s designed to do that,” says Møller. “Because stability is what provides our wind power plants with their tremendous stability. Even severe storms haven’t caused any problems.”

Møller presses a switch and two roof wings — standing on a secure grid, you can’t help but feel there’s very little between you and the abyss beneath your feet. The North Sea swell is lapping at the foundations 60 meters below. At the same time, the structure sways lightly in the wind — despite its weight of over 300 tons. “It’s designed to do that,” says Møller. “Because stability is what provides our wind power plants with their tremendous stability. Even severe storms haven’t caused any problems.”

However, this bounty of green energy does have its downside. Because such plants rely on the wind, long-term energy production plans are out of the question. As a result, these giants get up only when it comes to meeting the fluctuating demand for grid power. In contrast, other types of power plants, such as gas and cogeneration plants, can be run up or down according to demand. That’s why Energinet.dk, the state-run network operator, uses a sophisticated energy management system that is partially based on several weather forecasting systems to get the best out of variable wind energy. In order to quickly respond to fluctuations, excess wind-generated electricity is diverted to the grid. A host of sensors, both inside and outside the compartment, continuously measure the vibrations of the machine parts. Using this data, experts from Siemens can remotely recognize when a problem is brewing, because each unusual reading triggers an alarm. In this way experts can detect anomalies and prevent damage from occurring. Only the most observant visitors notice that the nacelle and blades incline slightly upwards at an angle of seven degrees. “We have to maintain a safe distance between the blades and the mast,” says Møller. “They are so flexible that they bend inward considerably in stormy conditions.”

Robust Blades. Søren Kringelholt Nielsen and his 800 employees at Siemens Rotor Blade Manufacturing, which is located 230 kilometers away in Aalborg, ensure that the huge blades are flexible. All the blades for the European market are produced here. The floor of the factory is covered with neat rows of the gigantic rotor blades, each of which is bigger than the wing of a jumbo jet. The surface of the blades is so smooth that you can’t see or feel a single seam, while the edges at the tips are nearly as sharp as knives. Despite their size, the aerodynamic blades can be bent by several centimeters using nothing more than your hand. “This apparent fragility is deceiving,” says Nielsen, who heads Rotor Blade Manufactur ing in Aalborg. “The blades are extremely robust. Imagine placing a mid-sized car at the end of a three-kilometer beam. The forces that are being placed on the other end of the beam are the same as those a rotor blade needs to withstand during strong winds,” explains Nielsen.

The secret of the blades’ stability can be found in the 250-meter-long production hall where they are manufactured using “Integral Blade Technology,” a patented process (see Pictures of the Future, Fall 2007, p. 60). What’s remarkable is that the rotor blades are manufactured as a single component without seams — a method that only Siemens has mastered. At the start of the process, workers roll out long alternate layers of fiberglass mats and balsa wood in a form to make a kind of "sand-
Swimming Packhorse. By the time a blade begins its life on a mast at Horn Rev II, it will have an amazing journey behind it. First of all, blades are strapped onto articulated trucks per rotor on top of one another, before placing the tower sections and the nacelle beside them. This swimming packhorse then transports its freight, which weighs over 1,000 tons, 50 kilometers to Horns Rev II.

From its nacelle 60 meters above the North Sea, Møller has spotted the Sea Power. “It takes six to eight hours to completely assemble a wind power plant,” he says. The assembly ship’s crane lifts the steel tower, the nacelle, and finally the rotor onto a yellow pedestal — a steel foundation that was driven 20 meters into the sandy seabed some time earlier. The components are then bolted together by hand.

“Naturally, this is possible only with good weather. As soon as the height of the waves exceeds 1.5 meters the work is called off. And this can happen quite often on the North Sea, which is renowned for being rough,” says Møller. He points at an old ferry that is anchored not far from the wind farm. “That’s our hotel ship. It’s home for the workers who are responsible for the installation and cabling of the wind mills. They spend two weeks at a time here at sea.”

In contrast, stays in the nacelles, which are far from comfortable, are of course much shorter. The limit is three days. In case evacuation is impossible in the face of a rapidly-developing storm, each tower is outfitted with emergency storage facilities for fresh water and energy bars. On the other hand, there are visitors who have climbed the tower with Professor Müller-Steinhagen’s colleague Dr. Franz Nielsen. To further increase their resilience, all the blades are equipped with a lightning conductor. “Statistically, each blade will be struck at least once by lightning.”

The vacuum sucks liquid epoxy resin through the resin finds its way through all of the layers which.” The bottom and top sections are subse-

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Tommorow’s Power Grids | Offshore Wind

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thermal power plants includes key components such as steam turbines and receiver tubes, power plant control technology, and systems for transmitting high-voltage direct current with low losses (HVDC, see p. 24, 28).

“Solar-thermal power works — there’s no question about it,” says Müller-Steinhagen. In fact, a cluster of power plants in California’s Mojave Desert has demonstrated for over 20 years that a huge amount of electricity can be generated with solar energy. The 100 megawatts fed some 350 megawatts into the grid — enough electricity to power 200,000 households.

Desertec: 100 gigawatts of installed capacity would cover 15 to 20 percent of Europe’s electricity needs.

There are many reasons why this technology is now being widely discussed in the context of Desertec, with increased awareness of the need for climate-friendly power being chief among them. In addition, technology for low-loss transmission of electricity over long distances has now established itself, while recent innovations have made solar-thermal power plants even more efficient. When oil prices begin rising again, as is expected after the economic crisis, solar power may quickly become competitive. In fact, its production in favorable regions already costs less than €0.20 per kWh.

Major Alliance. If there’s one person who might be called the father of Desertec, it’s Dr. Gerhard Kries. Kries is Chairman of the Supervisory Board of the Desertec Foundation, which developed the Desertec concept that is now being refined in the DII. A retired physicist, Kries said: “We can’t solve problems by using the same kind of thinking we used when we created them.” Kries believes this logic fits in very well with the issue of climate change brought about by CO2 emissions, as this development can only be counteracted by revamping the energy supply system. Over the years, he has put together an impressive group of supporters, including TREC, the Club of Rome, DLR, and Prince Hassan of Jordan.

“We all understood that putting a halt to climate change would require CO2-free technologies like wind power, geothermal systems, and, above all, solar-thermal facilities — all on a massive scale,” he says. Whereas Müller-Steinhagen is one of Desertec technology designers, Kries got the associated political process rolling. His work culminated in the launch of the energy supply system. Over the years, Kries got the associated political process support was obtained from companies such as Siemens.

The DII intends to develop business plans and financing concepts for the biggest-ever solar power project within three years. The goal is to build a belt of solar-thermal power plants in North Africa and the Middle East, which would be linked via high-voltage lines with local consumers and European countries. Plans call for achieving a capacity of 100 gigawatts (GW) and the supply of 700 terawatt-hours (TWh) per year by 2050, which would cover 15 to 20 percent of Europe’s electricity needs.

Obviously, these plants could meet an even higher share of the electricity requirement in the dynamically growing countries in which they would be located. The electricity requirement in the MENA Region (Middle East and North Africa) is expected to increase five-fold over the next 30 to 40 years, to 3,500 TWh. “Solar-thermal plants and wind power facilities could, for example, play a key role in the energy-intensive desalination of seawater,” says Kries. Moreover, because as much as 80 percent of the value created through construction of the power plant facilities will remain in the MENA countries themselves (e.g. through the production of mirrors, foundations, and frames), a project like Desertec would also greatly boost development in the region. According to estimates by Greenpeace, Desertec would lead to the creation of some two millions jobs in participating countries by 2050.

But solar-thermal plants have special requirements with regard to turbine size and complexity. For one thing, turbines in certain types of solar plants need to be able to start up very quickly when the sun rises. That’s one reason why many solar power plant operators opt for customized Siemens technology. In May 2009, Siemens opened a new turbine production hall in Görlitz, Germany, that produces the SST-700, the world market leader when it comes to parabolic trough power plants. In fact, Siemens’ share of this market is more than 90 percent.

With desert conditions such as those found in Andalusia in Spain, the SST-700 turbine is also being used in another power plant in Andalusia: Solnova 1 in Sanlúcar de la Mayor, near Seville. Power generation is scheduled to begin at the facility in 2009. SST-700 turbines are already in operation in many CSP plants around the world. The model is popular due to its reliability and specifications — which are very well-suited to the size class currently in operation — and its flexibility. This is important because in Seville we have light cloud cover about 90 days a year. The plant’s output can fluctuate considerably on such days,” says Valerio Fernandez, Director of Operations and Maintenance at Abengoa Solar, which operates Solnova. “The turbine therefore has to be flexible enough to make up for these fluctuations.”

As the morning sun rises, Fernandez inspects the Solnova construction site, where workers are busy tightening bolts and assembling and bolting piping equipment. “Here in Seville we have very good conditions for solar-thermal power plants: about 210 days a year of perfect sunshine, from morning to evening,” says Fernandez. The Spanish feed-in law for subsidizing solar-thermal power has triggered a real boom. Since 2006, producers have been entitled to receive a maximum of nearly €0.28 per kWh from the government, and civil servants are being buried in applications.

Big Up-front Investment. Depending on the location and sunlight intensity, it now costs up to €0.23 to produce 1 kWh of electricity, which is relatively high. Electricity from wind power, on the other hand, can already be produced at competitive prices in many regions in Europe. But things weren’t always this way. Thirty years ago, it cost around €3 million to install one MW of wind power output, whereas today it costs only €1 million. Experts expect a similar development with regard to solar-thermal power. Here, the high cost at the moment is mainly due to the initial investment. For example, a 50-MW facility with heat storage costs around €300 million, which has to be paid in full at the outset. This may explain why many solar power plant operators opt for customized Siemens technology. In May 2009, Siemens opened a new turbine production hall in Görlitz, Germany, that produces the SST-700, the world market leader when it comes to parabolic trough power plants.

Suitable: 100–150 GWh/km² year

Not suitable: > 150 GWh/km² year

areas needed for solar-thermal plants to provide electricity to CES 2050...
tured changes and thus must be replaced, molten salt can remain in the cycle. It also allows operation at temperatures up to 550 degrees Celsius, which boosts efficiency because bringing to higher temperatures and pressures. That’s why the salt eliminates the need for high-loss heat exchangers because the salt in the receiver tubes can also be used as the storage medium and can be pumped into an insulated tank as well. After it cools, the salt flows back into the receiver, where it again “harvests” solar energy. Construction of a new factory for producing Archimede receivers is expected to begin in northern Italy this year; the facility is expected to enter service in 2010. Archimede tubes are already being used at a solar field in southern Italy. “By acquiring an interest in Archimede Solar, Siemens is underscoring its intention to become the leading supplier of solutions for solar-thermal power plants,” says Ulmich. Instead of using special oil or molten salt, it’s also possible to produce steam directly in absorber tubes. This eliminates the need for an expensive heat transfer agent, as water can be used to generate steam directly. Together with the DLR, Siemens has been working on the associated technology for many years. Thanks to the major advances achieved so far, it will be possible to operate some of the parabolic collectors at the Andasol-1 power plant with such a direct steam generation system. Conditions for solar power generation are even more favorable in the deserts of the U.S. and North Africa than in southern Spain. Egypt, for example, is considered to be ideal for solar power because the Nile can provide sufficient cooling water for the condensers in the steam cycle. However, condensers can also be cooled in dry regions using air, although efficiency in this case is 20 percent lower. Such an approach might make sense in parts of Algeria, for example, where stone deserts offer an optimal location for solar-thermal power plants for a different reason. There are no sand storms that can damage mirrors. Algeria is the site for the future Hassi RmEl power plant, a 160-MW facility currently under construction that combines a conventional gas and steam turbine plant with solar technology. The facility will initially generate electricity for the local market. However, with the construction of more and more power plants, North Africa will eventually have an electricity surplus, which could be transmitted to Europe. Clearly, in such a case, losses must be minimized — and this is where high-voltage direct current transmission (HVDC) comes in.

Electricity Highway. “Transferring power via conventional AC lines over thousands of kilometers from Africa to Europe would involve enormous, huge losses,” says Dr. Dieter Retmann, Siemens’ leading expert for HVDC transmission technology. “Such losses can be greatly reduced by using HVDC lines and undersea cables.” HVDC lines lose only around ten percent of power over 3,000 kilometers — that’s roughly the distance from the southern end of the Sahara to Central Europe. Siemens is now building the most powerful HVDC connection in the world in China, where 5,000 MW of power will be transported, 1,400 kilometers (see p. 24). “Such HVDC lines are like electricity highways,” says Retmann. “We’re going to need them in Europe when we expand our grid and large amounts of electricity from wind power facilities will have to be moved great distances.” Desertec might therefore become a key element in Europe’s new energy networks. The project provides solutions in three key areas, according to Michael Weinhold, chief executive officer at Siemens Energy. “Energy systems must be effective in terms of three dimensions; he says, “economy, environment, and security. Desertec will be good for the environment, it will be designed in an economically manner, and it will enhance European energy security because it will substantially reduce dependence on fossil fuel imports.”

The key issue with solar-thermal power today is no longer feasibility but the ability to achieve efficiency in large-scale applications. The main issue for the MENA Region is to ensure continued stable economic development and a reliable supply of energy for drinking water systems. The water table in Sarara, Yemen, for example, is sinking at the rate of six meters per year, according to Müller-Steinhagen. In Egypt, new water sources with a volume equivalent to seven times the flow of the Nile need to be tapped by 2050. Desalination at solar-thermal facilities could meet a large portion of this requirement. In conjunction with modern technology, the sun that relentlessly beats down on this region, could one day be bringing water, electricity, and life to the desert.

Andreas Kleinschmidt

Making Solar-Thermal Power Competitive

When will solar-thermal electricity become competitive? Müller-Steinhagen: That depends on prices for conventional fuels — and in 2008, we saw just how volatile they can be. It also depends on the development of investment and operating costs for solar-thermal facilities. We’ve already overcome the first major challenge with the launch of the Desertec Initiative. As we begin producing more solar-thermal electricity, it will become cheaper. Costs will decline when large companies start using our technology and further develop the technology. One result will be the mass production of components. I’m confident that we can become competitive in about 15 years.

Saving the world with big projects is a concept that has sometimes caused major problems — for instance in dam construction projects. Isn’t it possible that this could happen with Desertec?

Müller-Steinhagen: Although Desertec is a gigantic project as a whole, it’s also made of many smaller and more easily manageable projects. After all, many projects, each with a capacity of at least 50 megawatts, could gradually go online. That sort of value is common in Spain today. This approach will work because investment costs can be kept at a manageable level. And with the right financial incentives, such plants can be operated profitably. At the same time, the infrastructure needed to transport some of the energy produced in Africa and the Middle East to Europe involves projects that can only be successfully implemented by a large number of big companies working together. One challenge is how to use high voltage direct current technology and that also possesses the necessary project expertise. Siemens is in a very good position to play such a role.

What type of research still needs to be performed?

Müller-Steinhagen: Our main goal is to increase the efficiency of CSP systems, and that could increase our efficiency to 20 percent from the current average of 15 percent, we could reduce the area needed for the mirrors by one-third. Don’t forget that the collectors account for nearly half of the total investment cost. We’re also experimenting with direct steam generation, where water in the receiver tubes is converted into steam and sent directly to the turbine. We have worked with Siemens to develop an insulated pressure container or the heat from the steam is transferred to an additional storage medium — usually in the form of the special salts that are also used in the receiver tubes. Utilizing salt as both the transfer agent and storage medium eliminates the need for a heat exchanger, which lowers both investment and operating costs. CSP power plants can also be built as central receiver systems, where the flat field mirrors reflect sunlight onto a central tower that is often taller than 100 meters. This approach enables the highest possible temperatures to be achieved (up to 5,000 degrees Celsius). However, the farther away the mirrors are from the tower, the lower the efficiency, which is why such plants must be kept small. A cost-saving alternative is offered by fresnel technology. Here, long strips of flat mirrors (which are cheaper than parabolic troughs) reflect light onto a receiver tube suspended above them (middle). However, the low initial investment cost for Fresnel power plants comes at the price of lower efficiency. Experts believe that the market for solar-thermal power plants will grow steadily in the coming years, and that additional growth between now and 2015. A number of competing technologies will probably continue to exist side by side as they undergo further development.

Andreas Kleinschmidt

Three Ways to Put Solar Power to Work

The basic principle underlying solar-thermal electricity generation (concentrated solar power — CSP) is simple: Energy from the sun heats water, either directly or indirectly. The water vaporizes, and the resulting steam drives a turbine whose motion is converted into electricity in a generator. The large turbines heated in today’s coal-fired power plants operate at over 600 degrees Celsius and at pressures of up to 285 bar, thereby enabling an efficiency as high as 46 percent. CSP plants have much lower steam parameters and outputs, which is why smaller turbines, like the Siemens IST-700, are used at such facilities. In addition, many CSP plants use special salts (especially those not equipped with heat storage) need to be started up very quickly at times when the sun is not shining, which require highly flexible turbines. There’s also another important difference between CSP units and coal power plants: Power generated at the former is completely CO2 free. All CSP plants concentrate solar energy using mirrors distributed across a small area in order to generate high temperatures. The most widely used technology today employs huge parabolic mirrors, with a receiver tube mounted along the focal line (top). A liquid flows through this tube as a heat transfer agent; a special absorber keeps the metal tubes from the hot side. The salt is heated to approximately 370 degrees Celsius, after which it transfers its heat via a heat exchanger to water, which drives a turbine in the form of steam. Alternatively, special salts can be used instead of thermal oils. These salts can be heated up to 550 degrees, thereby increasing the efficiency of the plant. Some companies are now also testing direct steam generation systems in which water is used as the heat transfer agent in the receiver tubes. The salt in the tube is then heated in a closed loop. As a result, a heat exchanger is no longer required. Many solar-thermal plants are also equipped with heat storage so that they can produce electricity at night as well. Here, steam is either stored directly in insulated pressure containers or the heat from the steam is transferred to an additional storage medium — usually in the form of the special salts that are also used in the receiver tubes. Utilizing salt as both the transfer agent and storage medium eliminates the need for a heat exchanger, which lowers both investment and operating costs. CSP power plants can also be built as central receiver systems, where the flat field mirrors reflect sunlight onto a central tower that is often taller than 100 meters. This approach enables the highest possible temperatures to be achieved (up to 5,000 degrees Celsius). However, the farther away the mirrors are from the tower, the lower the efficiency, which is why such plants must be kept small. A cost-saving alternative is offered by fresnel technology. Here, long strips of flat mirrors (which are cheaper than parabolic troughs) reflect light onto a receiver tube suspended above them (middle). However, the low initial investment cost for Fresnel power plants comes at the price of lower efficiency. Experts believe that the market for solar-thermal power plants will grow steadily in the coming years, and that additional growth between now and 2015. A number of competing technologies will probably continue to exist side by side as they undergo further development.

Andreas Kleinschmidt

How a Parabolic Trough Plant Operates
China’s River of Power

How do you supply five million households with hydroelectric power from a distance of 1,400 kilometers? The answer is: with high-voltage direct-current transmission. Siemens is building the world’s most powerful such system in China.

It takes a jarring ninety-minute ride to cover the distance from Kunming, the capital of Yunnan province in southwestern China, to Lufeng. Lush green paddy fields and herds of water buffalo flash by the car window. Then, at long last, deliverance comes. Our driver turns in at a blue sign bearing lots of Chinese characters and “800 kV” in Western script and lets us out just beyond a rolling gate. In front of us is a site measuring around 700 by 300 meters that looks like something from another world. Gigantic pylons dripping with cables soar into the cloudy sky, while workers below toil with spades and wooden wheelbarrows to finish the last of the landscaping. The air is alive with a sonorous hum. “That’s from the testing,” explains Jürgen Sawatzki, who is in charge of the installation of equipment from Siemens at the site.

The high-voltage overhead lines coming from the hills to the left of the fence are already carrying power, but the shiny new one that crosses the fence to the right and disappears over the mountain is still dead. It will go into operation in 2010 as a bipolar line transmitting power to Guangzhou in Guangdong province, over 1,400 kilometers away. From there it will supply five million households in the megacities Guangzhou, Shenzhen, and Hong Kong on China’s southeastern seaboard. This will reduce the country’s annual emissions of CO₂ by some 33 million metric tons a year, as the electricity comes from a dozen hydroelectric plants on the Jinsha (“Golden Sand”) River, one of the headwaters of the Yangtze, which provide carbon-free power.

The overhead lines arriving from the left of the site are carrying conventional alternating current (AC) that has been generated by hydroelectric plants, some of which are located as far as several hundred kilometers away. The 1,400-kilometer transmission line to Guangzhou, however, will carry direct current. High-voltage direct-current transmission (HVDCT) is not a new invention; as long ago as 1882, a transmission line of this type carried electricity from Miesbach in Bavaria to an electricity exhibition in Munich, 57 kilometers away. That, however, is where the similarities end. Back then the voltage was a mere 1,400 volts; in China, the line will transmit at a record 800,000 volts. “The HVDCT line in China is the ultimate example of this technology. It will carry 5,000 megawatts; that’s the output of five large power plants,” explains Prof. Dietmar Retzmann, one of Siemens’ top experts on HVDCT.
The problem is, however, that over long distances, the voltage would still be significantly higher than with transmission losses, the HVDCT link will cut the output of a mid-sized power plant or 160 rect current, the goal is to ramp up the voltage. In other words, the power is divided between two conductors in order to minimize transmission losses. At the same time, this is a precaution in the event that one pole should go down.

A number of tests are scheduled for the coming months. Eight Siemens engineers, accommodated in an office above the valve hall, sit in the control room, gradually ramping up the voltage onscreen. This is designed to push the capacitors to their very limits and reveal any weaknesses before the system enters service. A blackout in one of China’s large coastal cities would be a nightmare.

The left half of a large control screen displays the operating load of the transmission station in Lufeng at “0 megawatts.” The right side of the screen shows the status of the receiving station in Guangzhou, where the direct current will be converted back into alternating current and fed into the public grid. Here a default reading of “9,999 megawatts” is displayed. Were the station in operation, the screen would show a power of 5,000 megawatts as well as a raft of other data from Guangzhou, all of which will be transferred in real time via a fiber optic cable that is laid along the HVDC transmission route.

Know-how from East and West. Whereas the AC part of the system was built entirely by Chinese firms, the DC part contains a lot of Siemens know-how. Yet that doesn’t mean that the three components were made in Germany. Half of the 48 transformers of the German production, while the others were manufactured in China under the supervision of Siemens.

Savatzi’s has been in China for ten years now. The HVDC system in Lufeng is its fourth for network operator China Southern Power Grid. All in all, the project will take three years, from the award of contract in June 2007 to full commissioning in June 2010.

In the first project with China Southern Power Grid, Siemens handled 80 percent of the total contract volume, in the second 60 percent, and in the third 40 percent. In the fourth, the share is a bit higher, coming in at around €370 million out of the €1 billion that the system is costing. China Southern Power Grid has stipulated that most of the components to be supplied by Siemens must be manufactured in China by sub-contractors. So whereas Siemens is still responsible for the engineering of the thyristors, for example, these components and all the ancillary equipment are being manufactured under Siemens supervision by two Chinese firms.

Plugging into HVDC’s Advantages

High-voltage direct-current transmission (HVDC) is ideal for countries where power has to be transported over long distances. HVDC becomes financially viable from around 1,000 megawatts and 600 kilometers upward. The 1,400-kilometer HVDC link between the Chinese provinces of Yunnan and Guangdong will transmit at 800,000 volts, a new world record. Compared to a 765-kilovolt alternating current (AC) line of the same length, which would require immense compensation for transmission losses, HVDC will save around 36 percent in costs over a 30-year service life.

In the case of underwater cables, the advantages of HVDC come into play over distances as small as 60 kilometers. Over longer distances, AC lines act like huge capacitors that are charged and discharged 50 times a second, eventually losing virtually all their power. This effect can be compensated for by the use of costs, but such measures are not economical for underwater cables. As of May 2011, for example, a 250-kV HVDC line from Siemens will connect the Baltic Island with the Spanish mainland, 250 kilometers away, and carry 400 megawatts of power. The forthcoming boom in offshore wind farms will provide a further boost for the HVDC market.

HVDC PLUS is an innovative system from Siemens that features a new generation of power converter. With its compact dimensions, it is designed to provide flexible and reliable transmission from offshore wind plants. HVDC PLUS links are a special instance of this technology. The principle is the same as the one governing a normal HVDC transmission system, except that the transmission and receiving stations are on the same site. Their purpose is to link different AC power networks with dissimilar voltages and frequencies by converting alternating current into direct current and then back again. HVDC PLUS is also increasingly being incorporated into synchronous three-phase AC networks, both for long-distance transmission and to provide back-to-back links. This is because, as Prof. Dietmar Rettmann explains, HVDC PLUS has the major advantage over AC transmission that it acts like a firewall, automatically halting cascading failures within a network and thus greatly reducing the risk of a major blackout.

Gas-cooled insulated lines (GIL), meanwhile, are ideal for transmitting high power in urban environments, where space—the cheapest form of insulation—is usually at a premium. The lines are laid underground in a 50-centimeter pipe filled with a low-pressure gaseous mixture of nitrogen and sulfur hexafluoride. This gas insulates the conductor so well that a power of up to 3,500 megawatts can be transmitted at 550 kilovolt. GILs require little maintenance and they do not deflect the landscape. As a rule, they are used in major cities, where it is impossible to build high-voltage overhead lines. In terms of construction costs alone, GILs are between five and ten times more expensive than overhead lines. However, this extra cost becomes smaller once the costs of land and maintenance for overhead lines are factored into the equation. What’s more, GILs can become even more attractive economically as they increase transmission loads. Yet another advantage of GILs is that the metal pipes that encase them block electromagnetic radiation. This was an important consideration for the operators of the Lakeview center in Geneva, where a Siemens-built GIL, under the exhibition halls ensures that visitors and sensitive electronic systems are shielded from radiation fields. 
High-voltage direct-current transmission not only makes the supply of conventional electricity more environmentally compatible and reliable, but also facilitates access to power from renewable sources. Converters are indispensable parts of the technology. Their basic components are made, assembled, and tested in Nuremberg.

**The Art of Converting Volts**

About 12 square meters of transparent pink plastic wrap enrobes electrical equipment at Siemens that is about to set new records. Dr. Hartmut Huang, who heads the Technology and Innovation Department at Siemens Power Transmission Solutions, lifts the wrap and displays a swimming-pool sized multistory tower to which a multitude of multicolored, bucket-sized capacitors, coils and high-power transistors are fitted. “What you’re looking at,” he says, “is a completely assembled, bucket-sized capacitors, coils and high-power transistors, but by commonly used IGBTs (Insulated Gate Bipolar Transistors). “They can be used to convert alternating current (AC) from enormous power plants into direct current (DC) for transmission — and at the far end of the line, back to AC.

**Compact Converters.** For about two years now, Siemens has had a solution for this problem as well: a miniature version — about the size of a suitcase — of the standard HVDC converter. It is named HVDC PLUS. Depending on the power involved, it consists of 2,000 to 3,000 modules. These devices, which are also produced in Nuremberg, are switched not by thyristors, but by commonly used IGBTs (Insulated Gate Bipolar Transistors). “They can be controlled faster and more accurately, and can terminate the current in any module with millisecond accuracy. As a result, they generate nearly perfect current and voltage curves, which are synchronous. What’s more, they do so without the need to include additional elements for reactive power compensation,” says Huang (see box, p. 30).

The compact dimensions of HVDC PLUS amount to a significant benefit in large, densely built-up cities. For instance, in San Francisco, a 400 Megawatt HVDC PLUS system is currently under construction, where it will facilitate electric power transmission. Siemens has achieved a worldwide first, as these devices were previously used mainly in electric motor drives or as inverters for smaller solar systems. However, despite its advantages, HVDC PLUS technology is not likely to replace the well-proven thyristor converter in the short term. “When it comes to maximum buildable power, it still falls short of the classic variant. In addition, it also loses more power during conversion,” says Huang.

Both the conventional and the innovative modules are processed on an assembly line before being thoroughly quality-checked in a steel cube test cell, whose interior is completely protected by screens. There, every single module component — including the frame and mounting supports — is tested at up to 110 kilovolts and the resulting current values observed. “That’s our voltage-proof test,” Huang explains. Voltage arc-overs are an indication of defective contacts or insulation that needs to be corrected. In extreme cases they are audible as a hum, but experienced testers usually recognize them by the resulting, inappropriate current values.

Once the modules have passed all the tests, they are carefully packaged as ocean freight.

Laser control of high-power transistors is more tolerant of interference and enables a compact design.
SVC Plus — the Perfect Wave

Due to their weather-dependent power fluctuations, wind and solar power plants increasingly unsettle the stability of electric power grids and increase the probability of blackouts. A remedy is now available in the form of Siemens’ new SVC PLUS (Static Var Compensator) reactive power compensation system. This system, which is the latest offshoot of the FACTS (Flexible AC Current Transmission Systems) family, converts even the most irregular voltage wave shapes into perfect sine waves. Such waves can otherwise be produced only by power plant turbines weighing many tons. As a consequence, the space-consuming filter systems that smooth out voltage wave irregularities in conventional converter systems are no longer needed.

The formula for such potent power metamorphoses is known as modular multilevel technology. Each SVC PLUS module consists of an IGBT-based high-power switch and an electrically charged capacitor producing filter systems that smooth out voltage wave irregularities in conventional converter systems are no longer needed. “Every week we ship eight conventional and about 100 HVDC PLUS converter modules out of here. At present, the destination are an HVDC line that will connect the U.K. and the Netherlands, and an HDVC PLUS line in the U.S.,” says Huang. Due to increasing demand in recent years, the assemblers have had to increase their pace substantially despite the economic crisis.

Firewall for the Power Grid. This trend is expected to continue, not only because of the world’s increasing demand for electric power, but also because systems involving two converters with a short DC buffer stage between them are useful as coupling stations. Such systems can also be used between grids carrying different frequencies — for example, in the U.S. and Japan. “In the future, such stations could also be used within uniform grids to protect individual sections against mains faults, much as a firewall protects a computer against viruses,” says Huang. Among other benefits, this would further improve the reliability of electricity supplies in Europe. Due to the uniform nature of the European power grid, it is fairly easy for a network fault to spread, as occurred on November 4, 2006 to produce a blackout. Back then, a disconnected high-tension line across the Ems River combined with excess supply from wind power plants in northern Germany to cause a chain reaction of line overloads and automatic shutdowns that turned off millions of lights in many parts of Europe. The effects were even felt in parts of France and Spain.

“DC coupling stations could at least diminish the spread of such power failures,” says Huang. Power at the wrong frequency — in 50-hertz Europe, the maximum permitted variance is only one half of a cycle — would be converted into DC at all coupling stations, which would thus eradicate the fault. At the other end, each such station would transmit reliable power at a stable, specified frequency. While discussions about the possible use of converter-supported firewalls continue, scientists in Huang’s team are already working on new world records. “We’re in the process of testing even larger thyristors for conventional converter modules,” says Huang. “Our aim is to increase their power, and thus also the power of the converter. The researchers are also optimizing the control of IGCTs for HVDC PLUS systems. Their objective here is to reduce the number of modules in a system for a given power level, and thus to make high-power conversion even more economical.” — Andrea Haferdichter

Trapping the Wind

Power produced from renewable sources such as wind and sunlight is renewable. Experts are therefore looking at ways of storing surplus energy so that it can be converted back into electricity when required. One option is underground hydrogen storage, which is inexpensive, highly efficient, and can feed power into the grid quickly. Although this is all excellent news as far as the climate is concerned, it presents the power companies with a problem. Wind power isn’t always generated exactly when it needs it. As a rule, wind generators produce energy according to a projection by the German Renewable Energy Federation (BDEW), could rise to as much as 25 percent (149 TWh) by the year 2020. By then, Germany should have wind farms with a total output of 55 gigawatts (GW), compared to 22 GW at the end of 2007. Germany already accounts for approximately 20 percent of the world’s total wind power generating capacity. Until recently, it was the pacemaker, but has now been pushed into second place in this particular world ranking by the U.S.

The wind blows when and where it will, and it rarely heeds our wishes. These days, that can have a serious impact on our power supply, to which wind energy is now making an increasingly important contribution. In 2007, wind power accounted for 6.4 percent or 39.7 terawatt-hours (TWh) of gross power consumption in Germany, and this proportion, according to a projection by the German Renewable Energy Federation (BDEW), could rise to as much as 25 percent (149 TWh) by the year 2020. By then, Germany should have wind farms with a total output of 55 gigawatts (GW), compared to 22 GW at the end of 2007.

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The ideal solution is to cache the surplus electricity and feed it back into the grid as required. The power network itself is unable to assume this function, since it is a finely balanced system in which supply and demand must be carefully matched. It is also contrary to the nature of alternative technologies, particularly falling in the case of excess demand, or rising in the case of oversupply. Both scenarios must be avoided, as there would otherwise be a danger of damage to connected devices such as motors, electrical appliances, and computer systems. In this way, power plants would become the necessary part of a systematic electricity system, as they would not only generate electricity to meet demand at peak times — in the evenings, for example — but can be used for buffering, providing it as needed, or even storing power and feeding it back into the grid whenever the conventional power plant chose to pay some form of compensation.

To achieve this, Germany’s Renewable Energy Act stipulates that all forms of renewable energy are to be ramped up in the event of peak demand, and that conventional power plants have to be ramped down at times of oversupply. This applies to gas- and coal-fired plants, which are responsible for providing the intermediate load — in other words, for buffering periodic fluctuations in demand. For the power plants assigned to provide the base load — primarily nuclear power and lignite-fired plants — ramping up and down is relatively complicated and costly.

On windy days, this can have bizarre consequences. During years when the wind is so strong that we have to shut down all the power plants in order to avoid surges, Germany’s power plant industry is under pressure to come up with new ideas. Although little of the extra power can be used for anything but the movement of water, it does mean that there is still demand for pumped-storage power plants. Germany’s largest pumped-storage power plant is in Goldeck, about 30 kilometers from Berlin. It has an output of 1,060 megawatts (MW) and can, in an extreme situation, supply the entire state of Thuringia with power for eight hours. In all, 33 pumped-storage facilities operate in Germany, providing a combined output of 6,700 MW and a capacity of 40 gigawatt-hours (GWh). Each year, they supply around 7,500 GWh of so-called balancing power, which covers heightened demand at peak times — in the evenings, for example, when people switch on electric appliances and lights. The energy held in reserve in pumped-storage power plants can be called up within a matter of minutes.

In Germany, however, simply increasing the number of pumped-storage power plants isn’t such a simple option. There is a lack of suitable locations, and such projects often trigger protests. In the end, Germany’s power plant operators coordinate their activities with their counterparts in neighboring countries. En ergie Baden-Württemberg (EnBW) in Karlsruhe, for example, uses pumped-storage facilities not only in Germany, but also in Austria. In the Vorarlberg region of Austria, Norway, too, which has a long history of hydropower, is looking to market its potential for electricity storage. However, the financial expenditure for doing so would be substantial. Such a project would involve more than just laying a long cable to Norway. The grid capacity at the point of entry in both countries would also have to be increased in order to avoid bottlenecks in transmission capacity. “Such a step would be a great step forward because electricity worldwide are pumped-storage power plants.

Electric vehicles could serve as mobile and readily available storage devices for electricity.

Batteries and Compressed Air. Other major industrialized countries such as the United States and China also make significant use of pumped-storage power plants. In addition, major efforts are being made to find alternative methods of storing energy. The best-known of all electricity storage devices is the rechargeable battery, which can be found in every mobile phone and digital camera. However, the amounts of energy involved here are tiny by comparison. Therefore, many countries — and Germany is no exception — are looking to market its potential for electricity storage. The best-known of all electricity storage devices is the rechargeable battery, which can be found in every mobile phone and digital camera. However, the amounts of energy involved here are tiny by comparison. Therefore, many countries — and Germany is no exception — are looking to market its potential for electricity storage.
In the future, buildings will actively participate in the grid. In Masdar City (small pictures) narrow spaces between and under buildings will enhance cooling.

Small cogeneration plants in buildings (Pictures of the Future, Fall 2008, p. 78) could also be better integrated into power networks in the future. “If electricity demand is high, a cogeneration plant will deliver energy to the network, while the waste heat will be fed into a local heat storage system or into the thermal capacity of the building,” predicts Christoff Wittwer from the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany. “This heat can be used later by residents.”

Well-insulated water tanks capable of acting as heat stores are already available. In contrast, heat storage based on phase change is still at the R&D stage. Here, for example, surplus heat is used to melt a salt. Later, when demand for heat increases, the melted salt releases its stored heat and solids. Yield is very high: “These types of cogeneration plant have an overall efficiency of over 90 percent,” says Wittwer. “In terms of primary energy, that’s much more productive than large-scale fossil fuel power plants that don’t exploit waste heat.”

Managing Demand. Conversely, consumers can also selectively switch off devices at peak times to ease network loads. The key is to know when rates are lower. For example, washing machines and dryers can be run at night when electricity is cheaper. But which hours offer the best prices? “Many appliances are already able of determining this through signals in power lines,” says Dragon. “On and off times can be determined by a smart meter.”

This scenario would give utilities the advantage of being able to manage demand within their networks. It would also help them to prevent sudden peak loads from occurring — for example, when large numbers of consumers turn on their appliances at the same time. However, consumers would have to consent to having their appliances turned on or off by a utility depending on the network’s load — based on the premise that they would be paying less for their power. Ultimately, both parties have an interest in a flat load curve, which is achieved by leveling demand over each 24-hour period.

The challenge is to coordinate each building’s sub-systems with one another and control their communication with their surroundings. In other words, all isolated solutions should be combined in a platform. “That is not a trivial matter because these systems have developed independently over time,” says Dragon. “We are developing interfaces that allow control systems to communicate with one another.”

Software solutions that address this challenge are being developed by Siemens Building Technologies under the name “Total Building Solutions” (TBS). Here, a variety of systems are being linked into one unit. They include building control and security technologies, heating, ventilation, air conditioning, refrigeration, room automation, power distribution, fire and burglary protection, access control, and video surveillance. “Only if all of these systems harmonize perfectly can their economic potential be fully realized,” says Dragon. “Whether in a stadium, an office complex, a hospital, a hotel, an industrial complex or a shopping mall — TBS will ensure that the facility is working productively, users are being reliably protected, and energy is being used optimally.”

Large Savings Potential. The amount of energy that can be saved through the intelligent networking of power utilities and consumers varies from case to case. However, experts generally agree that savings of 20 to 25 percent are realistic. “This figure fluctuates depending on the type of building,” says Dragon. “Shopping malls often have a savings potential of up to 50 percent, while office buildings have between 20 and 30 percent. For hospitals, we’re forecasting about five to ten percent. The differences depend on how buildings are used. For instance, in Europe many shopping malls are open ten to 12 hours a day and closed on Sunday. But a hospital operates around the clock. ‘That’s why hospitals don’t have much scope for saving large amounts of energy. The heating can be turned off in an office building but not in a hospital,’” says Dragon.

Advanced technologies not only save energy in hot and temperate zones; they can also do so in icy areas. Take the new Monte-Rosa Hut of the Swiss Alpine Club, which is perched at an altitude of 2,883 meters. It will be largely self-sufficient — thanks to sophisticated building technology and components supplied by Siemens (Pictures of the Future, Spring 2008, p. 58). Power will be supplied by a photovoltaic system, supported when necessary by a cogeneration unit.

In order to maximize efficiency, the building’s control system will use weather forecasts and information on guest bookings, thus helping it to coordinate its power and heating systems as well as energy storage and appliance power demand. A smart algorithm will periodical- ly calculate the best end heating temperature, so that the desired room climate can be realized on time. “As a result, we are saying that not even the smallest amount of energy is wasted,” says Christian Buck.

Data centers need to be exceptionally efficient. For example, the data center at the SFO airport in San Francisco is designed to save 60 percent of energy typically consumed by such facilities. The cooling is done using glycol — a liquid that evaporates to produce refrigeration. Even more efficient are data centers cooled by free cooling. Here, the cooling is done using ambient air, so there is no need for refrigeration at all. “That’s a tremendous saving,” says Dragon. “Data centers in the desert are also being built, using air conditioning instead of refrigeration. We have already done some pilot projects.”

City planners expect improved efficiency to offset the high cost of implementing advanced energy solutions. In fact, the energy required per Masdar resident is projected to be only one fifth of today’s consumption. This goal can be achieved if forward-looking and modernized buildings are built close to each other. In line with this philosophy, buildings in Masdar will be built close to one another, along narrow, shaded streets. This will reduce air conditioning requirements. In addition, buildings will be built on concrete pedestals, thus helping to maintain cool temperatures by allowing air to circulate beneath them. Today, 70 percent of the energy consumed worldwide is used in buildings to provide heating and lighting. But in the future, intelligent building management systems will ease the load on power and heat networks — and even feed self-generated electricity into the grid.

The environmentally-friendly city of the future is being built in a desert in the United Arab Emirates. Not far from Abu Dhabi, workers from all over the world are building Masdar City. When complete, the city is expected to have 50,000 inhabitants, meet its energy requirements entirely from renewable sources, and produce zero carbon dioxide, a major greenhouse gas (Pictures of the Future, Fall 2008, p. 76). Power is to be generated primarily by solar-thermal power plants and photovoltaic facilities.

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When asked about the electricity meters in the Swiss municipality of Arbon, Jürgen Knaak, head of the local power utility, Arbon Energie AG, says, “It’s time to get out of the dark!” What Knaak is referring to is the fact that for a very long time nearly all electricity customers and suppliers around the world have suffered from a huge lack of information. Consumers know nearly nothing about their electricity consumption habits, while suppliers know very little about the state of their grids.

Today, however, suppliers are installing smart meters capable of such real-time data delivery. Having such data made available in something closer to real time would conserve resources, as consumption could then be flexibly adjusted, prices for consumers lowered or raised in line with peak loads, and power generation capacity stepped down when less electricity is needed.

Meters capable of such real-time data delivery were not available to the average consumer until recently — but now, more and more power suppliers are installing smart meters that electronically measure electricity consumption. Alexander Schenk, head of the AMIS Business Segment at Siemens’ Power Distribution Division, explains: “Smart meters don’t just substitute a digital display for mechanical cogs; they also automatically forward consumption data to a control center and have a feedback channel.” Among other things, this enables suppliers to send price signals to customers, who can then reduce consumption during peak times in order to save money. One smart meter now on the market is the AMIS model from Siemens, some 100,000 of which are scheduled to be installed in Upper Austria by early 2010 (see Pictures of the Future, Fall 2008, p.63).

Residents of Arbon, Switzerland, on the shores of Lake Constance will also soon be enjoying the benefits offered by the Siemens meter. “The near-real-time transmission of data from households, special contract customers, and the power distribution structure gives us the kind of insight we need as to what’s going on in the grid,” says Arbon Energie’s Knaak.

“This allows us as a supplier to make more precise forecasts of peak load times, and thus plan more efficiently.” Arbon residents will be among the first in Switzerland to know exactly how much electricity they’re using every month, instead of having to pay estimated fees, as was the case in the past, and then receiving a huge bill at the end of the year. So living in the dark about one’s own electricity consumption will soon no longer be an issue, at least not in Arbon.

The benefits that smart energy meters offer to electricity companies go far beyond improved grid load planning. For one thing, the manual reading of conventional meters is subject to errors that generate additional costs, such as the need for a second readings. These require disproportionate amounts of time and energy in comparison with standard billing trips. Smart meters, on the other hand, are read automatically. “On average, around three percent of the readings of conventional meters are erroneous and need to be repeated,” says Dr. Andreas Hom, head of Services at Power Distribution. “Smart meters reduce this error rate to nearly zero. So, if you’ve got an area with a million customers, you can save more than €1.6 million per year, which corresponds to 53 percent of the previous cost for readings.”

Smart meters enable consumers to monitor and manage their power use. Utilities also save money and, for the first time, gain detailed insight into network dynamics.

No More Flying Blind. Most smart meters are now being used in highly developed countries, with dozens of projects currently underway in the U.S. and Europe. Direct economic benefits are generated in such nations mainly through a decrease in blackouts and efficiency gains in service processes. By installing around 30 million smart meters with feedback channels, Italy’s state supplier ENEL, for example, has been able to automatically carry out 210 million meter readings. The initial investment of €1.7 billion can be amortized relatively quickly through savings of around €500 million per year, while service costs per customer and year have been reduced from €80 to €50.

EnBW O&G, which supplies electricity to the region east of Stuttgart, Germany, is now replacing its conventional meters with Siemens AMIS units along with the complete meter data management system. Ninety percent of the company’s new meters communicate with a central server that processes the huge amounts of data, with most of this data transferred occurring via power line communication — in other words, the grid itself.

And in New Zealand, Siemens went a step further by establishing a joint venture with Vector, a local power supply company. The JV runs Vector’s IT infrastructure and handles its readings and data processing operations, which form the basis for customer invoices. “Smart metering is leading to the formation of new business models,” says Philip Skipper, from Siemens Metering Services. “In this case, Siemens is serving as a service partner that does the work formerly carried out by the company’s metering department.”

Power companies worldwide have begun installing electronic smart meters that allow customers to monitor consumption practically in real time and thus conserve energy. Such companies benefit from better grid load planning and lower costs. Siemens offers complete solutions that include everything from hardware to software.

Power companies have begun installing electronic smart meters that allow customers to monitor consumption practically in real time and thus conserve energy. Such companies benefit from better grid load planning and lower costs. Siemens offers complete solutions that include everything from hardware to software.
Smart grids are a hot topic in the U.S. What’s your vision of this area? Arvizu: Of course no one knows for sure what a smart grid will look like, but I envision it to be flexible, interactive, less vulnerable than present systems, information-rich, and just plain more sophisticated. Today we see electricity mainly coming from a network of big cables that have central power stations at various intersections. It provides a base load, on top of which varying demands met. The future of the electric grid looks different, though. The grid will probably not be centralized for much longer. It will meet real-time needs better, and it will transport energy more efficiently than the present-day grid.

Can you flesh this out a bit? Arvizu: Today more than 60 percent of the energy content in our supply gets lost in inefficient conversion to electricity at the power plant or on its way to provide service to the consumer. Clearly, this has to be done much more efficiently — for example, transmission efficiency can be improved by long distances by using a high-voltage direct-current transmission system. The grid of the future will also be able to integrate much more energy produced by solar, wind, and other renewable energy sources. And since these sources will be more widely distributed throughout the country, energy will have to be bundled and distributed more intelligently and the grid will need to be able to accommodate coupled with varying loads. Finally, tomorrow’s grid needs to be protected from physical and cyber attacks.

What advantages does the smart grid offer for consumers and energy producers? Arvizu: Mostly it gives you one thing — the opportunity to make wise decisions about your energy use and ultimately save energy and save money! The smart network will allow consumers to monitor their electricity use, make choices about appliances and their use, and manage their overall energy needs based on this information. This will also allow energy providers to know how much energy their customers actually use. That in turn may help them develop more accurate predictions of energy demand and meet it accordingly.

How far has the smart grid advanced so far? Arvizu: Worldwide, there are a number of pilot projects. One particularly exciting example is in Boulder, Colorado and is called “Smart Grid City.” We are involved in this project, which interconnection challenges that the important element of the project is the installation by Xcel Energy, the sponsoring utility, of a broadband interconnection infrastructure that allows information to flow both ways between the consumer and the electricity utility. Forty-five thousand two-way meters are being installed. Additionally, a limited number of participating households will be able to see online how they consume electricity through everything that helps. And in several cases will have Web-addressable appliances that allow their power use information to be transmitted to the Internet, where the total energy use in one’s house could be calculated. This opens up the prospect of eventually doing away with the physical meter and measuring use only on the Internet.

How does the U.S. compare with other countries in terms of what smart grid implementation? Arvizu: When it comes to deployment of renewable energy technologies, the U.S. lags behind other industrial countries. Other countries have been driven primarily by heavy government subsidies for solar and wind energy. That’s what Germany has done. This has forced some countries, such as Denmark and Germany, to successfully deal with some of the interconnection challenges that the scale and demand side of the energy sources represent. Still, when it comes to the smart grid, we have an even playing field; everybody is facing the same challenges.

You often point out that energy in the U.S. has to become cheaper and be competitive with fuel in India and China. Today safety regulations, labor costs, and commodity prices keep energy prices high. How can they be reduced? Alternative energy in the U.S. continues to be more expensive than conventional energy. Arvizu: That has to change. When we speak of alternative energy, we mean wind, solar, hydropower, etc. These sources have to become the rule, not the exception. And they have to survive economically on their own, without any subsidies. I believe this can be achieved through technological innovation and market incentives such as emissions trading for CO₂. We also have now it’s time to see if they can be produced commercially. In contrast, there is a company named HelioVolt in Texas, which we helped to develop thin-film solar cells. They are not as efficient as those photovoltaic cells produced by RF Micro Devices, but extremely inexpensive. Both examples represent exciting next-generation technologies that may replace crystalline silicon solar cells — and these are just two of many exciting things going on in the lab.

What challenges will the massive integration of solar and wind power plants into the modern grid pose? Arvizu: The main problem is that wind and solar power are in variable, rather than constant, supply. Additionally, these plants are often far from urban centers. So one of the things that we have to do is to intelligently interweave various energy sources that produce the equivalent of a base load, which today is still being met by coal and nuclear power plants. Also, we should learn to use power when it is available. For example, we could use electric cars, refrigerators, hot water boilers and industrial machinery in a way that takes advantage of a cheap surplus of energy when it is available.

Wind turbine blades the height of a church tower are transported by railroad from a Siemens plant in Fort Madison, Iowa, to their destinations. These are limitations to the potential that realistically can be achieved. In one study we made some realistic assumptions and asked if it’s feasible to produce 20 percent of electricity in the U.S. from wind by 2030. Our conclusion is that this is not a crazy idea. The necessary technology already exists. The current remaining hurdles are politics, financing and transmission.

A consortium of companies, banks, and European states recently announced it intends to build a giant solar energy plant in northern Africa to transmit electricity to Europe. Is something like this conceivable for the U.S.? Arvizu: Sure. In the Southwest there’s plenty of sun and the desert is huge. At this scale and with appropriate transmission, solar energy becomes profitable.

Interview: Hubertus Breuer
The many hiking trails around the village of Niederensee in the state of Westphalia, Germany, offer tranquility, bird songs, the Möhne River and unspoiled nature. As idyllic as this setting is, a small hydroelectric power station built in 1913 does not look out of place here. With an output of 215 kilowatts, the facility is one of the region’s smaller power plants. Yet its Siemens-Halske generators have been tirelessly producing electricity for nearly 100 years. And now these hardworking old-timers have become a key part of a much larger, innovative high-tech plan. Since October 2008 they have been interconnected with eight other hydroelectric plants on the Lister and Lenne Rivers in a rural part of Westphalia known as Sauerland as part of ProViPP, the Professional Virtual Power Plant pilot project of RWE (a power plant operator) and Siemens. Just about everybody stands to gain from the project — power plant owners, electricity traders, power grid operators, and of course the end customer, who could profit from more intense competition. The virtual power plant concept complements the big utility companies with their large, central power plants by creating new suppliers with small, distributed power systems linked to form virtual pools. Such a pool can unite wind power, cogeneration, photovoltaic, small hydroelectric, and biogas systems as well as large power plants — fully automatically. “Individually, such plants have established a key prerequisite for new forms of marketing. ‘Individuals, such plants are too small to market their capacities through energy traders on the energy exchange, or an additional data set for load fluctuations to power grid operators,’” says Kramer. “To market electric power on the energy markets for minutes reserves — the power that must be available on demand within 15 minutes — a virtual power plant is required to have a minimum capacity of 15 megawatts.” Today, since the nine-member virtual power plant does not reach that level, it feeds its energy into the grid in accordance with German’s Renewable Energy Law (EEG). Following a planned expansion, however, its power will be sold directly in the energy market.

Cool Controls. At the heart of Sauerland’s virtual power plant is Siemens’ Distributed Energy Management System (DEMS). The system displays the present status of systems, genera- tes prognoses and quotations, and controls electric power generation as scheduled. The system overview is subdivided into producers and loads, contracts, and power storage. Conveni- ently positioned at the center of the display is the “balance node” (the sum of the incoming and outgoing power must equal zero). Additional information is provided on “forecasting and usage planning” and “monitoring and control.” As a result, a portfolio manager can view color bar graphs showing which power stations are currently running at peak load or base load and how much power they are producing.

As part of a virtual plant, even small energy producers can sell their power on the electricity market. Using plant status information, such as electric power output, and combining it with market forecasts, DEMS generates a forecast that also takes into account the next day’s prices and the total power available. Even weather data is factored into the energy manage- ment system to provide a forecast of the power available from sources with fluctuating availability, such as wind and sunshine.

Before a quotation is placed on the energy market through an energy trader, it is checked and approved by the portfolio manager. Once it has been approved and accepted by the mar- ket, DEMS generates an operating schedule for the individual power plants in the virtual plant. The schedule specifies exactly when and how much power must be available from which plant. “DEMS does such a good job of model- ing that its schedules can be run exactly the way it defines them,” says Dr. Thomas Werner, Product Manager, Power System Management at Siemens Energy. No manual corrections are needed.

Martin Kramer of RWE agrees. “The system is working extremely well. Once a schedule has been generated, the energy management system controls the entire process — including the requirements of the individual power plants — fully automatically.” DEMS was developed by Siemens when it became evident how the electric power grid and the electric power market would be af- fected by increasing supply from distributed and renewable energies (Pictures of the Future, Fall 2007, p. 90). In the background, communication systems ensure reliable connections between the control center and individual power plants. Siemens communications devices in power stations link the stations with the control cen- ter via wireless communication modems. The advantage of this approach is that it requires no costly cables or rented landlines.

As a virtual power plant is highly distributed. Its DEMS computer is in a control center in Plaidt near Koblenz, the operator stations are in Cologne, and the power plants are in the

Small, distributed power plants, fluctuating energy sources such as wind and sunlight, and the deregulation of electric power markets have one thing in common. They increase the need for reliable and economical operation of electric power grids. The virtual power plant is an intelligent solution from Siemens. It networks multiple small power stations to form a large, smart power grid.

Power in Numbers

As part of a virtual plant, even small energy producers can sell their power on the electricity market.

Externaly, the nine small hydroelectric plants in the project function as a single large one. Their total initial output for pilot opera- tion was 8.6 megawatts. Even though this virtu- al power plant is not yet actively participat- ing in electric power trading, its constituent plants have established a key prerequisite for new forms of marketing. “Individuals, such plants are too small to market their capacities through energy traders on the energy ex- change, or an additional data set for load fluctuations to power grid operators,” says Kramer. “To market electric power on the energy markets for minutes reserves — the power that must be available on demand within 15 minutes — a virtual power plant is required to have a minimum capacity of 15 megawatts.” Today, since the nine-member virtual power plant does not reach that level, it feeds its energy into the grid in accordance with German’s Renewable Energy Law (EEG). Following a planned expansion, however, its power will be sold directly in the energy market.

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timeframe to stabilize the net frequency at 50 or 60 hertz.

Prof. Christopher Weber of Duisburg-Essen University estimates that an energy trader with a virtual power plant can increase earnings by several hundred thousand euros by paying less or more power into the grid than had been specified in the operating schedule. To avoid this, the electric power producer needs to adhere as closely as possible to the agreed-on operating schedule—and that’s the purpose of an energy management system such as DEMS. An interesting alternative to generating additional power is for the central control station to briefly shut down large-scale consumers such as aluminum smelters. Another useful alternative is to sell electric power at the European Energy Exchange (EEX) in Leipzig, provided that the cost of producing one megawatt hour is lower than the current exchange rate.

There are other uses of virtual power plants, as was shown in the case of a municipal power plant in Germany’s Rhineland region. Augmenting electric power lines to supply energy for a new residential area would have required a large capital investment. So instead of new lines, the area’s electric power needs were met by installing distributed, gas-powered, biomass block-type cogeneration plants and interconnecting them to form a virtual power plant that delivers electric power and heating. This made it possible to postpone a huge investment for several years. Virtual power plants could also be “produced” from less obvious components, such as by interconnecting the emergency power generators in hospitals and factories with the battery storage systems common in telephone and Internet communications centers.

Virtual power plants also have a macroeconomic advantage. “The benefit of a power station network extends far beyond its present applications,” says Werner. At present consumption rates, for example, global copper reserves will be exhausted in 32 years (Pictures of the Future, Fall 2008, p. 22). And if the infrastructures of countries such as India and China consume as much copper as the industrial countries, shortages and price increases of this scarce metal are likely to occur soon.

But if newly-industrializing countries base the expansion of their energy infrastructures on intelligent power grids and virtual power plants that generate electricity near where it will be used, i.e. in a distributed system, fewer power lines will have to be built to transport electricity, and the limited copper reserves will last longer.

Harald Hossenmuller

Growing Demand for Renewables and Smart Grid Technologies

A

ccording to the International Energy Agency (IEA) and Siemens, by 2030, worldwide electricity generation will grow by 63 percent relative to 2008, to a total of 33,000 terawatt hours (TWh). An increasingly large proportion of this power will be based on renewable energy sources. The IEA and Siemens expect that the amount of electricity generated from wind, solar energy, biomass, and geothermal energy will increase nearly tenfold from 581 TWh to 5,583 TWh, with wind power driving much of this growth. According to these projections, the amount of wind-generated electricity fed into the grid will increase around thirteenfold.

Even more impressive is the growth in solar electricity, which is expected to grow 140fold, but from a much lower level. If at least a portion of the Desertec project (p. 19) is completed by 2030, much of this additional solar electricity could be produced by solar thermal power plants in the deserts of northern Africa and the Middle East, in addition to photovoltaic systems. According to a recent study by Clean Edge Inc., a market analysis company specialized in the clean technology sector, worldwide sales for solar thermal and wind energy systems and installations will increase from roughly $116 billion in 2009 to $325 billion in 2018. Sales of solar thermal systems, which Clean Edge did not take into consideration, must also be added to this figure. Wind power will generate some $140 billion by 2018.

Despite this growth in renewable energies, roughly 54 percent of the electrical power worldwide in 2008 will still come from fossil energy sources such as coal and natural gas. In order to protect the climate and to reduce greenhouse gases, it is crucial that the efficiency of the associated power plants—in other words, the conversion of the energy contained in the raw materials into electricity—be increased. Technologies must also be found to remove carbon dioxide—either before or after combustion process problems. One such problem that should not be underestimated is the fact that wind and solar power are incessantly and often unavailable when they’re needed most. A test performed by Ludwig-Bölkow-Systemtechnik GmbH using data from the E.ON electric grid showed that there were also days (March 17 and 18 in the graph below) when the available wind power exceeded grid demand. With continued massive expansion of the number of wind power plants, this situation will be exacerbated and become more frequent in the future, even as the supply of wind power continues to be well below demand on wind-less days.

There is a two-proposed solution to this problem. On the one hand, energy storage (see p. 31)—whether in the form of pumped storage power plants, compressed air storage, hydrogen caverns, or even the batteries of electric cars (see p. 44) — could be expanded. On the other hand, electric grids could be more comprehensively linked—across regions, national borders, or even continents. The expansion of power grids is already unavoidable because offshore wind farms (see p. 16) and solar thermal power plants in the desert will have to be connected. Siemens is among the companies currently involved in the erection of a high-capacity, high-voltage direct current transmission lines (HDC) in China to link hydroelectric plants in the country’s interior with mega-cities more than 1,400 kilometers away on the coast (see p. 24). The State Grid Corporation, a grid operator in China, expects $44 billion will be invested in HDC technology by 2012.

According to the UCTE—the Union for the Coordination of Transmission of Electricity—some $500 billion must be invested in new power and gas lines in Europe over the next 25 years. “German utility companies alone plan to invest €40 to €50 billion in the modernization of the grid, with €15 to €25 billion that going into smart grid technology,” says Roj Adam, a principal at Bos & Company.

Smart grids (see p. 12) involve not only intelligent electric meters and solutions for flexible billing, but also energy management, grid status monitoring, and the integration of a wide variety of small, decentralized power generators and consumers. All of this is intended to make power grids more transparent, more flexible and more accessible to users.

Market experts at All Research expect that roughly 73 million smart meters will be installed worldwide in 2009. Two years ago, the equivalent figure was just 9 million. In the U.S. alone, the government hopes to have a grand 41 million intelligent meters installed as part of 15 projects by 2015. The U.S. Electric Power Research Institute (EPRI) estimates that the creation of a nationwide smart grid over the next two decades will cost around $1.3 trillion.

Based on IEA and EPR data, market analysts at Morgan Stanley Research estimate that the worldwide market volume for smart grid technologies will increase from roughly $22 billion in 2010 to $115 billion in 2030. This corresponds to an average annual growth rate of 8.6 percent, making smart grid technologies one of the most exciting growth markets of the decades ahead.

How Renewables will Grow 2008-2030

Sources: Siemens, IEA, World Wind Energy Report et al.
Tomorrow’s electric vehicles will redefine mobility. Not only will they recharge in only minutes at fast-charge stations. They will also function as mobile power storage units for the smart grid.

In Spring 2009 at the Geneva Motor Show in Switzerland, Ruf and Siemens presented a Porsche 997 Targa-style model that had been converted into an electric car known as the eRuf Greenster (see Pictures of the Future, Spring 2009, p.96). This vehicle, which offers 370 kilowatts of power and a top speed of 350 kilometers per hour, also boasts high torque and impressive acceleration right from the start. Whereas a combustion engine needs some time in order to fully develop its power, an electric motor delivers its full performance immediately.

The Greenster is a pioneering vehicle that demonstrates just how chic electromobility can be. Still, because the model was developed in only three months, its individual components were not all part of a new component approach but instead represent a combination of available standard components. “The successor Greenster II model, which is already being planned, will have optimally matched components,” says Prof. Gerhard Spiegelberg, head of the Electromobility Team at Siemens Corporate Technology (CT). Such components include a fast-charge unit and precisely tuned components for battery management, motor control, and charging electronics. The Greenster II will be completed by the end of 2010.

Standardized Charging. The Dakaras, for their part, will be charged at the UN conference with wind power. Power will be used in a shuttle service between the conference center and the airport. Each vehicle can accommodate four passengers and their luggage. The Dakara concept includes a “power pump” from Siemens that communicates with the vehicle’s electronics. This is one of the key “technologies for electromobility” — and not just in Denmark. After all, drivers will want to recharge their electric vehicles at any location — be it a garage, supermarket, or company parking lot. In a manner similar to cell phone charging, the electricity used will be billed by a provider. However, for such a system to work, it will be necessary to reliably identify the vehicle and exchange data between its onboard electronics and the charge pump. In a project with energy supplier RWE, Siemens will soon be installing 40 charging stations at locations in Germany, with 20 stations planned for Berlin. In addition, RWE is now staging a roadshow in Germany that features the Greenster. Siemens is participating in the tour, which also made a stop at the IAA International Motor Show in September 2009 in Frankfurt am Main. Siemens is pursuing the development of electromobility through a comprehensive approach involving not only automotive engineering — as is the case with Greenster and the Dakara — but also systems for connecting vehicles to the power grid. Here, both the charging process and communications are being addressed. Spiegelberg refers to these two areas as linked via medium-voltage switchgear. Having several thousand vehicles parked in one place will require major facilities, and these will have to be installed in basements or separate buildings. After all, if 10,000 vehicles simultaneously tap the grid for 20 kW each, the resulting required output will be 200 megawatts — which is what a medium power plant produces.

Siemens covers all facets of electromobility — from vehicle technology to power grid integration.

From Wind to Wheels

Industrial companies and energy suppliers are working closely together to make the vision of electric mobility a reality. Along with automotive engineering, the focus here is on the interaction between vehicles, the power grid, and the technologies needed for storing and bidirectionally transmitting energy derived from renewable sources.

When the west wind rises and the North Sea begins to churn and send its heavy breakers crashing against the dunes of Jutland, thousands of windmills go into action on the Danish coast. Today, 20 percent of Denmark’s electricity is produced by wind power, making it the world leader in this area, and this figure of electric mobility a reality. A long with automotive engineering, the focus here is on the bidirectionally transmitting energy derived from renewable sources.

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40 kW, are connected to the grid, a total output of eight gigawatts would be available at short notice — more than Germany requires as a cushion against consumption peaks.

In addition to Siemens, the EDISON consortium includes the Technical University of Denmark (DTU) and its Risø DTU research center, as well as Denmark’s Bong Energy and Økstofa power utilities, the Euroiso research and development center, and IBM. In the EDISON project, various working groups are responsible for developing all the technologies needed for electromobility. Here, Siemens is mainly responsible for fast-charging and battery replacement systems. “Siemens’ portfolio also includes the development of bidirectional test rigs in Spiegelberg’s team. Later on, we’ll connect the vehicles to a simulation of the grid that will be provided by the Energy Sector,” says Holthusen. This will be done to determine how smoothly a vehicle can be connected to the grid infrastructure.

We can’t even begin to imagine the type of revolutionary breakthroughs that electromobility will lead to.

Prof. Gernot Spiegelberg (right). With the Greenter model, Siemens and Rull are demonstrating how attractive electric cars can be. When used as grid-connected storage units, they can earn money with their batteries.

Where Motors Are Going. While the Dakaras are being readied for their assignment in Copenahgen, Kuhn and his colleagues are testing a system for the Greenster II, the younger brother of the model presented last March. Greenster I was a concept car — but Greenster II will be the world’s first Porsche-based electric vehicle to be manufactured in a small production series. The key component here is a double motor for the rear axle. Whereas the Greenster I was equipped with a rather large central motor, in the Greenster II each rear wheel will be propelled by a small drive unit located relatively close to the wheel. Usually, the output of a motor is distributed across the wheels via a differential, which isn’t an ideal arrangement for fast cornering. The double-motor concept, however, uses an electronic control system that ensures optimal propulsion of the right and left wheels, which are exposed to different loads in a curve. It’s thanks to this phenomenon, which development of electric vehicles whose four wheels will each be equipped with their own small drive unit,” he says. These motors will recover all the energy that is available for the transmission and axle shafts, thereby creating more space.

Moreover, unlike axle shafts, electronic components can be installed anywhere in the vehicle and don’t necessarily have to be located near the electric motors. This will offer design possibilities never before seen. “It’s not just in Italy,” says Holthusen. “Electric cars will have to integrate large quantities of fluctuating wind and solar power and a growing number of small, decentralized power producers. The key technologies for such smart grids will include intelligent electric meters and virtual power plants.”

It’s already clear to Spiegelberg what will happen next. “The coming years will see the experts refer to as torque vectoring, that a driver can still handle a vehicle perfectly in extreme situations. With a central motor concept, all the power must be transferred via a bulky and heavy differential, which adds weight to the vehicle. With the double motor concept, however, a small control unit is all that’s needed to send commands by wire to the individual electric motors. Kuhn and his colleagues are now studying how well the electronic differential works. “It’s not just in the ‘outside car’ area that we’ve still got a lot of work to do,” says Kuhn. “The electric drive system is also highly complex in its own right.”

Siemens is building the world’s largest offshore wind farm with a capacity of 1,400 megawatts. The power generation process takes place onshore, and the electricity is transmitted offshore over a distance of 30 kilometers. All this adds up to a complex system.

Siemens is also building a high-voltage direct current transmission (HVDC) line, which will transmit 5,000 M W — equal to the output of five large power plants. (p. 24)

Siemens is building the world’s largest HVDC system in China. In 2010 the system will begin transmitting electricity at a record voltage of 800 kV over a distance of 1,400 kilometers from hydroelectric plants to the southeastern coast of China. This will cut the country’s annual CO2 emissions by around 33 million metric tons. The HVDC Grid will transport 5,000 M W — equal to the output of five large power plants. (p. 24)

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Despite the current economic crisis, Siemens is investing venture capital in agile, innovative companies, many of which work with green technologies.

Transparent Energy Systems began in a backyard in Pune, India, in the late 1980s with the production of small industrial steam boilers. Even then, the company’s boilers were more energy efficient than any others available in India. “The energy yield was at least five percent higher than that of boilers from rival firms,” recalls CEO B. G. Kulkarni with pride.

Today, 20 years later, Kulkarni and his team are involved in the production of major industrial systems. Among the solutions they offer are those that convert industrial waste heat, such as that produced by cement plants, into electricity. This saves money and helps protect the environment. Transparent Energy Systems generate up to 16 megawatts of power — energy that used to be blown into the air as unused heat.

“Our solutions meet our customers’ needs — and not just in India,” says Kulkarni. So in 2008 he started looking for a partner who understood all aspects of his products and business model — and reached an agreement with Siemens Venture Capital (SVC) in May 2009. SVC usually acquires a minority interest in companies and matches all key production power consumers. Food production facilities, where refrigeration units account for a big share of electricity consumption, are a good example. Using predictive algorithms, Powerit’s software determines when, how, and by how much to turn off or down equipment without affecting food quality or production. “Our experience with various industries gives us precise knowledge of the processes involved,” says Zak. “We use this data to generate complex decision-making matrices that help us balance energy savings with productivity requirements.” And the systems are adaptive, so they can adjust to a plant’s changing electric profile.” This strategy makes it possible to reduce the power consumption not only of ongoing processes but also of processes to be carried out at a specific time in the future. Powerit Solutions exploit such capabilities to take advantage of demand response programs — special contracts that allow providers to cap electricity supply at short notice, for example in midsummer, when air conditioners are running and the grid is in danger of overloading. Customers can save millions of dollars in just a few years through these programs, enabling them to recoup their initial investment very quickly.

While Transparent Energy Systems specializes in the utilization of waste heat (large image), Powerit Solutions (below) develops software that helps to avoid demand peaks, for example at wineries.

 Pictures of the Future | Siemens Venture Capital
52 Investments that Pay
Many cities can’t afford to invest in their deteriorating and inefficient infrastructures. However, modern transportation and supply systems not only improve quality of life but also save money. Pages 52, 72, 76

55 Simulation Tools on Tap
Designing networks of pipes, pumps and valves to transport drinking water and waste water is a huge challenge. Siemens is designing a simulation tool that vastly simplifies all of this, long before water flows.

56 New Life for Old Plants
Modernization could significantly boost the efficiency of hundreds of fossil fuel-burning power plants all over the world. Siemens has the necessary solutions.

60 Green Campus
Many educational institutions are burdened with energy-hungry and cost-intensive buildings. However, help is at hand in the form of efficient building technologies that quickly pay for themselves and then go on to save their operators money.

80 A Model of Mobility
Vienna, Austria boasts an excellent public transportation system. The city has also invested in LED traffic lights. The lights save lots of money and power.

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**The Living Desert**

Yemen, 2025. The formerly flourishing trading city of Shibam was once in danger of becoming a ghost town. Urban planner Bassam Haj Ali shows a former college friend how this ancient city became attractive and livable again, thanks in large part to high-tech infrastructure solutions.

The city of Shibam, once a trade hub of the Arab world, was on the brink of ruin. Its inhabitants were moving away, the clay houses were collapsing, and the infrastructure was crumbling. But a long-term modernization program brought back prosperity and population growth. In 2025 Shibam is one of the most modern cities in the Arab world, as urban planner Bassam Haj Ali proudly explains to his old friend François Runné.

There it is — the Manhattan of the desert! After a short ride down some steep reddish-brown cliffs, French architect François Runné is overwhelmed as he gazes on the clay houses of Shibam. “Yes, it’s really amazing, isn’t it?” says his college friend, urban planner Bassam Haj Ali, who has halted his horse next to Runné’s. “Three hundred clay buildings, some of them 30 meters high. And just imagine, the oldest house was built when Columbus set out westwards to find a sea route to India.” But then he sighs, “Just a few years ago this magical place was almost destroyed.” “Yes, I heard something about that,” says François. “The city used to be a trade hub of the Arab world, but with the advent of...
modern means of transportation it lost signifi-
cance. People moved away, and the houses and the infrastructure started to deteriorate. It was a vicious circle."

"That didn't start to happen until the begin-
nning of this millennium," explains his friend. "An international development company came to our city along with some government repre-
sentatives. They built schools, dug deep wells to re-
 vive oases in the surrounding region, and thus helped local farmers reap rich harvests. Mean-
while, they trained local craftsmen to restore the clay houses not only with the traditional methods but also by combining these methods with state-of-the-art technology whose effi-
ciency would offset the additional costs. Thanks to the know-how they acquired, the craftsmen became sought-after workers throughout the country. As the years went on, the city regained its former prosperity and was able to take over responsibility for the project. Ever since then I've wanted to be part of it."

François, who is squinting because of the bright sunlight, smiles at his friend. "By all ac-
counts, you've been successful, too," he says. Bas-
sam smiles back at him. "As you know, modesty isn't one of my strong points. Today Shibam is one of the most modern cities in the Arab world," he says. François looks at him in sur-

Bassam laughs and pulls a device resembling a flashlight out of his belt pouch. "The impor-
tant thing is what's behind the scene," he says as he presses a button. The device emits a small cloud of steam that settles to the ground at a

52

pictures of the future | fall 2009


not surprising that there are often breakdowns and accidents. In some cases, manhole covers have even become electrically charged."

New York is not alone in its predicament. London, for example, has a water main net-
work that loses more than 30 percent of its contents every day. Many residents of the British capital were unable to shower for days in the summer of 2006 because water leaking from defective pipes was being absorbed by the dry ground underneath the city. Infrastructure is vital for the survival of any city, regardless of whether the subject is traf-

transport and energy networks. That's counterproductive because modern infrastructures not only improve urban quality of life, they also save money.

Infinite Infrastructures — Scenario 2025

N

egative energy measures generally pay for themselves quickly. Many projects that Siemens is implementing around the world through its Environmental Portfolio clearly demonstrate how cities can reduce their emissions and energy costs while recouping most of the associated investment."

In Istanbul, for example, the company is equipping Bosphorus Strait ferries that are used by some 250,000 people every day with mod-
ern diesel-electric drive systems, which con-
sume much less fuel than the engines previ-
ously employed. Siemens has also improved the efficiency of the Ambardi combined cycle power plant by five percent through design optimization measures, whereby the increase corresponds to an added output of around 65 megawatts. In addition, Siemens has been op-
erating one of its most efficient production fa-

Steam pipe explosions and tangled power lines in New York, leaks in London’s water networks — even in industrialized countries, cities are struggling with dilapidated infrastructures.

I

vestment that Pay

Even as cities continue to grow, most are plagued by outdated infrastructures. With municipal budgets tight, too little investment is being made in sustainable transport and energy networks. That’s counterproductive because modern infrastructures not only improve urban quality of life, they also save money.

New York, July 18, 2007. A column of dust and smoke rises up from a street in Man-
hattan. Fire trucks, ambulances, and police cars rush to the scene at Lexington Avenue near Grand Central Terminal. But they’re not responding to a terrorist attack, as initially feared. Instead, an 83-year-old high-pressure steam pipe has burst, creating a 20-meter hole in the street. New Yorkers have suddenly be-

in the street. New Yorkers have suddenly be-

New York's steam pipe system is not only the largest in the world; it’s also one of the old-
est. Dating back more than 100 years, the net-
work’s first municipal heating system extends over 170 kilometers throughout the city, supplying heating and air conditioning units in large buildings with the steam they need. New York is also home to an extremely complex network of underground power and gas lines, subway tracks, and sewers, all of which run very close together, either next to or above or below one another. It is therefore
that consumes 80 to 90 percent less electricity than conventional traffic lights, and also lasts more than 630 million liters of water a day.

Companies like Siemens offer sophisticated consulting, installation, and financing services. The city of London, for example, built systems made up of hollowed-out tree trunks, water wheels, and water towers in order to supply their citizens with fresh water. In medieval Germany, this early form of hydraulic engineering was known as ‘water arts’.

Some 500 years later, water supply networks have really become works of art. Often stretching over hundreds of kilometers, today’s water distribution networks are by no means mere conduits. The Romans, for example, had an elaborate system of aqueducts to transport water over long distances. And towns in the middle ages built systems made up of hollowed-out tree trunks, water wheels, and water towers in order to supply their citizens with fresh water. In medieval Germany, this early form of hydraulic engineering was known as ‘water arts’.

Water distribution networks are by no means an invention of the modern age. The Romans, for example, had an elaborate system of aqueducts to transport water over long distances. And towns in the middle ages built systems made up of hollowed-out tree trunks, water wheels, and water towers in order to supply their citizens with fresh water. In medieval Germany, this early form of hydraulic engineering was known as ‘water arts’.

“Siemens researchers use virtual process models to develop and refine the automation technology required for optimized operation of water networks.”

Cutting CO₂. A study by McKinsey on infrastructure in London and a study by the Imperial Institute for Climate, Environment, and Energy regarding a CO₂-free future for Munich (see Pictures of the Future, Fall 2008, p. 58, and Spring 2009, p. 6) indicate what a sustainable long-term investment might look like. Siemens participated in both studies. In London, for example, it would be possible to use currently-available technology to reduce energy consumption, water consumption, waste, and emissions by over 40 percent by 2025. That’s more, it would be possible to do so without negatively impacting the lifestyles of the city’s residents. The interest required over 20 years would be equal to less than one percent of London’s annual economic output.

Munich, for its part, could reduce its CO₂ emissions by 80 to 90 percent by 2058. Here the emphasis is on measures for increasing energy efficiency. The list includes heat insulation and heat recovery systems in buildings; the exploitation of energy-saving electrical devices and lighting systems; the use of buses, trains, and electric cars; the construction of combined heat and power plants and renewable energy facilities; and the transmission of low-CO₂ electricity over long distances.

Such huge investments would also have to be invested in the modernization of existing buildings and the construction of new ones in accordance with the energy-saving passive house standard. Such investments would, however, be in line by annual energy cost savings of €1.5 to €2.6 billion by 2058, which corresponds to savings of around €2,000 per resident. All in all, the savings achieved over 50 years would total over €30 billion — a figure that should convince even skeptics that, when thinking about energy and infrastructure, the economy and the environment go hand in hand.

Sebastian Weber

Modernizing Infrastructure | Trends

Infrastructure investment accounts for around €700 billion of the total outlay for stimulus packages worldwide. As a result of Siemens’ extensive range of modernization proposals it will be possible to reduce energy costs by ten percent (see p. 66).

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Efficient solutions in the form of LED traffic lights, diesel-electric drives in the Broppeus hieron (aerostatic), and modernization measures at Denver Airport dramatically reduce operating costs.

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 length of the mains enormous, but the com- plexity of the network itself means that with- out some form of computer support it would be virtually impossible to assess the impact of operational procedures on the pressures and flow rates throughout the system. This is the case when, for example, a water main has to be temporarily shut off for upgrading or en- largement of the network, which can result in undesirable consequences such as an increase in water pressure in nearby mains. The planning, construction, and opera- tional management of such networks present a special challenge. Problems in harmonizing the control and automation technology are by no means uncommon,” explains Dr. Andreas Pirsing, an automation and process control engineer at the Siemens Water/Wastewater Competence Center in Nuremberg, Germany, which is part of the Industry Automation Divi- sion. Indeed, until recently the only way of as- certaining whether the automation technology in a new water network actually functioned as intended was cumbersome. “Our objective is to de- velop and perfect automation technology for a planned or upgraded water network on the ba- sis of a virtual process model of that network. In this way, we can be sure that the automa- tion technology and the network are perfectly matched automation technology substantially reduces water and energy consumption, model with all its virtual pumps, motors, and valves. Using virtual water flows, it is then pos- sible to test the operation of the entire system with all its open- and closed-loop control sys- tems. This includes an examination of poten- tial incidents such as a pump running dry due to a valve being closed erroneously or leaks re- sulting from excess pressure in the system. Conversely, faults can be introduced — a stuck valve, for example — in order to test how the automation technology reacts. Once it has been demonstrated that the real automation technology is compatible with the virtual process model, the solution can go to the customer. If all goes as planned, Pirsing will present a prototype of his integrated engineering tool in 2010. “Using this technology, we will be able to show the customer that a system functions flawlessly before construction begins,” he says. “That’s something completely new in the water industry.” Pirsing, who is confident that this system will help Siemens substantially increase its share of the 64 billion water industry. At present, the company holds around ten percent of the world market. “Siemens still has plenty of room for improvement in this area,” says Pirsing, referring to Avedi Kuhail Corporation, which researchers are currently redefining the art of water engineering. According to Dr. Oliver Geden, an expert for EU climate policy at the German Institute for International and Security Affairs in Berlin, effective climate protection begins when “many people consume in an environmentally sustainable way, without having to think twice about what they’re doing.” For this to happen, says Geden, it will take huge structural changes in how we generate and consume electricity, including expanded use of renew- able energy, and more efficient conventional power plants. Significant progress has already been made in the construction of new power plants. From the period over the 1992 to the present, the effi- ciency of the latest coal-fired power plants in the industrialized West has risen from 42 to 47 percent. This amounts to a huge advance in climate protection. For instance, a 700- megawatt (MW) generating unit, an increase in efficiency of five percentage points trans- lates into a reduction in annual CO₂ emissions of around 50,000 metric tons. This is particu- larly important for China, where, according to the International Energy Agency, one new coal-fired power plant with an efficiency of over 44 percent enters commercial service every month. When it comes to upgrading existing power plants, however, there is still massive un- tapped potential, both in economic and envi- ronmental terms. The average efficiency of Eu- rope’s coal-fired power plants is a mere 37 to 38 percent. Only about one in 10 plants tops the 40 percent mark. That’s hardly surprising, given that steam turbines in Europe are, on average, almost 29 years old. Gas turbines, on the other hand, are usually of a more recent vintage, with an average age of just under 12 years. Nevertheless, the German Association of Energy and Water Industries (BDEW) esti- mates that around one-quarter of Germany’s power plants will need to be modernized in the immediate future. As Ralf Hendricks from Siemens Energy explains, the increasing exploitation of alter- native energy sources is also accelerating the pace of modernization. “In Europe, power companies have to convert a lot of older combined-cycle power plants from base- to peak-load operation,” says Hendricks, who is responsible for so-called lifetime management and thus for power plant upgrades. The reason for the conversions is that Eu- rope is ramping up use of land-based and off- shore wind farms. When winds are strong, these farms generate lots of electricity, which means conventional plants can scale back out- put. But when winds die down, the latter have to be able to reach peak load rapidly to com- pensate for load fluctuations. The ability to re- act rapidly not only secures a power company high prices on the power market; an upgraded power plant also reaches its operating point more quickly, which cuts CO₂ emissions. Siemens is a specialist in upgrading steam turbines, a job that primarily involves replacing the rotor and the inner casing. The latest in turbine blade technology and enlarged flow areas boost the efficiency and performance of the turbine. In addition, the use of new seals in high- and intermediate-pressure turbines reduces clearance losses, which likewise in- creases efficiency. These measures lengthen the service life of the turbine, allowing it to remain in operation for an additional 15 to 20 years. As a rule, Siemens also renews the con- trol system for the turbine set or the power plant as a whole (Pictures of the Future, Spring 2009, p. 27). According to Dr. Norbert Henkel, responsible at Siemens for the modernization of fossil fuel and nuclear power plants, it costs between €20 million and €60 million to com-prehensively upgrade a steam turbine system for a medium-sized power plant. “By modern- izing the turbine, we can teas e an extra 30 to 40 megawatts out of the plant. As a result, the initial capital expenditure is amortized within just a few years,” he explains. Power generator Energie Baden-Württem- berg (EnBW), for example, has invested around €30 million on upgrading its cogenera- tion plant in Altbach, near Stuttgart, a meas-
In Europe, there are over 500 steam turbine plants that now require modernization — in India, less than 30.

Modernizing Infrastructures | Power Plant Upgrades

A new control system and upgraded steam turbine from Siemens boost output at EnBW’s cogeneration plant in Altbach, Germany by 11 MW and reduce CO₂ emissions by 50,000 metric tons a year.

rewriting that will keep it in action for the next 30 years. Siemens renewed the plant’s control systems and upgraded its steam turbine, replacing the blades and seals, which has made it more efficient and boosted its output by 11 MW. The entire outer casing could be retained. With around 4,000 operating hours at full load per year, the plant has benefited from the upgrade with a reduction in its annual CO₂ emissions of 50,000 metric tons. As a result, the plant is now classified as one of EnBW’s “green” facilities and may, if required, rack up additional operating hours.

North America’s power plants are even older than Europe’s, with an average of 34 years for steam turbines in the U.S. and Canada, and 17 years for gas turbines. Siemens is involved in a number of major upgrades in this area. Some of these cover more than just the turbine.

In the U.S. and Canada, many of the plants in France, the U.S., and Canada are rapidly upgrading their facilities. In this sector, climate protection is still largely a corporate affair. Unlike its stance on the automotive industry, the European Union is prepared to let market forces, rather than regulation, bring about power plant modernization. That said, climate expert Geden foresees a major upheaval in the power plant market from 2013 onward, when CO₂ emission certificates in this sector will all be auctioned.

Rewarding Efficiency. Back in Europe, power companies in the western member states are rapidly upgrading their facilities. In this sector, climate protection is still largely a corporate affair. Unlike its stance on the automotive industry, the European Union is prepared to let market forces, rather than regulation, bring about power plant modernization. That said, climate expert Geden foresees a major upheaval in the power plant market from 2013 onward, when CO₂ emission certificates in this sector will all be auctioned.

Power companies will therefore have to pay for a percentage of their CO₂ emissions through the purchase of emission certificates. An exception, however, has been made for many Central and Eastern European countries, giving them until 2020 to catch up. During this time, the most efficient power plants will set the benchmark there too. Power plants meeting this standard will receive emission permits free of charge. Emissions trading will thus ensure that old power plants become increasingly unprofitable. And once the last inefficient plant has been decommissioned, each electricity consumer will have become a little bit easier on the environment — without even thinking about it.

Katrin Nikolaus

* Name changed

Top-Notch Treatment

A diagnosis of cancer is not necessarily a death sentence — not even in emerging economies. This is demonstrated by the clinical success of institutions such as the Southern Medical Clinic in Trinidad and Tobago and the Children’s Cancer Hospital in Cairo. Both demonstrate how Siemens technology helps improve cancer treatment.

PhD Marianne Vorbuchner, an oncology workflow manager at Siemens Healthcare, has supported the Southern Medical Clinic — a Siemens benchmark clinic for the entire Caribbean — for years. The advantages of integrating all diagnostic and treatment steps on site are tremendous, she says. “Previously, patients from Trinidad and Tobago who wanted to have first-class cancer treatment had to travel to the U.S. or the UK. Today they receive fully integrated care, all in one place.” Patients are now being spared major inconveniences and significant travel expenses.

An additional advantage of the integrated oncology ward is the generally shorter treatment periods it offers. A largely paperless and efficient facility, the clinic has an excellent IT network. Diagnoses are automatically trans-
Siemens not only supplied diagnostic and treatment devices but also the entire building infrastructure.

The veterinary clinic’s efficient processes also save valuable time in the struggle against cancer. And this, in turn, often cuts costs, because a diagnosis before a tumor metastasizes helps to avoid the elaborate treatments that would be necessary at a later stage of the illness. As Damil Hadidi, a senior medical physicist at Southern Medical puts it, “The way all of the systems are integrated makes it easier for everyone to do their jobs and improve efficiency.” Diagnostic and therapeutic equipment at Southern Medical includes computed tomography and magnetic resonance scanners from Siemens, as well as ultrasound devices and a Primus linear accelerator. In the field of radiation therapy, every millimeter counts. Here, the major objective is to damage as little healthy tissue as possible. “With MRI Molecular Imaging (MRI), we’re able to accurately pinpoint the location of any malignant tumor and direct our biopsies and even our surgical therapy to that specific site,” says surgeon Adrian Indar.

For George Rhammaesar, his treatment in the new Millennium Wing of the Southern Medical Clinical Center was a true chance of a successful recovery, and treatment that has fewer side effects and is less strenuous than previous measures. In addition, the Clinic’s modern oncology department is aesthetically pleasing. Visitors are welcomed by a colonnade and tropical flowers grow around a bubbling fountain. A Unique Center in the Middle East. Meanwhile, on another continent, the architects of a new children’s cancer hospital were also inspired by the philosophy that pleasant surroundings promote recovery. The futuristic buildings of the Children’s Cancer Hospital of Egypt (CCHE) in Cairo are not located far from the well-known Khan el-Khalili souk and the city’s southern quarter of Sayyida Zeinab. The building’s shape is modeled on that of a felucca, the traditional sailing vessel used on the Nile River. The clinic looks somewhat out of place in this neighborhood, which Cairo natives call “schooners and toy trucks.” In this clinic, laughing children sometimes forget that this is probably the worst period of their lives.

The CCHE is the only pediatric oncology center of excellence in its kind in the Middle East. In fact, it is comparable only to advanced cancer institutes in the U.S. and Europe — an evaluation that was confirmed by distinguished participants in the First Scientific Symposium held by CCHE in July 2009.

In addition to diagnostic and therapeutic devices, Siemens also provided the building infrastructure — including heating, ventilation, and air-conditioning systems, the fire protection system, the electrical installations, and the data network. Thanks to their high energy efficiency, these systems help to minimize the hospital’s operating costs.

Although far apart, the Southern Medical Clinic in Trinidad and Tobago and the Children’s Cancer Hospital of Egypt have much in common. They are bringing ultramodern technology and health care solutions, that are modern and economically, and, above all, are providing hope to those in need. — Andreas Clemens

The cattcombas near the Bahnhof Zoo train station in Berlin, Germany, are a place where you might expect to find a phantom, or perhaps creatures that would look good painted in acrylic colors on a canvas. Indeed, you would think artistic inspiration is a given in this wending labyrinth — a place where you spend more time ducking down than walking upright. Despite this fact, the approximately 4,000 students at the Berlin University of the Arts (UdK) have never seen the tunnels in the basement of their facility. Instead, the wall below is the realm of Robert Müller, head of the UdK’s Technical Services Department. Müller, who has a degree in architecture from the UdK, is not searching for inspiration in the 19th century vaults, however. Instead, he’s on the hunt for money — or more specifically possibilities for saving it.

The old building, with its extensive heating and ventilation system, the electrical installations, and the data network. Thanks to their high energy efficiency, these systems help to minimize the hospital’s operating costs.

Although far apart, the Southern Medical Clinic in Trinidad and Tobago and the Children’s Cancer Hospital of Egypt have much in common. They are bringing ultramodern technology and health care solutions, that are modern and economically, and, above all, are providing hope to those in need.

The whole hospital enjoys digital technology, with fully integrated state-of-the-art radiology, nuclear medicine and radiation therapy departments. An advanced hospital information system eradicates data flow inconsistencies, which would otherwise slow down treatment delivery and impair quality. Siemens also delivered and installed five operating theatres, a fully equipped intensive care unit with 30 beds, and a complete laboratory with highly advanced equipment.

The director of CCHE, Prof. Hany Hussein, is particularly pleased that the hospital could begin operating so quickly. “In cooperation with Siemens, we managed to implement the systems in just one third of the time we had originally planned,” he says.

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Andreas Clemens

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The economic crisis is presenting steelmakers with a major challenge. Although most producers can’t afford costly new plants, they still have to make their production processes more efficient in order to reduce costs and emissions. Siemens VAI offers innovative modernization solutions that cut costs and protect the environment.

Efficient Siemens solutions, such as those for blast furnaces (large image) and electric arc furnaces for melting scrap (right), can radically reduce operating costs and emissions.

The heat from a coking plant can power a steam turbine that generates enough electricity for 30,000 households.

The year consists of three cooling chambers — two in full operation and one on “hot stand-by.” The latter is only charged with about ten percent of its actual quenching capacity and is ready in case a problem occurs. Quenching is thus possible at all times, including possible maintenance periods.

With CDQ, hot coke is cooled to 180 degrees Celsius, even as 1,000 degree coke is fed into the cooling chambers from above. A circulating gas flows in at the bottom of the cooling chamber and absorbs the heat. The gas, now at about 800 degrees Celsius, is channeled with air back into the waste heat water boiler.

Here, more than 500 kilograms of high pressure and high temperature steam can be produced per ton of coke. Connecting a steam turbine yields 15 to 17 megawatts of generating capacity. That’s equivalent to the power produced by five large wind turbines and adequate for the requirements of about 30,000 four-person households. What’s more, as the coke in the CDQ process is drier than wet, like in a tobacco pipe,” says Andre Fulgenzio, Product Manager for sintering plants at Siemens VAI in Linz, Austria.

To allow some of the gas to be reincinerated into the process, it is first fed into a chamber. Here it is mixed with waste gases from the sinter cooler, to ensure the oxygen content is at least 16 percent and thus high enough for combustion. With Selective Waste Gas Recirculation technologies, for example, waste gas produced during sintering can be reincinerated. In a sintering plant the ore is baked on a sinter strand, which is similar to a furnace grate. In this way, the fine ore is prepared for the blast furnace. Here, the ore is ignited on the sinter strand, and wind boxes suck out the waste gases from below. “The ore burns from the top down, like in a tobacco pipe,” says Andre Fulgenzio, Product Manager for sintering plants at Siemens VAI in Linz, Austria.

The heat from a coking plant can power a steam turbine that generates enough electricity for 30,000 households.

Efficient Siemens solutions, such as those for blast furnaces (large image) and electric arc furnaces for melting scrap (right), can radically reduce operating costs and emissions.
In Cremona, Italy, steel is being produced in a new, continuous process that does away with the need for cooling. As a result, energy requirements have been almost halved. Inventor and major industrialist Giovanni Arvedi has teamed up with Siemens VAI to build a “green steel mill.”

Giovanni Arvedi is a true cavaliere, a genuine knight of the old school, but he’s also — in another translation from Italian — a Cava- liere del Lavoro, a knight of work. That’s the name of the order of merit awarded to him by the Republic of Italy in 1984 in recognition of his service in the fields of industry and commerce. In 2009 he received the prestigious Bessemer Gold Medal from the International Institute of Materials, Minerals and Mining in recognition of this audacious approach to hot strip manufacture. Arvedi’s success story actually began in 1973, when he founded the Acciaieria Tubifi- cia Arvedi plant in Cremona, which was equipped with what were then the most advanced technologies available for manufactur- ing steel and producing hot-rolled tubes. In the early 1980s Arvedi acquired a significant share of the Falck Group and with the purchase of Falck’s Celesti subsidiary acquired one of the largest sales and service companies in Italy’s steel processing industry. Today the Arvedi Group has over 2,000 employees and annual sales of more than €1.3 billion. However, it was only recently, following a series of impressive technological innovations, that this industrialist from northern Italy real- ized his greatest accomplishment: completely endless strip production (Arvedi ESP) — a new and highly efficient steel production process. The idea behind Arvedi ESP is simple in principle. In conventional plants, steel cools to the ambient temperature during a number of production steps and is then reheated (at considerable cost) before being turned into the end product — sheet steel — in a rolling mill. In the Arvedi ESP production process, instead, steel is rolled while it is still hot, thus saving energy, and is processed into sheet steel in a single, seamlessly-linked process. In Cremona this process begins as it does in every conventional steel mill. After tapping, the molten steel is cast into a strand. Like a very long carpet, the glowing-hot band flows along the production line. In conventional con- tinuous casting steel production, the molten steel is cast into slabs that are typically 23 cen- timeters thick, which are then allowed to cool and harden. The slabs are stored until they are subsequently heated again just prior to being rolled to a customer-specified thickness. “Thanks to Arvedi ESP’s innovative process technology, remarkable savings in terms of en- ergy use and costs are achieved in the new Cremona mill,” explains Andreas Jungbauer, sales manager at Siemens VAI, the company that built the facility for Arvedi in late 2007. “Instead of cutting the steel strand and storing it for a period, in Cremona it’s left in one piece and moves along the line in a single process from casting to rolling to coiling the finished sheet steel on a coiler. Because the process doesn’t require subsequent reheating of the steel, up to 45 percent of the energy that would be needed in a conventional mill can be saved. In Cremona, only 135 kilowatt-hours per metric ton of steel are needed, an un- precedented figure in the industry,” says Jung- bauer. Naturally, the process also reduces as- sociated CO₂ emissions generated by the plant to a similarly dramatic extent. It also lowers process costs by as much as 50 percent.

Less Energy, Higher Quality. All of this may sound simple, but in terms of process technol- ogy it’s a very formidable challenge. Jung- bauer explains: “In contrast to conventional mills, the temperature of the steel strand in the Arvedi ESP process falls only slightly after casting. Then, as soon as it has attained the solid phase in a temperature range from 1,100 to 1,200 degrees Celsius, it goes through the first roll set in the high reduction mill, reduc- ing the thickness of the strand to between one and two centimeters.”

After initial rolling, the strand must be re- heated only slightly in a ten-meter-long induc- tion furnace. This electric furnace, with an in- stalled power of 30 MW, is more precise and therefore more efficient than the furnaces nor- mally used in the more than 200-meter-long gas-fired conventional steel mills that have to heat steel from ambient temperature to more than 1,000 degrees Celsius. In terms of heat- ing demand, this means a saving on the order of one magnitude (in other words: 10 times). After heating, the second rolling process begins in the finishing mill, in which the thick- ness of the hot strip is reduced down to as little as 0.8 millimeters, depending on customer requirements.

“The rolling process in the finishing mill demonstrates another advantage specific to Arvedi ESP technology — endless rolling,” says Jungbauer. “Previously, semi-processed hot strips had to be re-fed individually into the rolling mill. That’s a high-risk process that tends to result in numerous imperfections on every sheet, even when everything goes well. Endless rolling in the Arvedi ESP process avoids threading problems typical of conventional batch production.”

Sophisticated Process Control Technology. After leaving the finishing mill, the strip passes over long roller tables and is cooled with water before coiling. “Conventional processes are in- ferior to this step,” says Jungbauer. “because it is not possible to produce ultra thin gauges without encountering production problems or lowering productivity. But with Arvedi ESP technology the steel band is always pulled tightly. As a result, it is possible to avoid a wide range of threading-related problems.”

The entire process for the production of a hot rolled coil is carried out in only 3.5 minutes on a line that is 190 meters long from the point of solidification to the final hot rolled coil — a world record. But the uninterrupted process demands a lot from its associated control technology, which must precisely synchronize the individ- ual production steps with a margin of error of only fractions of a second.

Siemens is the first company worldwide to have implemented this process on the basis of Giovanni Arvedi’s patents. Initially, annual production will be in the range of two million tons of steel, with an op- tion for expansion to over three million tons. Industrial production got under way in June 2009 following a successful test phase. Next to the steel plant is a field of sunflow- ers, a fitting symbol of climate-friendly tech- nology based on energy conservation. Here, in one of the world’s most energy-intensive in- dustries, steelmaking has succeeded in a highly environmentally-friendly manner. What’s more, the end product, thin steel sheet in coils weighing up to 32 tons for deliver- ey to customers, is of superior quality to con- ventional steel products. Indeed, what sets steel produced using Arvedi ESP technology apart is its excellent dimensional precision, surface quality, and homogeneous internal structure. In addition, the Arvedi process eliminates the need for the otherwise commonly used “cold-rolling” process, which entails subse- quently rolling the steel, for instance for auto- motive production. With its extensive experi- ence in industrial automation and sensor technology, Siemens was deemed the right partner for industrial implementation of Gio- vanni Arvedi’s vision. As licensee, Siemens now markets the innovative technological solution worldwide.

The modern knight, Giovanni Arvedi, on the other hand, is open to technological inno- vations because they give him a decisive ad- vantage over competitors.

Andreas Kleinschmidt
Modernizing Infrastructures | Airports

Siemens is developing measures to save energy for Denver Airport (below). Thanks to Siemens technologies, Stuttgart Airport (right) has already cut its energy bill by around 40 percent.

Denver International Airport is a majestic facility. The roof of its passenger terminal is adorned with 34 pavilions made of translucent Teflon as a tribute to the nearby Rocky Mountains. With 51 million passengers in 2008, the airport is one of the world’s busiest. Its passenger traffic is the 11th-highest in the world, and its number of flights is the fifth-highest. Its complex infrastructure also makes it a huge consumer of energy, as it required 216 million kilowatt-hours (kWh) of electricity in 2007, or more than four kWh per passenger.

In early 2008, the airport’s operating company therefore asked Siemens’ Building Technologies (BT) division to draw up concepts designed to cut energy use. In mid-2009 BT released a study offering optimization proposals aimed at reducing the airport’s overall natural gas demand by ten percent and kWh consumption by 12 percent. For its study, BT examined the terminal, waiting halls, and office and equipment buildings. Along with energy-saving considerations, the study also took into account the impact the proposed measures would have on the environment, operating capacity, and passenger comfort.

The study produced a total of 26 proposals, the most effective of which involve measures that would address heating, cooling, ventilation, lighting, and baggage transport systems, which together account for more than 80 percent of total energy consumption. “Naturally, airports are looking to achieve extensive savings in terms of not only costs but also energy consumption and carbon dioxide emissions — and to do so as simply as possible and at a low level of investment,” says Uwe Karl, head of Airport Solutions at BT. There are also more expensive measures, such as the use of alternative energy generation systems that would immediately result in a high CO₂ reduction but would pay for themselves only after a long period.

To help the airport operator with its decisions, the study lists the cost of each individual measure, as well as the associated energy reduction and its amortization period. A good example of how to achieve a major effect at relatively low cost is offered by systems that control terminal ventilation in line with utilization. The installation of these systems, which employ CO₂ sensors and intelligent ventilation control units, would cost $215,000 — but would lead to annual energy-cost savings of $425,000. Such an investment would thus pays for itself after only six months. Another relatively simple way to save energy is to install energy-saving lamps and LED lighting systems. Lights in the passenger terminal at Denver International are left on 18 hours a day, seven days a week; those in the parking garages and on the runways and apron run even longer. The use of energy-efficient lighting systems could reduce electricity consumption by more than 11 million kWh per year, which, given the U.S. energy mix, corresponds to around 10,000 tons of CO₂.

Another measure involves the provision of heat and hot water using biomass, which can cover all requirements in the summer and serve as a supplementary energy source in the winter. Installation costs for such a system would total approximately $3.5 million, while energy savings would add up to almost $500,000 per year, with an associated CO₂ reduction of around 7,000 tons per annum. After conducting a detailed analysis of the proposals, the Denver International Airport opted to implement three areas,” says Karl. The first area involves finding out which devices can be turned off or modernized, as old machines are often the biggest energy wasters. It therefore makes sense at any airport to use energy-saving lamps that operate in accordance with ambient light conditions and utilization requirements. “In many cases you’re dealing with just one main switch for all the lights,” says Karl. “But if you optimize lighting systems to function in line with ambient light conditions and the utilization of specific areas, you can cut costs substantially.”

The second area addresses the use of renewable energy sources such as wind, biomass/biogas, geothermal sources, and fuel cells. “Here, decisions have to be made based on individual circumstances,” says Karl. Denver’s airport covers almost 140 square kilometers, for example, making it by far the largest in the U.S. in terms of area; so it makes sense to consider the use of biomass/biogas and wind energy.” The Siemens study thus proposes such measures as well. The third area focuses on solutions in the fields of power generation, alternative energy, baggage and freight logistics, IT services, and building technologies. The goal here is to manage the many energy-hungry systems in use with the help of intelligent IT solutions aligned with airport processes, and to regularly monitor and compare energy consumption over time. “Many airports have distributed and independent systems, however, which makes it difficult to gain a good overview,” Karl explains. Here as well, the key is to implement intelligent controls that eliminate the problem of constant energy consumption.

Investments that Pay for Themselves. The comprehensive analysis of energy consumption patterns at an airport forms the basis for the generation and implementation of energy-saving measures by specialists. This is the approach being taken at Detroit Airport, where Siemens has been serving as an “energy manager” since 2001 within the framework of a multi-stage project. “Our objective here is to increase the comfort and safety of existing systems and reduce energy and maintenance costs — and to do so with as little expenditure as possible,” says Karl. The airport operator therefore sought out a company that had the comprehensive expertise that was necessary and could also offer energy performance contracting. With this form of financing, the vendor contractually guarantees the savings, decides which measures will be implemented, and finances them. In return, the saved energy costs are paid to the vendor until its expenses for financing, planning, and monitoring are paid in full.

With energy performance contracting, the customer doesn’t have to spend any of its own money, but benefits from the savings once the investment has been paid off. The operator of Detroit Airport assessed numerous energy service companies, and two remained in the running following the call for bids. Siemens offered the lowest price and therefore won the contract. Since 2001 Siemens has been serving as an “energy manager” for the Detroit Airport. As part of this project, Siemens has implemented measures that reduced energy costs by 11 million kWh per year.
guaranteed the greatest energy savings — and was awarded the contract. “Our systems are like a puzzle; each piece is dependent on the others so that the system functions as a whole,” says Len Cranston, who runs the Detroit airport’s machining center. “Siemens had to serve as the general contractor, decide for itself which optimizations were necessary, and then provide the entire scope of services within the defined timeframe and on budget.”

BT’s energy manager in Germany, having served in a similar role at an energy management system in a factory for more than 10 years, says that cost savings were achieved immediately and with relative ease. “BT is unique in that its plants have been designed to be energy efficient from the ground up,” he observes. “We have been able to achieve savings of up to 40 percent.”

A CO₂-free airport is possible if a facility’s complex infrastructure is looked at holistically.

How to Exploit Savings Potential.

Siemens Building Technologies is also active as an energy manager in Germany, having served in this capacity at Münster/Osnabrück Airport since 2001. Here, savings were achieved not with major investments but through systematic optimization. The operation of the cogeneration plant, for example, was continuously improved in response to the prices of electricity and natural gas. Many unnecessary lights were shut off completely, incandescent bulbs were replaced with low-energy lamps, and sensors were integrated into the heating and cooling system with its 30-year-old, 2,000-ton compressors as the airport’s biggest electricity consumer. All systems were replaced with steam turbine-driven centrifugal chillers, which use less energy and are easier to maintain. The boiler was modernized so as to maintain constant high temperature. Pumps, lines, and flow sensors were also replaced. The control equipment, which was so old that it was no longer possible to get parts for it, was completely replaced. A new computer control system is the new nerve center of the system. In addition, the lighting systems were modernized and numerous smaller measures were implemented. The greatest of the complete energy-saving project totaled $15 million. The project reduces energy costs by 23 percent each year, which corresponds to an impressive $2 million in savings.

Siemens has also been working on an energy-saving project at Seattle Airport since 2003. In addition to replacing lighting and heating systems, the project focuses primarily on upgrading the airport’s 30-year-old heating, ventilation, and air conditioning systems. Overall, electricity consumption in Seattle has been reduced by four percent and natural gas consumption by eight percent.

Tapping Ambient Energy

Light, temperature differences, vibrations. Our environment is full of energy sources. A new generation of radio sensors will harvest these sources, thus achieving independence from batteries and power cables, while making it possible to affordably equip industrial plants with self-powered data delivery electronics.

Radio sensors are particularly well suited for hard-to-access systems. The most advanced such devices draw their energy from light, temperature gradients, air flows (right), and vibrations (left).

Pictures of the Future | Fall 2009

Radio Sensors

The automatic wristwatch has been showing us how it’s done for decades. Our environment is full of energy sources that can be used to drive equipment. In the case of time pieces, a sophisticated mechanism uses the wearer’s body movements to wind the spring. The watch runs entirely without a battery, but only if it’s moved often enough.

A similar idea is behind self-powered radio sensors, which are currently making headway in industry. They take all kinds of measurements, transmit them via radio to a control room, and obtain their energy by tapping directly into environmental sources, such as light, vibrations, temperature gradients, and air flows. All of this is referred to as energy harvesting because special converters harvest ambient energy, generate electricity, and store it in a capacitor until enough of it is accumulated to power the sensor.

Self-powered sensors offer many advantages. They are easy to install because they use and require no wires. With these sensors, old systems can be monitored and utilized more effectively, and the cost of retrofitting is not so high as to nullify its advantages.

There are also many potential industrial applications. “Self-powered radio sensors are particularly attractive wherever something is moving or rotating, such as the industrial robots in the automobile industry,” explains Prof. Leonard Rendl of the Institute of Microsystem Technology at the University of Freiburg. “Wiring for such applications is very costly and time-consuming to install, and rotary motions require expensive sliding contacts,” he adds. Another interesting potential field of application is in extreme environmental conditions, such as the presence of high voltages or the monitoring of areas that have to be protected against potential explosions.

System condition monitoring is another area that is tailor made for the use of radio sensors. “It makes a lot of sense to monitor the condition of machines for possible wear,” says Wiebking. Damaged bearings are a rare occurrence with electric motors. But if a motor fails, production comes to a halt. “If the drive system for the rollers in a steel mill or a roll in a paper machine fails, for example, damages of up to $2 million can occur per year,” says Dr. Leif Wiebking, a sensors specialist at Siemens Corporate Technology (CT).

Installation often requires more than an hour per each individual sensor, compared to only between five and ten minutes for radio sensors,” he adds. In many cases, use of radio sensors can obviate the installation of hundreds of meters of wire — wire that in an industrial environment can be damaged, leading to additional costs over the service life of the sensor.

The trend is therefore away from wire and toward wireless data transfer — a trend that will become increasingly important in the years ahead. Market researchers at ON World expect radio sensors to experience average annual growth of around 77 percent and predict that their worldwide market volume will total $3 billion by 2011. They consider industrial automation, building automation and control, and the status monitoring of machines to be attractive areas of application. “And because radio sensors make the most sense when both the power cord and the battery can be eliminated, self-powered devices will carve out a big piece of this pie for themselves,” predicts Wiebking.

Wiring would be extremely expensive if it were used to modernize existing systems that are characterized by limited accessibility. That’s why sensors are the preferred method for modernizing such systems. It was largely due to such scenarios that Siemens was the first company to develop self-powered radio sensors that are tough enough for industrial use and require no wires. With these sensors, old systems can be monitored and utilized more effectively, and the cost of retrofitting is not so high as to nullify its advantages.

Because there is no need to replace batteries, they are practically maintenance-free in opera-

T. Gitta Rohling
Radio sensors monitor production plants, warn of failures, and thus prevent costly outages.

Radio sensors detect mechanical vibrations and store this information in a capacitor during the ambient conditions. "Solar cells are always a viable option," says Harald Pötter of the Fraunhofer Institute for Reliability and Microintegration (IZM) in Berlin. "However, they require a lot of light, and the associated converters must re- main free of dirt.

Thermoelectric generators do not have any problems with shadows, dirt, and dust, but they do require heat and a temperature difference — otherwise their efficiency is too poor. The extraction of energy from vibrations, on the other hand, is very highly dependent on the spectrum of the vibrations. Since the converter and the vibrations should ideally be in resonance, the vibration spectrum should be as narrow as possible," says Pötter. "As you can see, there is no perfect solution for every case — when it comes to radio sensors, there are always solutions to be invented anew for each application."

Cutting Energy Consumption. A crucial prerequisite for efficient radio sensors is the continued miniaturization of their electronics, which reduces the size of the devices and their electrical consumption. However, the amount of power required for performing measurements and transmitting results varies from one application to another.

A temperature measurement requires several tens of microwatts, for example. Another important factor is sensor power consumption during periods of inactivity, since standby op- eration accounts for most of a sensor's power needs. Thus the few microwatts required to do nothing add up over the course of a day and must be minimized to the greatest extent possible.

Among a sensor's components, it is generally the radio chip, which, although active for less than 10 percent of all time, has the highest power requirement. It consumes several tens of milliwatts. Radio protocols must therefore be kept as lean as possible — a diffi- cult task since, in addition to sensor data, a substantial amount of information for the management of a network must also be trans- mitted. Siemens uses the ZigBee radio stan- dard or IEEE 802.15.4 in its products, but has also developed its own proprietary, extremely energy-efficient method. "All in all, the stage is set for broad deploy- ment," says Siemens' market analyst Martin Wich. "The U.S. stimulus package — the American Recovery and Reinvestment Act — calls for infrastructure expenditure amounts to the equivalent of about €25 billion in Germany, transport, buildings, health, water supply net- works, security, and IT. Development of intelligent energy networks, known as smart grids will be supported along with expansion of high-speed lines and digitization of data and processes in healthcare.

The government of China has also launched various programs for infrastructure measures — with total fund- ing equal to €350 billion, including €166 billion from pro- grams that existed before the economic crisis, and €64 billion in the form of additional economic stimulus ele- ments. China is earmarking €73 billion for development of the nation's rail system alone. Also slated for extensive upgrading are the drinking water and waste removal in- frastructures in Chinese cities and the energy efficiency of buildings. Market experts from Morgan Stanley predict that China will account for approximately 80 percent of the total infrastructure expenditures in East Asia.

World Radio Sensor Market

<table>
<thead>
<tr>
<th>Source: ON World Inc.</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<tr>
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<td>Machine condition</td>
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World Radio Sensor Market

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Stimulus Spending

<table>
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<tr>
<th>Country</th>
<th>$41 trillion worldwide</th>
<th>$150 billion in the next 20 years</th>
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<tbody>
<tr>
<td>EU</td>
<td>Approx. $700 billion</td>
<td>Approx. $410 billion</td>
</tr>
<tr>
<td>China</td>
<td>Siemens' markets affected by stimulus packages</td>
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<tr>
<td>Siemens</td>
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</tr>
<tr>
<td>U.S.</td>
<td>$15 billion</td>
<td>$55 billion</td>
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<tr>
<td>Europe</td>
<td>$20 billion</td>
<td>$60 billion</td>
</tr>
<tr>
<td>Rest of world</td>
<td>$30 billion</td>
<td>$90 billion</td>
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The single most important factor in reducing energy consumption and costs will be improving the energy effi- ciency of buildings. This is because the largest share by far — approximately 95 percent — of the energy used to provide heat, hot air, air conditioning, lighting, and ventilation for buildings in Europe is consumed by structures that were built before 1980, says an analysis developed by TH Pro- jectmanagement GmbH in Berlin.

"The U.S. stimulus package — the American Recovery and Reinvestment Act — calls for infrastructure expenditure amounts to the equivalent of about €245 billion in Germany, transport, buildings, health, water supply net- works, security, and IT. Development of intelligent energy networks, known as smart grids will be supported along with expansion of high-speed lines and digitization of data and processes in healthcare.

The government of China has also launched various programs for infrastructure measures — with total fund- ing equal to €350 billion, including €166 billion from pro- grams that existed before the economic crisis, and €64 billion in the form of additional economic stimulus ele- ments. China is earmarking €73 billion for development of the nation's rail system alone. Also slated for extensive upgrading are the drinking water and waste removal in- frastructures in Chinese cities and the energy efficiency of buildings. Market experts from Morgan Stanley predict that China will account for approximately 80 percent of the total infrastructure expenditures in East Asia.

Worldwide, stimulus programs for recovery from the economic crisis with a total volume of about €2 trillion have been announced and are already being imple- mented in part. Roughly one third of this sum — €700 billion — will be in the form of infrastructure investments, with the rest to be used for measures such as tax breaks for private households. For Siemens, analyses show that the market volume relevant to the company in terms of planned spending on infrastructure in the three fiscal years from 2010 to 2012 is about €150 billion. The largest share of this total, more than €85 billion, will be spent in the U.S., followed by China with €425 billion and Germany with about €45 billion. In all these countries, plans call for developing major shares of the stimulus pro- grams to green technologies. In China the figure is about 52 percent, in Germany it amounts to 60 percent, and in the U.S. it adds up to 31 percent. Based on Siemens' cur- rent share of the global market, calculations indicate that the markets served by Siemens could generate a potential contract volume of approximately €415 billion for the com- company, including about €66 billion, or 80 percent, on aero- nautical technology.

Christian Buck

Trillions of Dollars for the Modernization of Infrastructure

Modernizing Infrastructures | Radio Sensors

up to €100,000 per hour are not unusual," says Webkling.

The condition of the bearing could be con- tinuously monitored with the help of a sensor, allowing the wear to be recognized in time so that the component can be replaced while the machine is shut down for some other reason. This can be accomplished by bolting an elec- tronic unit the size of a matchbox onto the motor. The unit analyzes the motor's vibration spectrum once a minute and sends the data via radio to a control unit. In the event of irregularities — if the machine is not running smoothly, for instance — the control unit issues an alarm so that a technician can check and replace the bearing either immedi-
Siemens technology allows Bosphorus ferries to use much less fuel, supports Formula 1 racing, and provides switchgear for the world market from one of the most modern production centers in Turkey.

Modernizing Infrastructures | Istanbul

Modernizing Infrastructures | Istanbul

Refurbishing the Megacity

Istanbul is renowned as a bridge between East and West. Because most technical innovations in Turkey first see the light of day here, the city is a beacon for this rapidly-growing country. Siemens technology supports this journey into the future with upgrades for the city’s power, transportation and healthcare infrastructures.

Gökcê’s blue dress flutters in the wind. Every morning she takes the ferry across the Bosphorus, from the Asian side, where she lives, to the European side, where she attends college and has a studio. The young artist, whose work already has been shown twice in art exhibitions in Turkey sponsored by Siemens, loves the morning crossing. “Every time, I am conscious of the fact that I am traveling between two continents,” she says.

Jenny also makes the brief trip every morning, only in the opposite direction, from her apartment on the European side of the city to her job on the Asian side. In the coming months she will be setting up a human resources department for a Swiss company, and then will move back home to Berlin.

Gökcê Er and Jenny Baylam: two women in their late twenties who love Istanbul, work here, and feel at home amid the charming chaos of this megacity with its 13 million inhabitants. “Although maybe just a little less chaos wouldn’t be bad,” says Jenny. Bringing the infrastructure up to the latest standards and making life in cities like Istanbul even more attractive — that’s also Siemens’ objective.

For decades the Bosphorus ferries have served as one of the main components in Istanbul’s traffic infrastructure, and as one of its tourist attractions — in addition to the Hagia Sophia, which is about 1,500 years old, and the city’s countless palaces and bazaars. But many of the ferries are showing their age. Their propellers are turned directly by heavy diesel engines, running usually under peak load. “The poor efficiency of this outdated technology is bad for the environment and harmful for the engines,” explains Emin Goren, a sales specialist at Siemens’ Drive Technologies Division. “With conventional drive engineering, variable adjustment of the engine speed isn’t possible, so the engines wear out faster. And that means they must be serviced more frequently.” That’s why IDO, the company that operates the vessels, has chosen diesel-electric drive systems from Siemens for the latest generation of Bosphorus ferries.

These systems convert the power of four diesel engines into electrical energy, which is then finely adjusted to serve the needs of each propeller. Individual diesel engines can thus be shut off, for instance while maneuvering to moor at a landing. The remaining engines continue to run at their maximum efficiency — with less sooty emissions, better fuel efficiency, and cost savings. And thanks to the reduced level of engine vibration, passengers enjoy a more comfortable trip. “Some of our captains were skeptical when Siemens delivered the first diesel-electric drives for ferries in Turkey to us,” says Nejdet Özguç, Chief Engineer on the Kadıköy, one of the new Bosphorus ferries. “But they have given way to satisfaction. “We can maneuver the ferries with greater certainty now, save on diesel fuel, and there is less maintenance work than before — which means we can go home earlier to our families,” says Özguç.

The Bosphorus ferries — although they travel at a modest 25 kilometers per hour — are one of the fastest means of getting around Istanbul. They are used every day by approximately 250,000 travelers, and each vessel has a capacity of about 1,800 people. Seemingly endless traffic jams on the city’s main thoroughfares turn even short trips of just a few kilometers into journeys that can easily last an hour. The two Bosphorus bridges, in particular, are chronically congested.

High-tech Race Track. For those who want to see something that really moves fast — albeit in circles — the place to be is Otoñrom, the Formula 1 race circuit east of the city. Solutions that Siemens supplied for the circuit, which went into operation in 2005, include electric switchgear, optical fiber connections for data transfer, the telephone system — which more than 600 journalists rely on for international connections during Grand Prix races — and the crucial elements of every race: the signaling system, complete with LED starting lights, the chronometry system, and the track video monitoring system, all of which are from Siemens.

Levent Pekün, Technical Director of the race circuit, is operating a joystick in the control center. During races Charlie Whiting, the Formula 1 Race Director, sits where Pekün is, in front of 30 monitors that provide an overview of the entire circuit. Pekün selects one of the cameras, zooms in, and moves it first to the left, then to the right. “In the event of an accident, quickly getting an overview can save lives,” he says, pushing a button to play a video of an accident at the start of a race in 2008. All races are stored on servers and accessed for determining causes of damage later. “This Siemens solution already has helped us many times,” he adds.

A new Siemens switchgear plant consumes 25 percent less energy and 50 percent less water than the old one.

A new Siemens switchgear plant consumes 25 percent less energy and 50 percent less water than the old one.
with sensors that turn off the lights when no movement is detected after an extended period. And waste water is purified in one of the facility’s two water treatment units and used to water the thriving gardens in the plant’s inner courtyards.

Top Hospital. While industrial production for the global market takes place on the outskirts of Istanbul, tourists from all over the world jostle in the narrow lanes of the city’s center. But not all the tourists who visit Turkey’s largest city are there for the sights. Some are shop-

At Acibadem Maslak Hospital, which has converted to digital processes, “no paper — no pain” is the motto. to go back and forth to the pharmacy with prescriptions printed on paper. Says radiologist Cengiz Badek, “Here, thanks to Siemens, the rule is — no paper.”

What’s more, Hospital Director Özün Yegen Çaiban insisted on having the latest Siemens technology for the diagnostic equipment in the radiology and cardiology departments, and for the ultrasound systems in gynecology. “We wanted only the best,” she says. “Acibadem, the company that operates the hospital, has been working with Siemens since the 1990s,” she adds. “We felt that we were in good hands during our expansion. After all, only a strong partner can ensure nearly 100 percent availability of installed equipment.” In order to achieve this target, Siemens technology detects faults even before they happen.

For instance, should the level of helium — which cools the magnet in magnetic resonance tomographs (MRI) — fall to a point approaching a critical value, a warning light is displayed at the Siemens location in Kartal, in the Siemens Uptime Support Center on the other side of the Bosporus. In the center, Ege-

In many respects, the tunnel manages itself,” explains Enis Amasyali, the project manager at Siemens Industry Solutions Division who is responsible for the tunnel. “And that’s worth a lot,” he adds. “The technology detects a fault as it happens, not just after it has occurred.”

In addition to monitoring the workmanship itself, cameras featuring smart image-processing software also keep an eye on the surrounding environment. The cameras provide automatic, early detection of any significant changes, allowing them to exit their vehicles and escape via fireproof cross connection doors to the other tunnel tube or from the nearest tunnel portal opposite a fire zone. Of course, drivers traveling at a normal speed away from a fire zone stand a good chance of reaching safety.

program routines for these and other emergency scenarios are designed to proceed automatically and without delay. For example, if a fire were to break out, the tunnel entrance would be closed, detectors activated, and a power supply from two independent sources, backed up with emergency generator sets, would be secured for both tunnels. In this way, the unaffected tunnel could be used as an escape route. In addition to monitoring the tunnel itself, cameras featuring smart image-processing software also keep an eye on the surrounding environment. The cameras provide automatic, early detection of any significant changes, allowing them to exit their vehicles and escape via fireproof cross connection doors to the other tunnel tube or from the nearest tunnel portal opposite a fire zone. Of course, drivers traveling at a normal speed away from a fire zone stand a good chance of reaching safety.

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ent of the grid can supply the building with power. The system is monitored by digital sys-
tems, meaning that fewer people are needed than originally planned. Instead of a team of eight for continuous monitoring of the electric infrastructure, only two people are required.

Growing Energy Demand. When everything runs smoothly, most of the power for Istanbul comes from a nearby plant in Ambalı, where gas turbines and steam turbines deliver reliable energy. In 2006, Siemens succeeded in boosting the output of two of the plant’s gas turbines by almost five percent by optimizing design, which is why the plant can generate 1,362 megawatts today. During the modernization phase, the overall lifespan of the gas turbines was extended along with their main-
tenance intervals. This has driven down opera-
tional costs. At plants of this scale, even small improvements have significant effects.

By 2020, however, Turkey’s energy require-
ments could double, as Deemir Ansal, Sales and Marketing Manager at Siemens Energy ex-
plains. That means more capacity is needed — a fact that has convinced some major users to make themselves energy independent.

Take Istanbul Atatürk Airport, for instance. Siemens delivered not only the switchgear needed for constructing a new digital platform, but also the digital infrastructure for the integration of vari-
ous energy systems. Adil Akkaya, Electric and Electronic Systems Coordinator at TAV Con-
struction, the sister company of airport opera-
tor TAV Airport Holding, explains that, “This system enables us to generate our own elec-
tricity using gas-powered facilities. With our energy requirement — 95 million kWh per annum — we have sufficient economies of scale to cost-effectively gener-
ate our own power.” Should energy demand and en-
terprises evolve in the small-scale power plant, the monitoring team can switch to power grid. Re-
gardless of which source they use, in both cases the power is generated and transported using Siemens technology.

For Jenny and Gökce, these innovations remain behind the scenes — even though the young woman benefit from their effects. They are enjoying life in Istanbul and looking for opportunities in the megacity. For Jenny, her new role as the human resources manager, Istanbul is a career stepping stone, while for artist Gökce, Istanbul is the environment in which she can develop her creativity and shape and mature. And even if the two never meet during their ferry trips across the Bosphorus, they have one thing in common: their love for Istanbul.

Interview by Andreas Kleinschmidt

As mayor, you have returned Miami to financial stability. Putting the city on the right track to deal with its carbon footprint should be your easier task. Díaz: Sure to tell you this, but you are completely wrong. Curtailing the energy con-
sumption and CO₂ emissions of cities is really a huge task. We have to get reductions on a large scale as soon as possible, and you have to make those cuts sustainable. Our reduction target for 2020 is 25 percent below 2006 levels citywide. Changing the design of a city intelligently is the most important thing that you can do with respect to climate change. A large part of why we keep growing emissions in U.S. cities is suburban sprawl. Sprawl simply highway. It’s a huge project that will help us to keep a lot of heavy traffic out of the city’s core. We are doing this with a private partner. Such projects are good for both sides, because they build on the drive and creativity of both the government and the private sec-
tor. When it comes to large projects, like public transport, our partners of choice are obviously large companies — international household names like Siemens.

Infrastructure projects are long-term measures. Have you had some quick wins in reducing emissions? Díaz: The Miami city government tries to motivate people by giving a positive example

The Road to Greener Cities

“Climate change starts in the head,” says Miami Mayor Manuel Alberto Diaz, 55, in other words, when driving to work is such a deep-rooted habit, change has to start from one’s mind set. Well-designed cities that are characterized by technologies that enhance energy efficiency can facil-
itate this process. Since his inauguration in 2001, Diaz has pushed for green poli-
cies, ranging from funding the retrofitting of houses to expanding public transport. In addition to these efforts, he also managed to turn around Miami’s desolate budget during his eight years in office. During 2008, Diaz was president of the U.S. Conference of Mayors. He studied political science and law and has worked as a lawyer; he remains a part-
ner in the law firm of Diaz, O’Naghten & Borgognoni.

adds up to more cash and thus more storing of natural resources. We are countering this development with a program called Miami 21. It’s the master plan for making Miami, an agglomeration of about half a million people, more fit for the future. We will create mixed use developments, where you have shops within walking distance and use a system for self trans-
portation. After all, if you want to get people out of their cars, you have to offer a viable alternative.

What might this alternative look like in Miami? Díaz: We are currently planning an eight-to ten-mile streetcar project that will connect our most heavily-populated areas with the employment centers. These centers include the business district and developments on the eastern portion of the city, as well as our police department and our state hospital.

Díaz: “We are serious, we have set the emission reduction targets for government buildings at particularly ambitious levels. Our goal is to achieve a 25 percent cut by 2015, compared with 2007 levels. Making air conditioning more efficient is one way of getting large gains quickly. We installed about 40 solar panels at the city hall, thereby covering about 10 to 15 percent of its energy requirements. The project also included a lighting retrofit — including my office. The financial rewards have been shared with a private concern that took on the project. We are also changing our vehicle fleet. Last year we bought our first hybrids. This new way of thinking is catching on in the private sector. Our new baseball stadium, for instance, will be a LEED-certified building. (Leadership in Energy and Environmental Design is a rating system established by the U.S. Green Building Council.)

Was there a key moment for you, when you realized how important sustainable development really is for cities? Diaz: I came to Miami from Cuba at the age of six. Miami is surrounded by outstanding natural beauty, including two national parks. So as a young kid, growing up in this area you are sensitized to this kind of environment and you start to appreciate it. I spent my formative years on the beach, took field trips to the Everglades, and got to realize that in Miami, in terms of nature, you are really part of some-
thing special. However, it’s also something very fragile. And this makes you think — hey, I want the same thing for my kids and their kids.

Interview by Andreas Kleinschmidt

Begins with Public-Private Partnerships

According to the Metropolitan Infrastructure Sustainability Study commissioned by Siemens, nearly two-thirds of the mayors in the United States see great eco-
nomic opportunities in technologies aimed at protecting the climate. In this con-
nection, measures that could be implemented include the more efficient and thus more economical operation of all types of devices and systems. The survey of 140 mayors from 40 U.S. states revealed that the most important issue for them was the current tightening of funds available for investments. On the other hand, federal stimuli packages include additional funds for certain green investment projects in 2009. Four of six cities, however, report that their infrastructure budget for 2009 has declined due to the financial crisis.

Tom Coselan, CEO and Executive Director of the U.S. Conference of Mayors, says, “We therefore have to succeed in making our infrastructure more sustain-
able with the resources available.”

The results of the survey also make clear that the consequences of neglecting public infrastructure measures over the past decades are substantial. In 2006, Siemens asked urban development experts throughout the world about the challenges facing megacities (see Picture of the Future, Spring 2007, p. 14). They considered obsolete infrastructure, such as crumbling bridges and outdated water treatment plants, to play a secondary role. In fact, only 14 per-
cent of the participating experts considered this to be an urgent issue. However, the latest survey of U.S. mayors tells a completely different story. It turns out that 42 percent of the respondents viewed run-down and outdated infrastruc-
ture and its costly maintenance and repair as one of the major challenges they face in their jobs. But the renewal of obsolete infrastructure also harbors opportunities. The replace-
ment of outdated structures with efficient, sustainable solutions is already aomized very quickly and also lays the foundation for livable cities. Siemens sees special opportunities in innovative solutions that combine environmental and economic gains, as many of the technologies required to do so are already available today. They just need to be deployed. For more information, read about studies on sustainable infrastructures in London and Munich, Pictures of the Future Fall 2008, p. 58 and Pictures of the Future Spring 2009, p. 6.

Andrew Kleinschmidt

U.S. Mayors: Renewed Interest in Infrastructure

Since taking office, Mayor Diaz has fought for environmental improvements throughout Miami. His plans cover energy conservation, public transit, and concepts for sustainable land use.
The shining silver, 11-meter-long prototype rolls almost silently along the test track near Strasbourg, France. Airval, the new airport people mover from Siemens, reaches a top-speed of 80 kilometers per hour. “And yet you don’t hear the train coming,” says Marc Zuber, Marketing Director for STS Turnkey Systems at Siemens Industry Mobility in Paris. Even on curves, nothing squeals or rattles. When this elegant train is in motion, the ride is so smooth that passengers feel as though they are already in the air, especially as the land-scape races past the floor-length windows. Even more exciting is the view of the test track through the panoramic windows at the front of the train—a view the passengers can enjoy because Airval is a fully automated train. There is no driver.

According to Zuber, large airports with widely separated terminals will benefit most from this automatic train system. A preview of the system can be seen at Charles de Gaulle Airport in Paris, where the predecessor of Airval has been in service since April 2007. Called CDGVA L and based on VAL 208, the train connects the three terminals in only eight minutes. “The trip used to take more than 20 minutes by bus,” recalls Zuber. In a survey, passengers praised not only the ride but also the reliability of the Siemens-manufactured train and the short headways. CDGVA L runs every four minutes around the clock. In the first year alone, the switch from buses to the electric people mover reduced CO2 emissions by some 2,000 tons.

Airval, an advanced version of VAL 208, is expected to offer even more benefits to large airports beginning in late 2010. “It is often difficult to predict airport passenger volume,” says Zuber. Airval has thus been designed to be particularly flexible. Transport capacity can be easily increased from 1,000 to 30,000 passengers per hour and direction. Additional cars can be sent on demand from a depot to a route that is experiencing particularly high loads; here, cars are automatically coupled to the train within just a few seconds. An Airval train can consist of one to six cars. The trains can also reverse direction at any time. According to Zuber, this facilitates the around-the-clock operation that is necessary at airports: “Maintenance can be performed at night on one track of a two-track route without shutting down operation,” he adds.

Thanks to the latest version of Siemens’ Trainguard MT CBTC train control system, Airval can be operated with headways of just one minute. “When a train leaves the station, the next train is practically pulling in behind it,” says Zuber. To make such short intervals possible from a safety standpoint, the train is in permanent contact with control points along its route via a broadband radio link. This system ensures complete safety through the exact tracking of the relative position of the trains along the line.

The cars are also monitored using high-resolution video cameras, whose images are transmitted via radio to a monitoring center. In addition, the radio link will benefit passengers by allowing them to enjoy Internet access over the train’s Wi-LAN network.

In addition to flexibility, passenger comfort was another key consideration during development of the airport people mover, which will also be introduced under the name “Cityval” as a metro system for large cities in late 2010. “If you want people to get out of their cars, you have to offer them an attractive alternative,” says project manager Philippe Carpentier. “No one feels comfortable in hot, noisy, overcrowded subways. Our trains are air-conditioned, we provide large monitors connected to a dynamic information system, and our design is attractive.” The large windows are intended to help passengers feel in touch with the city during the route segments that are above ground.

Rubber Tires. Perhaps the train system’s greatest trump is the clever use of a surprisingly simple technology. A look at the test track outside Strasbourg shows why the train is so quiet. Airval is equipped with rubber tires that roll along a concrete guideway with two wide, smooth lanes. In the center of the guide-way is a guide rail to which Airval is connected via two rollers arranged in the shape of a “v.” Just beside the guide rail is a power rail. The rollers automatically follow the rail and steer the axle in the proper direction like a drawbar coupling system. “The rubber tires enable the vehicle to be steered faster,” adds Zuber. To make such short intervals possible, the train’s kinetic energy is converted to electrical energy.

Combining regenerative braking and ultracapacitors can cut energy consumption by 40 percent.

The vehicle feeds the energy back into the grid, where it can be transferred to an accelerating train. “This process can be very easily optimized in a driverless system because the control system can coordinate braking and ac-celeration,” says Carpenter. With conventional service, you never know when the driver will brake.

The chasis and the passenger cabin are manufactured separately for now. “This allows us to react more flexibly to the needs of our customers,” says Zuber. For example, an air-port operator can choose how many seats there should be or whether the configuration should allow passengers to move between cars. And the train’s one-of-a-kind steering sys-
Lots of Light for Little Power

Outfitting traffic lights with light-emitting diodes (LEDs) can help cities slash their power costs. These tiny 10 watt lights consume between 80 and 90 percent less electricity than the lamps in conventional stoplights. What’s more, to ensure safety, conventional lamps have to be replaced every six to 12 months, whereas LEDs are genuine long-burners.

“They run for around 100,000 hours, which means they only have to be changed every ten years,” explains Dr. Christoph Roth, product manager for signal generators at the Traffic Solutions Business Unit of the Siemens Mobility Division. When replacing conventional lamps with LEDs, it makes sense to combine the control unit and convert the light to 40-volt LED circuitry. “That means you can use signal light units with only six or seven watts,” says Roth, who estimates that the upgrading of traffic lights at 700 intersections can save a city €1.2 million a year in power expenses. Traffic lights alone, one of the highest mass transit quotients in the world, Wiener Linien plans to reduce by 40 percent by 2013 with capital expenditures alone bringing savings of €140 million. Fitted with conventional lamps, Germany’s traffic lights would consume 1.3 billion kilowatt-hours a year. Refitting with LEDs has cut that figure to 175 million kWh — which corresponds to a reduction in carbon emissions of 180 to 24 megatons. Municipalities can recoup the costs of replacing conventional lamps with LEDs within two to four years, Roth explains. “There are very few towns and cities in Germany that haven’t already converted in part to LEDs, and it’s the trend we’re seeing worldwide,” he says. In Europe, for example, Siemens (p. 68) and Budapest have already fully converted. In Germany, freiburg, Münster, and Mannheim have all taken advantage of a customized financing solution provided by Siemens Finance & Leasing, a subsidiary of Siemens Financial Services. “Our financing model has terms of between four to 15 years, with the repayment schedule calculated on the basis of potential savings, which makes it very flexible compared to standard municipal loans,” explains Jörg Dethlefsen, a member of the executive management at Finance & Leasing. Freiburg, for example, has converted 53 traffic lights to LEDs, a move that has brought its annual savings of €45,500 since 2006. These savings will finance the repayments over the 15-year term of the loan and then flow into city coffers. “Assuming the potential savings have been properly calculated, our financing solution won’t pose any financial risk for the city in question. What’s more, it gives municipalities the scope to invest in other areas,” Dethlefsen adds.

Traffic control centers, low-floor streetcars (pictured left) and many other measures have helped turn the Austrian capital into a role model for holistic mobility concepts.

According to “Megacity Challenges,” a study by Siemens commissioned from UK transport consultants MRC McLean Hazel in 2007, the central problem facing cities with ten million or more inhabitants is how to ensure mobility. In a follow-up analysis — “Vienna: A Complete Mobility Study” — the same company has now shown that the study’s conclusions also apply to smaller cities such as Vienna, with its 2.5 million inhabitants. Transport experts from MRC McLean Hazel confirm that Vienna is one of the world’s most attractive places to live and a model city for modern mobility. As a key transport and logistics hub at the heart of Europe, Vienna is currently reaping the rewards of a long-term investment strategy with the city’s transport operator at the rate of 15 to 20 percent per year, and, last but not least, a Siemens systems alliance and its sister companies — with a volume to a smoothing traffic flow and to preventing gridlock.

Holistic Approach: “Vienna is pioneering a holistic mobility strategy. And the city is now putting our complete mobility concept into practice,” says Grundmann. The goal of the complete mobility approach is to network different transport systems with one another as efficiently as possible.

“The realization of this complete mobility concept involves close cooperation with Siemens IT Solutions and Services,” Grundmann explains. The fruits of this collaboration include a control system for public transport called “PTnova” that was developed with Wiener Linien and is now running as a pilot project. PTnova controls all sales-related processes such as ticketing, customer management and the administration of season tickets. It also automates the entire data flow. Any mobile static ticket machines, ticket printers, and point-of-sale systems can be connected to PTnova. “The use of enhanced information and communications technology can make mobility chains more efficient and public transport more attractive,” says Grundmann. PTnova’s capabilities are in line with the recommendations of transport experts from MRC McLean Hazel. Their study proposes schemes for saved CO2 emissions. As a result, it would help to attract more customers to public transport.

In Brief…

In cities worldwide, infrastructure is crumbling. At the same time, urban areas account for around 80 percent of global greenhouse gas emissions and 75 percent of total energy consumption. Although city planners are often interested in environmentally friendly solutions, many at first see merely the high costs entailed. Analysts estimate that an infrastructure expenditure of €41 trillion will be required over the next 20 years. Siemens solutions offer a number of benefits to urban areas that together fit into the following categories:

- Energy: Siemens technology is helping improve energy consumption. In the Southern Medical Clinic in Trinidad & Tobago, the replacement of conventional lamps with electronic measurement systems saves 15 percent of the energy consumed. Siemens’ ESP Steel Production: Andreas Jungbauer, Industry andreas.jungbauer@siemens.com Andre.Fulgencio@siemens.com Siemens Factory, Istanbul: Kerim Ogul, Energy kerim.ogul@siemens.com Nefisie Akçelik Tunnel: Emre Goren, Industry emre.goren@siemens.com Siemens Factory, Istanbul: Kerim Ogul, Energy kerim.ogul@siemens.com

Siemens IT Solutions and Services,” Grundmann adds. These solutions include 44 high-speed trains for intercity connections and 40 subway trains as well as the associated control, signaling, and safety technology; 300 ultra-low-floor streetcars, which Siemens is delivering to the city’s transport operator at the rate of 15 to 20 percent per year; and, last but not least, a Siemens systems alliance for the city’s urban rail transport.

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Even a city like Vienna, which boasts an excellent public transportation system, can gain added attractiveness through the use of the latest mobility concepts.
An exhibition train called the “Science Express” is rolling through Germany. On board are multiple themes illustrating how research and technology will change our lives. Siemens is providing major support in the form of exhibits and accompanying activities. The goal is to get young people excited about science and technology.

Science: A Moveable Feast

Siemens is one of three business partners, along with Bayer and Volkswagen, that are providing support. The company has made available 13 exhibits on topics such as energy and the environment, health, mobility, and urban life. “The idea is to get young people interested in science and technology,” says Siemens Chairman Peter Löscher. “In my opinion, for example, sustainability is the most urgent issue of the 21st century. It’s also a key theme of the traveling exhibition. That’s why we firmly support the exciting journey into the world of tomorrow it offers.”

The Science Express spends an average of three days in each city it visits, attracting so much attention that long lines are not uncommon. Many people therefore show up at the platform as early as 10 a.m. “We’ve got school classes going in every ten minutes,” says the train’s “conductor.” Siemens has in fact organized tours of the train for around 80 partner schools as part of its support program.

The company also placed several eight-page inserts in Der SPIEGEL and other magazines, as well as producing films for television and various websites on the topics addressed by the exhibition.

From Blue to Green-Collar Jobs. With fewer students studying the natural sciences or technology-related subjects, campaigns like the Science Express are urgently needed. According to the Association of the German Chambers of Industry and Commerce (DIHK), Germany lost around €20 billion worth of gross domestic product in 2007 due to a lack of specialists. But science-related opportunities are great in fields like environmental technology, where Germany is currently the world leader and holds 16 percent of the market, while Europe accounts for a 45 percent share of the market.

“I can see a clear trend from blue to green-collar jobs,” says Lüchter. “For example, sustainability is the most urgent issue of the 21st century — and a key theme of the exhibition.”

In order to address such issues and initiate a discussion about the jobs of the future, Siemens organized a supporting program for the exhibition train featuring two panel discussions with distinguished experts in Munich and Nuremberg. This will be followed at the end of October in Berlin by an international conference known as “Future Dialogue” that will feature representatives from the realms of science, business, and government. The conference will focus on the key future issues of sustainability, climate change, healthcare, and urbanization. “To shape the future, we need men and women of diverse backgrounds who can contribute their knowledge and unique cultural perspectives,” Lüchter explains. “In fact, the sky’s the limit for such motivated individuals.”

Step phen,” says a man on Track 7. “We’ll be moving shortly.” Around 100 people are standing on the wet platform. But they’re not waiting for the train to chug out of the station. That’s because this “Science Express” is much more than just a train — it’s a mobile exhibition. And the exhibition has been rolling through Germany since April 2009. By November, the Science Express will have stopped in more than 60 cities, with some 1,500 visitors coming to see it each day. The train, which is 300 meters long, offers a detailed look at the world of science and technology, addressing questions such as: Where will we be living and working in 20 years? How can our healthcare system remain affordable given an aging population? Will machines one day be able to think like us? How can we provide a growing global population with sufficient food and energy without damaging the environment? Each of the train’s 12 rail cars is devoted to a different topic, providing a taste of things to come and how new technologies will change our lives.

The train was designed by the Max Planck Society, which also attracted millions of visitors in India with a similar train. The Science Express is being funded by the German federal government and many institutes and research groups as part of the exhibition series for Science Year 2009 and the celebrations surrounding the 60th anniversary of the founding of the Federal Republic.

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Steffen Strobel is definitely one such individual. A computer science student, Strobel is one of the 13 winners of Germany’s nationwide Young Researchers 2009 competition. Strobel developed an infrared camera system that makes the veins that lie underneath the skin visible on a computer, thereby enabling doctors to make more precise injections, for example. German Chancellor Angela Merkel presented Strobel with a special award for the most original work submitted for the competition. Strobel, 20, has always been interested in medical and computer technology. “That’s why I’m so excited to see how these topics are addressed in the science train,” he said.

Fundamental Research and Applications. The “Express” begins with questions concerning where we come from and where we’re going. The second rail car takes visitors on a journey into the past. Inside it’s dark, the ceiling is mirrored, and stars flicker on the walls. Here, the visitor learns how the universe came into being. Then it’s on to smaller things — more specifically the nanoscale — in the third car. Like a giant zoom-in, the view homes in on the earth, humans, and the materials of which matter is made. Visitors to the fourth car pass through a futuristic metallic web that unnoticeably transforms itself into a cell-like structure.

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Siemens presents the digital factory of tomorrow in rail car 6. Here, the miniature facility...
simulates the fully-automated production of small soccer balls, as the eyes of interested vis-
tors follow the nine-meter long glassed-in 
manufacturing line with its tiny humming 
machines. The latter process the raw 
material at various stations before the final 
product emerges. All processes are controlled 
and coordinated with one another from a con-
trol center. Over on the far left, machines vir-
tually press and punch the leather into small 
pieces and sew these into balls that they pass 
on to the next workstation. Other machines 
later check final product quality, with all of this 
done completely automatically.

Such facilities can be very interesting for students. “A lot of the topics dealt with in the 
train are really exciting — but soccer is some-
thing I and others can really relate to,” says 
Anja, a twelfth-grader at a Munich high 
school. Anja also thinks that the train is much more exciting than a normal museum. “It makes 
you really want to do research yourself and learn new things,” she says. Anja herself is 
mostly interested in the food industry, bio-
chemistry, and medical research.

Data isn’t the only thing that travels around 
the world; more and more people are also 
traveling faster and further than ever before. 
And this development also harbors risks, as it 
ensures that disease organisms such as flu 
viruses spread more rapidly. Modern technology 
such as that contained in the thermal imaging 
camera in car 7 helps make things safer at 
places like airports by identifying people with 
fever. Although there will always be illnesses, 
it will be possible to identify and combat them 
at an earlier stage than is now the case.

In general, car 8 looks like a real operating 
theater. It’s cool, bright, and sterile looking. 
Images projected on the walls show doctors 
performing surgery in interactive films that 
illustrate how state-of-the-art medical equip-
ment from Siemens can significantly ease the 
strain of an operation on patients who are at 
risk. For example, inserting a new heart valve 
via a catheter no longer requires opening the 
rib cage, as a small chest incision is now suffi-
cient. This is facilitated by equipping the oper-
rating room with a special X-ray system that 
provides images from inside the body during 
an operation. Integrated industrial robot tech-
nology allows the surgeon to position a so-
called Carm X-ray device almost anywhere 
around the patient. The system, which can 
even generate 3D images, helps to make the 
procedure more precise and less costly.

Flight through Energy Stations. Rail car 9 
tackles the issues of climate change and to-
morrow’s sustainable supplies, one of the most important topics for researchers and 
developers at Siemens. Many visitors are fasci-
nated by an interactive table that shows the 
complete energy conversion chain. Visitors 
simply move their fingers along a touch-sensi-
tive monitor surface to fly through various 
energy conversion stations that represent 
everything from oil production facilities and 
pipelines to power plants, wind power facilities, 
power lines, transformer stations, industrial 
consumers, and private houses.

A click tends the flight “down,” thereby al-
lowing viewers to gain a deeper insight into 
the topic at hand. Users can also look at videos 
and graphics that show what form the most 
environmentally-friendly and efficient energy 
supply and utilization systems might take in 
the future. One example is wind power, whose 
systems are more technologically advanced 
than those of any other renewable energy 
source. Siemens is building more and more 
wind farms at sea; the ones off the coasts of 
England and Denmark are the largest in the 
world. The world’s first floating wind turbine — 
located off the coast of Norway in waters 
220 meters deep — is also now being tested.

To illustrate how people in poor countries 
can be provided with clean drinking water, 
Siemens is also presenting a membrane filter 
system that can be set up anywhere at relatively 
low cost. The system’s tubes have hair-thin 
filters with tiny pores that filter out all impuri-
ties and germs, ensuring that no bacteria, 
or even viruses, can pass through.

Siemens is also working on solutions that 
address challenges associated with the mega-
trend of urbanization. More than half of the 
world’s population already lives and works in 
cities, and that figure will increase to two-
thirds by 2050. A key question is therefore: 
How will people live then? Car 10 examines 
the most important aspects of the answer.

Among the things that will be needed are in-
telligent transport systems and new building 
technologies that will make living together in 
large cities as comfortable as possible, while 
at the same time protecting the environment.

One such system is the “comfort sensor” 
from Siemens, which visitors can try out for 
themselves. The sensor measures ambient CO 2 
content and humidity. If, for example, CO 2 
concentrations should rise to a critical level in 
a conference room, the system will issue a 
warning that the room needs to be ventilated 
to avoid participants’ becoming fatigued and 
unfocused. Similar sensors could be used in 
the future to further automate building man-
agement systems, thereby generating huge 
energy and cost savings. That’s because, de-
pending on location and operating strategy, 
heating, ventilation, and air conditioning sys-
tems account for 30 to 70 percent of total 
building energy consumption.

Light-Emitting Ceilings and Wallpaper. 
Energy-saving illumination with light-emitting 
diodes is another car 10 topic. Here, Siemens 
subsidiary Osram demonstrates how powerful 
white and colored light-emitting diodes can 
already shine today — so much so that they 
can be used in general household lighting sys-
tems or as car headlights or traffic lights.

Osram also offers a look at the future in the 
form of a small illuminated house which, 
rather than using conventional lamps, is 
equipped with flat organic light-emitting 
diodes (OLEDs) embedded in windows, ceil-
ings and parts of the floor.

A “comfort sensor” warns if a room should be aired 
out before the people inside begin to get tired.

A cloudy sky, the OLEDs in the ceiling 
create a pleasant diffuse light for the rooms. In 
the future, it may thus be possible to equip 
bedrooms with new types of light-emitting 
wallpaper and children’s rooms with transpar-
ent, bendable light-emitting walls.

Osram has turned on the lights in another 
special way in car 11, where visitors look 
around to all sides, their faces illuminated in 
a pulsating play of colors, as they walk through 
a tunnel made of 1,900 colored LED tiles.

Strobel has now arrived in car 11, where he 
finds an exceptional exhibit: a 3D face scanner 
that experts from CT and Siemens IT Solutions 
and Services combined with biometric recog-
nition systems for fingerprints and hand veins 
especially for the science train. The system is 
based on the use of infrared rays that pass 
aver an individual’s face to register its surface 
in a fraction of a second, after which it calcu-
lates and generates a 3D image of the face 
that is precise down to just tenths of a millime-
ter. Visitors can rotate their scanned image on 
a computer screen and then send it in an e-
mail. The scanner can also identify visitors 
by the basis of their fingerprints and by the 
equally unique pattern of their hand veins. 
As an expert for infrared cameras, Strobel is truly in 
his element and gets right to work testing 
the system. “It’s really exciting to be able 
to experience this technology up close,” he says. 
Scanners like the one on display could be used to 
authorize access to automated teller ma-
chines or certain websites in the future.

Car 12, which contains a lab where school 
classes can perform experiments, marks the 
end of the exhibition. Visitors rub their eyes on 
encountering daylight as they leave, visions of 
the future still fresh in their minds.

It’s still raining at Munich Central Station — 
and there’s still a long line at the entrance to 
the science train. The world outside is still the 
same — but perhaps the visitors to the exhibi-
tion have changed somewhat. After all, al-
though the train never moved, the people in-
side had the feeling they were on a fascinating 
journey — a trip into their own future.
Fused Realities
How can doctors better treat a range of conditions in real time? Thanks to new techniques from Siemens that fuse information from different diagnostic modalities, many conditions are becoming transparent.

The Illusion of Presence
Tomorrow’s meetings, training and repair activities will take place in cyberspace. The result will be faster service, reduced travel, and a sharp cut in CO₂ emissions.

Simulating a Monster
Siemens is developing a simulator for the gigantic bucket wheel excavators used for mining brown coal. The objective is to train operators without damaging machinery.

Dignity in the Digital World
Jaron Lanier, a pioneer in the field of virtual reality, discusses values in cyberspace and describes the future of the virtual workplace.

Predictive Vision
Crowd flow simulation will make public places safer. The technology makes it possible to recognize potentially dangerous situations before they happen.

Small Worlds
Materials scientists at Siemens use simulations to develop materials with improved properties.

By 2020, even experienced doctors will sharpen their skills on downloadable, life-like, virtual patients, allowing them to prepare for the most challenging emergencies — and opening the door to new ways of meeting and interacting with colleagues.
Janice administered the virtual cocktail the vasculature and improve circulation. Dr. parin and aspirin in quantities that had been optimized for the patient's condition to dilate tentatively. A glance at the ECG, however, apy. But then his heart beat and blood pressure twitched convincingly in response to the therapy, even as the file voice droned on. Gee, she's impressed.

"Incredible," I said to myself as I touched the "Admit" icon that appeared on the display, after all, successful emergency care is all about good teamwork, and you can never be too good at that.

So a second later there she was, Dr. Janice, a young cardiologist with — and I have to admit that this is my one real weakness — blond hair and one of those little bunched-up pony-tails that really gets me going.

But before my mind had a moment to wander, a virtual electrocardiogram (EGG) on the display began flashing and beeping, indicating that the patient had gone into ventricular fibrillation — spasms of the cardiac muscle that can lead to sudden death within seconds. At this point, an angiodysphase voice from the patient's file began calmly announcing: "Fifty-nine year-old male with a history of smoking, obesity and poorly-controlled hypertension.

The patient was successfully treated earlier for an acute atrial fibrillation. The patient's vital signs, in particular the rhythm of the heart, are unaltered.

"Any plans for the weekend?" I asked nonchalantly as the catheter reached its target and the balloon tip began to inflate. I squeaked. "Oh brother, this is a tough one," I said to myself. "Ms ah, Dr. Janice, please administer 3,000 units of heparin and Atropine," I said with a tense smile, referring to a powerful an- ticoagulant and a blood-thinning agent that would hopefully buy us some extra time. "And fill a catheter in there to clear that obstruction," I added.

To avoid wasting a minute on routine procedures, the patient had already been outfitted with a catheter, so that all I had to do was grab a wireless, handheld device to steer the virtual wire into position. I watched the ultra-sound and equipped tip of the device snake its way toward the obstruction as I looked down at the patient, the goggles allowing me to see through the patient as they would during a real operation by superimposing a CT image and the catheter's coordinates on the patient's anatomy with flawless registration.

"The patient was successfully treated earlier for an acute atrial fibrillation. The patient's vital signs, in particular the rhythm of the heart, are unaltered."

As we signed off on the training document, Dr. Janice looked up at me from the other side of the virtual reality wall. My spirits lifted in anticipation. "So where do you live?" she asked. "Sydney," I announced hopefully. "Oh my, that's a long way from Montreal," she said, but then added playfully, "Let's meet in Second Life."

Across this continent, scientists have been tuning into a steadily-growing spectrum of what they call "mixed realities" in which elements of the real and virtual are combined in varying amounts (see articles on conferencing p. 95, commissioning p. 98, peerless streams p. 101, and materials p. 102). But it is at the far end of the spectrum — in the virtual world — that the potential for revolutionary competitive advantage is taking shape for major in-dustry companies such as Siemens.

"For us, the virtual world is more than im-portant," says Dr. Reinhold Achatz, who heads Siemens Corporate Research and Technolo-gies, "it is mission critical. The value proposition is that when you can create and test devices before they exist in the physical world, you save time and money, while potentially increasing quality and flexibility."

And, as Achatz adds, Siemens is ideally po-sitioned to do exactly that: "There are automa-tion software companies, and companies that understand digital factories. But there is no other company besides Siemens that has the ability to drive both of these areas."

How to Transmit a Product. Just how profi-cient Siemens is becoming in the virtual world is illustrated by its development of the first vir-tual, semi-automated digital inner ear hearing aid pre-manufacturing system, which is now being tested in Shanghai, where highly-expen-sive yet inexpensive labor is available. There, when a worker receives a digital mold of a pa-tient's inner ear, which is taken by scanning a real mold, programs help the worker to hollow out the mold, while ensuring the smoothness of all inner and outer surfaces. Throughout the process, programs help to ensure that the shell remains of uniform thickness and precision is crucial since the digital version of the shell will be exactly duplicated when trans-mitted to physical manufacturing.

Once the digital shell is complete, other pro-gress suggests optimized placement of the hear-ing device's minuscule components. Workers need only check the system's suggestions and click "next" to continue. "When performed man-ually, shell crafting and component placement easily add up to unusable results," reports Siemens Corporate Research (SCR) Program Manager Dr. Fang. "But with the automation steps we have developed, that process is set to be reduced to only one or two minutes, and eventually it will be completely automated."

Following quality testing, the virtual devices are electronically transmitted to production centers, most of which are in North America, the largest market for such devices. "Thanks to the new technology, the number of products returned has already been reduced from 20 percent to five percent," says Fang.

Mixed-Reality Buildings. Not only are very small products such as digital hearing aids being developed, personalized and perfected in the virtual world, so are major facilities ranging from skyscrapers to power plants. The U.S. military,
for instance, now requires that all its new build- ings start out as computer-generated models. “The reason that many organizations are mov- ing in this direction is clear,” explains Dr. Mirka Appel, a specialist in industrial augmented real- ity with Siemens Corporate Technology in Mu- nich. “Facilities that are born in the virtual world can be upgraded there as well. And as technolo- gies evolve, improvements can be planned and tested on a virtual model before being im- plemented in the real world. It all adds up to potentially huge savings for the customer.”

But there’s a catch. Unlike hearing aids, which are assembled by a single manufacturer, it takes dozens of contractors to assemble a com- plex facility such as a coal-fired power plant, and many of them fail to follow the CAD model to the letter. “Along the way, they produce new technical drawings,” says Appel. “And the re- sult is that, although a 3D CAD model can rep- resent hundreds of man-years of work and mil- lions of dollars of investment, the actual plant often diverges significantly from its model.”

To pinpoint the salient differences between a real plant and its CAD counterpart — and thus walls to support particularly heavy structures — as geographical reference points,” says Ap- pel. As long as some part of an anchor plate is visible in a photo, the program recognizes the room and the angle of view from a combina- tion of geometric features and augments the photo by overlapping the appropriate CAD de- sign — in perfect registration — onto the im- age. “The software needs a lot of reasoning ca- pabilities to do this,” says Appel, who adds that the technology is now being implemented on a pilot basis in a power plant in northern Europe.

The value proposition is that when you create and test devices in the virtual world, you save time and money.

Siemens researchers are on the road to modeling the morphology and electro-mechanics of the human heart — and are already automating the assembly of hearing aids in the virtual world.

Once a building’s CAD design is proven to be accurate, its virtual model can be dynami- cally mixed with real-time views for any num- ber of purposes. “For instance, evolving fire safety regulations may require updates of evacuation routes,” says Yakup Genc, PhD, program manager for the 3D Vision and Aug- mented Reality Program at Siemens Corporate Research in Princeton, New Jersey. “In this case, the building manager would be able to perform a virtual fly-through of an entire building by superimposing real-time camera views of escape routes on CAD diagrams. This would provide up-to-the-minute information about potential obstacles, fire extinguishers, exit signs and lighting — all of which could be — in principle — automatically documented.”

Virtual copies of real buildings can also sim- ply and reduce the cost of maintenance and training services. As SCR President and CEO Paul Camuti points out, “One of the things we are working on is how to bring experts into a building operation system in Second Life (for more, see p. 95) to shorten the time it takes to respond to a problem.” The concept, which is par- ticularly valuable for complex, out-of-the-way facilities such as wind parks and offshore drilling platforms, works as follows: At such lo- cations, an on-site technician may tap a world- class expert to resolve a problem with, say, a wind turbine generator. “In this case, the ex- pert — if authorized — can log into the wind park’s web site and enter the virtual world copy of the problem tower — no climbing skills required,” says SCR’s Genc. “That’s full VR. But if the expert wants to see and hear exactly what the local technician is looking at, that can be provided by a head-mounted mini cam, the images from which can be superimposed on the virtual view — which might be called aug- mented virtuality.” The result, says Genc, is a great system for troubleshooting and training. “For instance,” he adds, “the off-site person can point to an item with a cursor that the on-site person sees in exactly the same spot through augmented reality glasses. The 3D environ- ment makes distance collaboration possible by combining physical and virtual realities.”

Duplication World. As office buildings, wind parks, power plants, roads, bridges (think Google Street View) and even private homes are added to the virtual landscape, a digital duplicate of the real world is being pieced to- gether. Add to that the fact that an ever-grow- will come to include not just the physical char- acteristics and appearances of objects, but their functional ones as well. Data on heat and fluid dynamics, radiation, fatigue, and electro- magnetic characteristics, for instance (see box), may be available on the virtual versions of everything from hearing aid components to auto parts, thus opening a new kind of econ- omy in which virtual products are optimized for each other in terms of dozens of factors.

Me, Myself or My Avatar? Just as models of inanimate objects are becoming hyper-real through simulation of a widening spectrum of characteristics, human biology is coming into sharper focus — with amazing implications when applied to the virtual world. “There is an analogy betw een manufacturing cells and hu- man body,” says Arthur F. Pease, PhD, head of SCR’s Integrated Data Analysis Department at SCR. “That’s the essence of virtual reality. In ‘real’ life, you can’t ask a heart, for instance, in terms of factors such as morphology, dynam- ics, electro-mechanics, tissue, myocytes, ion channels, and molecular profiles,” says Dorin Comaniciu, PhD, head of SCR’s Integrated Data Systems Department. “But what is most impor- tant in all of this is that as we combine macro, micro and nano-levels of knowledge, the infor- mation will be personalized. That’s where the value for patient and physician becomes clear.”

Value indeed. Think electronic patient files that contain up-to-date — albeit vastly simpli- fied — functional models of their namesakes’ circulatory systems, etc. Want to know how a particular combination of agents will af- fect the treatment of your arrhythmia? Run a simulation on your avatar — not on yourself. That’s the future. “If we build models all the way out to molecular profiles, we will be able to an- swer questions predictively in the virtual world

Virtual Realities | Trends

90

Pictures of the Future | Fall 2009

Siemens researchers are on the road to modeling the morphology and electro-mechanics of the human heart — and are already automating the assembly of hearing aids in the virtual world.

Bringing a product to life in the virtual world requires integrated analysis capabilities that simulate the physical world in which the object will eventually operate.

Consistently valuable for complex, out-of-the-way facilities such as wind parks and offshore drilling platforms, works as follows: At such locales, an on-site technician may tap a world-class expert to resolve a problem with, say, a wind turbine generator. “In this case, the expert — if authorized — can log into the wind park’s web site and enter the virtual world copy of the problem tower — no climbing skills required,” says SCR’s Genc. “That’s full VR. But if the expert wants to see and hear exactly what the local technician is looking at, that can be provided by a head-mounted mini cam, the imaging spectrum of products and components is being developed there as well, and you have the potential for something called ‘crowd sourcing’ — the idea that content authoring in the digital world is so distributed that it comes from everywhere. ‘If you’re planning a new so- lar thermal installation, why not test it out on the virtual world’s copy of the local utility’s transmission network before you build it?’ asks Genc. ‘There’s no need to reinvent the wheel.’

What’s more, as computing power and the level of detail in simulations continues to grow, information fusion in the digital world analogy between manufacturing cells and hu- man cells,” says CT Head Reinhold Achatz, a specialist in automation; “and my expectation is that as we approach a deeper understanding of biology, we will be able to model the hu- man body down to the cellular, and perhaps even the genetic level — much as we model materials on the molecular level today.”

At Siemens, that process is already well un- der way. “Over the next few years, we expect to be able to model the human heart, for instance, in terms of factors such as morphology, dynam- ics, electro-mechanics, tissue, myocytes, ion with a high level of accuracy,” says Comaniciu. And what about training for surgical emer- gencies? Is it as case for pilots, there’s no safer place for surgeons to earn their wings than in the virtual world. “Ninety-nine percent of surgeons’ time is routine. But it’s that one- in-a-million emergency that demands one- hundred percent of a team’s expertise,” says Dr. Frank Sauer, head of the imaging and Visu- alization Department at SCR. ‘That’s the emer- gency you can train for over and over again in the virtual world. ‘Now all that’s needed are a few willing avatars!’

Arthur F. Pease
A case in point is a groundbreaking group of orthopedic and trauma-related procedures taking place at the Ludwig Maximilian University Surgical Clinic in Munich, Germany. There, using technology patented by Siemens Corporate Research (SCR) in Princeton, New Jersey, a modified Siemens C-arm X-ray system suitable for use in operating rooms has been outfitted with a camera-mirror module that produces an optical image of precisely the same area being imaged by X-rays. In practical terms, what this means is that the surgeon takes one X-ray of the area in question, after which the optical image is superimposed on the X-ray image. The result is that the surgeon not only sees the area of interest on a nearby monitor exactly as it appears to the eye, but also sees the underlying anatomy in perfect registration.

“With a scalpel is placed on the skin in preparation for the initial incision, the underlying bones and fracture lines are clearly visible, making it perfectly clear where the incision should be made,” says Prof. Nasser Navab, one of the inventors of the system and Chair for Computer-Aided Medical Procedures & Augmented Reality at the Technical University of Munich (TUM). “Without this innovative technology, many patients would have to be X-rayed several times before an operation could begin,” Navab adds. The system also provides additional support during an operation — for example, by helping surgeons locate the exact position where a drill should be placed in relation to the anatomical structure below. This is important, for instance, when placing screws at the right angle, as it prevents the exposure of patients or medical personnel to unnecessary additional radiation.

Augmented reality is also providing hope for more precise surgical treatment of breast tumors. At Beth Israel Deaconess Medical Center in Boston, Massachusetts, for example, Dr. John V. Frangioni has developed a new optical examination procedure known as FLARE (Fluorescence-Assisted Resection and Exploration, see Pictures of the Future, Fall 2008, pp. 89, 91) that employs unique medical image fusion and visualization software developed by Siemens. In combination with a near-infrared fluorescence dye, which was recently successfully tested in a clinical study and is now being further optimized, the system is able to make sentinel lymph nodes, which may be afflicted with cancer cells, visible.

“The core elements of FLARE developed by the Frangioni Lab are two near-infrared (NIR) light sources and cameras that detect fluorescent substances in the body. With two separate NIR fluorescent channels, one could show tissues to be resected such as tumors, while the other might show tissues to be avoided such as nerves or blood vessels, thereby helping to avoid damage. These NIR images are merged in false color with images acquired by a color video camera enabling visualization of the NIR fluorescent dye in an anatomical context.”

Meanwhile, at the National Institutes of Health (NIH) in Bethesda, Maryland researchers — with support from colleagues at SCR — have developed an image-fusion procedure designed to locate life-threatening arrhythmias. Based on the use of X-ray images and magnetic resonance (MR) scans, the system has been used extensively at NIH to superimpose views of the heart's soft tissue structures derived from MRI onto live X-ray images. For example, using MR images to depict an arrhythmia-causing scar in the left ventricle, a catheter can be steered to the scars most likely to benefit from treatment.

Working along similar lines, this time in collaboration with Johns Hopkins University, NIH researchers used an image fusion system in an animal study to provide precise real-time images of the path instruments should take through the jugular vein during minimally invasive procedures targeting the portal vein, which transports blood from the abdominal cavity to the liver.

“The researchers used a conventional Esquire MR scanner from Siemens to produce high resolution 3D images of vessels in order to create a ‘road map’ of the portal venous system. They then combined these images with X-ray images from an Axiom Artis scanner. To ensure that the image data sets from both devices would fuse precisely to form a single picture, the two systems were calibrated via markers on a pig’s abdomen that were visible on both MR and X-ray images. Physicians used the MR images to segment the portal vein and surrounding structures and superimpose them on the X-ray images during navigation of a catheter in the portal vein. Initial results showed that the superimposed MR images allowed faster and more precise entry into the portal vein.

The researchers still have more than enough challenges to overcome before their X-ray-MR fusion technique can be utilized in clinical applications. Says Christine Lorenz from SCR: “The technique functions well when the organs being examined don’t move too much. However, what we really need to make this kind of procedure successful in the abdomen or heart is to develop techniques to compensate for cardiac and respiratory motion — we’re working on it.”

Ultrasound and CT. Another widely used diagnostic method is the ultrasound-echo technique, which provides immediate results with little effort. Its resolution is low, however, and a great deal of experience is required to properly interpret its 2D images. Researchers Ali Kamen, PhD and Wolfgang Wein from SCR want to overcome these drawbacks by combining it with CT imaging. “Ultrasound delivers a lot of data, but no 3D information,” says Kamen. “We can get that with CT images.” He describes how the two modalities can work together: A patient with a liver tumor, for example, would first be scanned using CT. A doctor can use the result-
such information is not sufficient for a diagnosis, the doctor can inject an ultrasound contrast agent containing micro-bubbles into the blood vessels. These tiny bubbles reflect sound waves, and clearly show how much blood the tumor is being supplied with, thereby simplifying the diagnosis. “The stronger the blood flow in the tumor, the more active and threatening it is,” Kamen explains. 

The goal is to allow doctors to merge both applications to produce a single image. This will not only help with diagnoses but also with treatments, such as tumor removal. “Our research project is designed to ensure that equipment operators receive all information at a glance regarding how and where a tumor is, and from which direction it can be resected without damaging important blood vessels,” says Kamen. “We’re now testing the system at the Mayo Clinic in Rochester, Minnesota.”

Mapping the Heart. Meanwhile, a team at SCR headed by Dr. Frank Sauer is making progress in the treatment of heart disease with the help of AR technology. “We now have realistic 3D depictions of the heart, which enable us to view catheter records in a surgical setting and get intra-operative treatment much better than ever before,” says Sauer. This development was made possible by an integrated system that combines CT or MR images and electrophysiological heart mapping and visualization (CARTO mapping). The 3D heart images produced with the tomography system are exact and precisely contoured. After these images have been obtained, a doctor navigates an electrophysiological mapping catheter into the heart chamber. Three alternating magnetic fields underneath the operating table are used to pinpoint the position of the catheter sensor tips. These sensors record the spatial anatomy, and their electrical signals create an electro-anatomical map of the heart. The electrophysiological images are then merged with the CT or MR images with the help of software.

The catheter operator in the electrophysiology lab sees the heart chamber on a monitor in real time, and can thus use the 3D image to maneuver the catheter safely and quickly. SCR and Siemens Healthcare are working closely on this technology with Biosense Webster Inc. (BBI), a subsidiary of Johnson & Johnson. The navigation software has already been marketed by BBI under the name CartoMerge. Siemens Healthcare in Erlangen, Germany, is also developing AR systems. Recently, for instance, it presented a navigation system targeted at minimally-invasive spine operations and trauma surgery. With Capa-CNav, doctors put together a 3D X-ray data set of the area to be operated on, allowing them to optimize the planning of implants, for example. During the operation, the doctor navigates using an infrared stereo camera that sees the system’s small reflecting marker spheres, which are on the surgical instruments. Software processes these signals, allowing the doctor to continuously view the position of the instruments in the patient’s 3D image. If necessary, the doctor can, for example, virtually check whether the implant screws are ideally positioned and the right size before inserting them.

“How quickly such AR systems make their way into hospitals depends on how well image fusion systems can be integrated into the clinical workflow,” says Navab. “The key is to de-liver the images in real time.” Navab, who worked at SCR in Princeton until a few years ago, is convinced that “augmented reality” will become widespread in medical technology over the next ten years. “It’s crucial, however, he emphasizes that “this development occurs in close cooperation with doctors and hospitals; otherwise they won’t accept the new technology.”

Virtual Realities | Healthcare

Augmented Reality in Medical Systems

Conventional medical imaging systems are used by doctors to examine parts of the body before most operations. During treatment, doctors can view a monitor image acquired by computer tomography, magnetic resonance tomography, or other imaging procedures. These days, such systems are also used to precisely measure and visualize the position of surgical instruments, whose locations within the body can be viewed on a monitor. Such a situation is not always ideal, however, especially when difficult and complex treatments are required. That’s because images recorded before an operation do not always fully correspond to the actual situation at the time of the procedure. Moreover, such computer-generated images are spatially disconnected from the surgeon’s view — when the surgeon uses his instruments. In contrast, the virtual image is properly aligned with the patient’s anatomy; otherwise the doctor might misplace the surgical instruments within the body. Virtual images must thus be produced in real time during an operation. Physicians and medical device developers expect that new navigation equipment will be ideal for minimally-invasive surgery, doctors will be able to focus more closely on surgery, and not have to divide their attention between the patient and a monitor. All also simplifies hand-eye coordination because doctors view real and virtual instruments from the same angle. Orientation within the patient’s body is supported by 3D real images, thereby enabling doctors to work with much greater precision and more easily avoid errors.

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The Illusion of Presence

Tomorrow’s meetings, training and repair activities won’t be what they used to be. Instead of high-energy expeditions powered by planes, rental cars and hotels, we’ll fly through virtual space on a kilowatt or two of server power.

Oscar Zanabbar often flies to meetings. In fact, you can see him, arms outstretched, Superman style, effortlessly winging his way over golf courses and office parks, coasting through buildings, and touching down at a packed conference table or a neon-lit control center. To the casual observer, Zanabbar’s paraplegic life has all the trappings of a video game — the ability to levitate, choose from multiple identities, and travel to far-off places in seconds. But like the virtual world he inhabits, Zanabbar is the product of two opposite trends: the quest to escape reality and the steadily improving capability to duplicate and augment it.

“The virtual world is undergoing a maturity curve that is carrying over capabilities developed for gaming into the world of training,” says Zanabbar’s real-world incarnation Steve Russell, PhD, a member of the Integrated Data Systems Department at Siemens Corporate Research in Princeton, New Jersey. A specialist in virtual world conferencing, Russell points out that major virtual world sites such as OULive, Unisfair and Second Life now have millions of members, each of whom is represented by one or more avatars, which may be realistic or fantasy representations of themselves. But virtual world sites are also hotspots to the virtual counterparts of countless corporate and government organizations, many of which have paid tens of thousands of very real dollars to buy “land” and build often elaborate facilities for a wide range of purposes. Why are organizations as diverse as the U.S. Marines, the University of Kansas, and Siemens flocking to the virtual world? The reasons are as many as a psychological as practical. “When you’re in the virtual world, it’s very different from a phone call or a teleconference,” says Russell. “Participants feel they are sharing a place and an experience. It’s social, you see expressions on avatars’ faces, you hear the real person’s voice. All this is good for team building.” At the same time, the practical advantages are clear: they range from greatly reduced time and travel costs — with associated reductions in CO2 emissions — to hybrid forms of training and service that aren’t possible in the real world. Take Siemens’ “Virtureal” site in Second Life, for instance, a demonstration project that is ready for real-life deployment. The site was inspired in part by an actual Siemens building in Dallas, Texas. The Dallas facility contains a control center that continuously monitors the real-time status of a range of automated systems in buildings in other cities. But the Virtureal site (see left image on following page) can do the same thing from Second Life— offering the potential of eventually replacing a real building with a virtual one.

Sites such as Virtual tour open the door to dealing with problems that technicians might be unable to resolve today. For instance, such a center can “fly in” a remote specialist for a visit to a virtual copy of the actual work site, which can include live camera feeds from the on-site technician’s cell phone. “At that point, simply by knowing which panel the technician is looking at, the specialist can embed his avatar into
the virtual environment, walk it to the techni-cian’s exact location, and see what’s on the read-outs,” says Russell. “The on-site technician and the off-site specialist see the same thing, and they have the illusion of being together.”

Defended by multi-level security or hidden within a company’s own powerful firewalls, facilities such as Virtual2 can be effectively invisible and “unsearchable” to unauthorized individuals. Virtual worlds thereby offer an ideal venue for a variety of other purposes, including employee motivational events, training, and everyday meetings. Earlier this year, for instance, according to Linden Lab’s Second Life, IBM’s elite Academy of Technology held a conference in which the avatars of over 200 people attended some 17 breakout sessions. IBM estimates that the event cost one-fifth of what it would have cost in the real-world, with much of its price tag going for virtual real estate, buildings and associated design services.

Just Face It. For those who find that avatar-based environments do not offer sufficient re-alism in terms of eye contact and facial expres-sions, Siemens has developed ViviConf — software that allows peers to see each other as they really are in the context of a virtual meet-ing using nothing more elaborate than a single off-the-shelf PC video camera and microphone. Unlike other dedicated conferencing systems, which partition views of participants in boxes or use specialized meeting rooms painted in exactly the same color, ViviConf uses a software developed by Siemens’ Technology-to-Business Center (TBT) in Berkeley, California to subtract each participant’s background from each image in real time. This allows users to choose from a number of common, shared backgrounds that can create a high atmosphere to a meeting. All that’s needed is a very brief training phase in which the camera sees the background alone. After that, participants in a ViviConf meeting can move their heads, hands and arms, and these movements will be accurately and clearly seen by all other partici-pants without background-associated artifacts.

“A common background is the key point in terms of maintaining the illusion that partic-ipants are in the same place,” explains Stuart Goose, who, along with Jinhu (Jason) Hu, PhD, developed ViviConf at the TBT for Siemens Enterprise Networks, which is now analyzing a number of implementation scenarios. The illu-sion of presence even works for people who don’t have a video camera, since ViviConf al lows them to insert an avatar of themselves into a meeting. “Having a visual representation of each participant is important,” says Goose, “because then people can’t forget that you are present, even if you are very quiet.”

The illusion of presence in ViviConf meet-ings is also being extended to the audio do-main. At Siemens Corporate Research (SCR) in Princeton, New Jersey, for instance, develop-ers have come up with a system that connects people’s voices with their faces. “When some-one speaks, the software synthesizes a stereo effect in order to give the other participants a sense of the direction of the speaker’s voice that matches his or her location in the virtual meeting environment,” says Yuki Gens, Program Manager for 3D Vision & Augmented Reality at SCR. “The critical feature here is to make this tech-nology automated and absolutely dependable.” Although it relies on a single inexpensive desktop camera for each participant, ViviConf offers plenty of potential for advanced applica-tions. It can be used to carry this technology to the point where groups of engineers can use it to collaboratively design CAD models, perhaps even using haptic gloves,” says Goose. Already, he points out, participants can use it to virtu-ally walk inside relatively simple models. “But already, ” he says, “if you could simulate your customers to walk — or even fly — through part of a virtual plant, complete with animations of production lines and machine sounds.” Now that’s the kind of flight that even Star Zanzibar might wish to take.  

Arthur F. Pease

Many people have enjoyed the benefits of virtual product planning at one time or another — for instance when buying a cus-tom-tailored kitchen. Whether on your own or in conjunction with a sales assistant, you can conjure up a model of the kitchen on a moni-tor and select the desired modules. Everything can then be revised with just a few clicks of the mouse.

The end result of such exercises is usually a static digital design. But suppose you could view the image from any desired angle, aug-ment it with written or voice annotations, or even insert video clips — that’s the promise of 3D documentation and archiving.

“We expect this process to become stan-dard for the development of complex products such as engines and medical equipment,” says Sylvia Glas, an electrical engineer who heads a pilot project for multimedia applications in technical documentation at Siemens Corporate Technology (CT).

“The benefits of developing products in the virtual world are wide-ranging. “The most no-table are that many processes are simplified, shortened, and made more cost-efficient,” says Glas. In digital engineering the model data is available long before production of a prototype. This means that detailed brochures can be printed before there is a concrete ob-ject to photograph. What’s more, the product can also be depicted on a monitor so clearly that sales personnel can refer to a ‘look and feel’ experience.

The pioneers in creating objects in the vir-tual world are the aerospace and automotive industries. In these sectors it is routine for models to be developed using computers and then tested in the virtual world before the first physical prototype is produced. This can dra-matically reduce the cost of development — something by as much as 50 percent.

This exciting new world works only, how-ever, with products that are designed, devel-oped, and visualized using a computer right from the beginning. “That’s the only way to have full availability of all the data needed for a virtual model,” says Glas.

For the CT pilot project, Glas’s team chose a new drive system from the Siemens Industry Sector’s Large Drives Division — the HT-direct motor, which works using a permanent mag-net. The product was selected because all of its engineering data was already available in digital and 3D form.

Interactive Animation. Using this data, Glas’s team tested a range of design and produc-tion programs to see which was best suited for gener-ating virtual and spatial models. “Ultimately,” says Glas, “we decided on 3D PDF from Adobe, because it is a free program within Adobe Acrobat Reader, which is standard on all office computers at Siemens.” A generic tool, 3D documentation offers plenty of potential applications across a spec-trum of fields. Take healthcare, for instance. Here, if doctors need to share a lung scan with colleagues or patients, the only way to do so today is to copy it to a CD and physically mail it. And recipients may still require a specialized program to view it, explains Sarah Witzig, project manager at Siemens Corporate Research (SCR) in Prince-ton, New Jersey. But if such a scan exists in a standard format such as 3D PDF from Adobe, it can be read on any computer, complete with annotations.

Replacing User Manuals with Images. Siemens’ new 3D documentation system of-fers a number of time-saving advantages. From a product pipeline perspective, it reduces start-up tim es by as much as 50 percent. Training and manufacturing runs are extrem ely short. It also has the potential advantage of sharply reducing the need for translation processes or for operational functions can be provided using a standard with a content object as a need for translation. Training content can be changed at every location and digitally up-dated to include the latest developments. Even a model’s inner workings can be easily displayed, for example by clicking a mouse to make the product’s representation transparent.

The new 3D documentation technology will also help to accelerate business interac-tions, whether within the product develop-ment with the production line, or marketing with sales, or ordering and billing with human resources. “Eventually, our standards will have to be agreed upon,” says Witzig. “Right now, we are working on the tools for convert-ing data from different systems into formats that are required for creating a 3D PDF in an automated fashion,” says Witzig.

One format that will be supported by this project is the 3D PDF, which will be the new 3D PDF is now commonly established as today’s standard format for visualization and exchange of 3D data. It will soon make cooperation between com-munication partners much easier. The JT data format is a technology from Siemens PLM soft-ware as well as by many automotive industry companies. As the real world, the virtual world consists only of many separate elements that naturally come together to form a complete picture.

Katrin Nikolaus
Simulating a Monster

Siemens is developing a simulator for the gigantic bucket wheel excavators used for mining brown coal. The objective is to test new automation systems and to train tomorrow's machine operators without risking damage or increasing downtime.

How can one of the world's largest industrial machines fit into a room measuring only 15 square meters? Just ask Dr. Thomas Baudisch. He and his team, which goes by the name of FINEx (Functional and integrative engineering of mechatronic systems) deal with the development of systems in virtual space.

The team proceeds as though this lab — on three rather modest control cabinets in Baudisch's laboratory. There, scientists simulate the actions of the huge machine on a computer with Siem ens' new software that's connected to the electronics cabinets by a thick cable.

A large poster on the wall of the lab depicts such a bucket wheel excavator extracting brown coal. “The image constantly reminds us of what a monster we’re dealing with,” jokes Baudisch. Since November 2008, Baudisch has been working with an interdisciplinary team of experts from the fields of mechanical engineering, information technology, mathematics, and electrical engineering to develop a simulation system that is customized for the bucket wheel excavators owned by the RWE power company. “Our excavators are between 15 and 50 years old,” explains Thomas Niell, who is responsible for the electrical engineering of conveyor systems at RWE. If the steel structure of a bucket wheel excavator is properly maintained, it is practically indestructible.

Not so with the electrical system that controls the machine. After 40 years at the latest, the electric cables have deteriorated so much from exposure to UV radiation and from wear and tear that they must be completely replaced. “And the innovation cycles in electrical engineering have become so much shorter that we have to replace the system sooner and upgrade it at shorter intervals,” says Niell. That’s a trend in all sectors — even in the mining industry, which generally ranks on the conservative side.

New Technology — New Features.

For RWE, the time has come to upgrade its bucket wheel giants to the latest state of technology. With this in mind, the company is working with Siemens in Cologne to develop a completely new automation system for 16 excavators that use open-pit brown coal mining in the Rhine and Ruhr coal fields — a triangle between the cities of Aachen, Mönchengladbach, and Cologne.

“We have to pre-test the new automation programs in order to minimize excavator downtime during the implementation phase,” explains Niell. “This is where the research team at Siemens comes in. It’s developing a simulator for testing the new automation system.

“The industrial use of simulation is increasing everywhere,” says Roland Rösen, head of the Digital Product Program within the Global Technology field of Modeling, Simulation and Optimization at CT. Rösen explains that simulation technology is used to test the operation of the control system,“the first prototypes for the virtual commissioning of control systems already exist. It’s still difficult to predict how soon these methods can be widely used in the development process. Siemens researchers are using sophisticated simulation technology to test the controls of a huge bucket wheel excavator. The operator interface (small photos) is identical to that of the real thing.

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Dignity in the Digital World

Jaron Lanier, 49, is widely credited with having either coined or popularized the term “Virtual Reality.” Lanier received an honorary doctorate from the New Jersey Institute of Technology in 2006 and the IEEE Virtual Reality Career Award in 2009. Over the years, Lanier has played a key role in the development of teleimmersion and real-time facial impression tracking for avatars. He and his colleagues at Microsoft are working on intriguing unannounced projects.

What are the major trends driving the introduction of virtual reality systems?

Lanier: Moore’s law and materials science. On the Moore’s law side, pretty good levels of 3D rendering have become commoditized and are already miles ahead of what we could do not so many years ago for millions of dollars. Cheap, fast computing power is thus the muscle that’s driving this today. Materials science, on the other hand, is bringing us better chips, improved optics, sensors, actuators and displays. These things are driving our experiences in the virtual world and opening up great new possibilities.

Such as?

Lanier: Such as improved sensing that allows us to detect all the details that produce the expression on a person’s face in a truly 3D way. If you can do that, you can project yourself through your avatar in virtual worlds in contact with others — be it through realistic telepresence or through fantasy worlds in which you are another creature. This is important because humans developed in such a way that face-to-face communication was essential for our survival. We respond to things such as changes in the shape of the mouth and eyes in a fundamental way. So facial sensing is very important in supporting this.

Could advances in this area trigger a significant reduction in transportation use?

Lanier: If you look at human qualities or footprints, about 20 percent of it is accounted for by transportation. So, hypothetically, we should be able to implement communication technologies that reduce the need for at least some of that movement. Yet that has obvious not happened as a result of the existence of telephony or email, or websites, or based on the current technology level of video-conferencing. So the question we have to ask is, could it happen if there were a more satisfying level of communication? I believe the answer is yes. So reducing our global carbon footprint could come down to how good an algorithm is at sensing the corner of somebody’s eye. Speaking very roughly, I think that top-quality services along these lines could probably reduce humanity’s global carbon footprint by a tenth in ten to fifteen years.

Wouldn’t whole-body haptics be the ultimate in VR sensing?

Lanier: This is a fascinating modality because it’s the one with the highest bandwidth. It would open access to cognitive powers that seem to be innate, such as the ability of the hands to find harmonically correct paths between chords on a piano without the need for conscious thought. Whole body haptics would allow us to enter, explore and virtually experience structures that we cannot even see.

Will immersion in virtual worlds eventually demand a connection between the human brain and computers?

Lanier: If, like me, you see people as sacred centers of experience that should be surrounded by a kind of moat of respect, you might find it a little creepy to find yourself in a world in which software can be connected directly to the brain. This could create extraordinary artifacts of power where some people might control a transpersonal phenomenon, while others would have no power at all. So I think it’s worth being conservative about the core of personhood.

In what ways might the virtual world enhance our personhood?

Lanier: There is a grand process that has been present throughout the history of humanity that is called neoteny. This process refers to the carry-over of the child phase of life into adulthood. If you look at human history, you find that as we have become more successful, childhood has become longer. The virtual world fits into this because it helps make dreams real. Children flip between the world as they imagine it and the world as it is. But by being able to build a shared objective world that is as fluid as imagination — and adults — can bring some of the qualities of imagination into a world that is shared with others. I believe that’s what actually started to happen. I see VR as an accelerator for the process of neoteny.

How might the virtual world change the world of work?

Lanier: That’s complex because there are so many different kinds of work. But my vision is that the virtual world will become the place in which each individual can achieve a form of success that suits his or her character. That’s what a successful future for mankind looks like. Over the last couple of centuries, every time a technology has gotten better, it has put some people out of work. But it has also created new jobs. And the new jobs are usually more diversified and pleasant than those they replaced. Looking ahead, therefore, the question of human dignity is the only question that matters. It is the only purpose of developing technologies.

Interview conducted by Arthur F. Pease

Predictive Vision

Crowd flow simulations will enable us to make public places safer. The technology makes it possible to recognize potentially dangerous crowd congestion and take appropriate measures — before an incident occurs.

Siemens researchers can simulate pedestrian flows over time. Using this new technique, threatening situations can be recognized before they develop.
The simulator uses time-lapse motion, which is ten times faster than real-time in simulating 5,000 people.

Todays production materials are characterized by high performance. But researchers seek to further improve them, the parameters that influence their performance become so varied that it becomes impossible to comprehend and experimentally detect their numbers and complex interrelationships," says Dr. Wolfgang Kosser in describing the challenges materials researchers face. Kosser works at Siemens Corporate Technology (CT), where he supervises the development of new materials, which are used in everything from light emitting diodes to detectors in medical systems, and coatings for gas turbines.

"Where do you begin when optimizing materials? Should you start with their structures, chemical compositions, or the processes used to make them? It immediately raises other questions. If, for example, you want to give a porous substance a different reaction, you can change the size, shape, or distribution of its pores, but which measure will be most effective? Its as if researchers were standing at a control panel full of switches whose effects they are only vaguely familiar with. What's more, changing one parameter may cause changes in others in unpredictable ways. Producing and testing every conceivable variant in a laboratory takes too much time and costs too much money.

But there is one tool in particular that can help to accelerate this process significantly: computer modeling (see Pictures of the Future, Spring 2006, p.70). By developing a material in the virtual world, scientists can analyze the effects individual parameters will have on its behavior. They can thus identify relationships between material properties, specific microstructures, and chemical compositions, and use this information to induce a desired behavior. In this way, they know which changes are likely to be successful even before lab testing begins. Virtual materials are also perfectly defined — free of the unknown side effects that occur in the lab, which can easily mask the presence of the effect being pursued. Models of virtual materials work under precisely defined conditions, so if a material alteration does not produce the desired effect in a simulation, you can assume with near certainty that it won't work in the real world.

Researchers thus use models to determine the physical limitations of a material, while at the same time overcoming the physical limitations of an experiment by means of the virtual world, scientists can analyze the effects individual parameters will have on its behavior. They can thus identify relationships between material properties, specific microstructures, and chemical compositions, and use this information to induce a desired behavior. In this way, they know which changes are likely to be successful even before lab testing begins. Virtual materials are also perfectly defined — free of the unknown side effects that occur in the lab, which can easily mask the presence of the effect being pursued. Models of virtual materials work under precisely defined conditions, so if a material alteration does not produce the desired effect in a simulation, you can assume with near certainty that it won't work in the real world.

Analyses at the Atomic Level. Researchers want to precisely understand how the structure and composition of a material will affect its behavior in each application, since that's the only way to find out how they can give a material the desired properties, or ensure that a component will not fail. Their work takes them deep inside a material. Around four years ago, for example, Rossner's colleague Dr. Stefan Lam penscherf began experimenting with multiscale modeling, which combines various simulation methods to enable scientists to completely describe a material all the way from its atomic structure to its behavior in a component. The models address the most diverse dimensions: Microstructures such as pores, grains, and cracks typically measure only fractions of a millimeter, for example. Typical structures can be accurately described using the Finite Element Method (FEM), a procedure that subdivides a virtual material down to the smallest building block — all the way to the size of individual grains that typically measure anywhere from a few tenths to several hundreds of a millimeter.

To examine a material's chemical composition, on the other hand, researchers require methods that can describe interactions on an even smaller scale, namely those involving atoms. Here, the most precise technique is provided by the density functional theory (DFT), which describes the quantum mechanical interactions between atoms. Extremely high computational requirements, however, which can amount to several days, severely limit the use of this method. As a result, DFT methods can address only around 1,000 atoms.

In contrast, simulating a structure measuring only one-thousandth of a millimeter at the
The foundation for successful materials development is the close interplay between experiments and models.

Researchers refine the microstructure of highly porous ceramics using a virtual copy of the original (left), which was created based on digital measurement data (center) from a computer tomograph.

Researchers at Siemens use computers to develop materials in the virtual world, addressing everything from atomic structures to industrial objects interactively and in a multi-media context. (p. 92)

Siemens has developed a cost-effective documentation and archiving technology that makes it possible to visualize everything from diagnostic images to virtual models of industrial objects interactively and in a multi-media context. (p. 96)

Siemens is developing a simulator for huge bucket-wheel excavators. The goal is to test automation technology and train equipment drivers on virtual machines. (p. 98)

Combining Simulations

In Brief

− From automated, virtual production lines for hearing aids to fully functional 3D copies of actual buildings and training applications in cybersecurity, Siemens is the leader in business applications in the virtual world. (p. 84)

− Siemens researchers have successfully fused images using data from CT, MR, ultrasound and other modalities and used augmented reality for visualisation, which can significantly improve diagnosis and treatments. (p. 92)

− More and more activities are being transferred to the virtual world. Siemens’ “virtualite”, for instance, can do the same things as its real world counterpart, opening the possibility of replacing a real location with a virtual one. Such capabilities are set to sharply reduce travel-related energy costs and improve service availability. (p. 95)

− Siemens has developed a cost-effective documentation and archiving technology that makes it possible to visualize everything from diagnostic images to virtual models of industrial objects interactively and in a multi-media context. (p. 96)

− Siemens is developing a simulator for huge bucket-wheel excavators. The goal is to test automation technology and train equipment drivers on virtual machines. (p. 98)

− Simulation of crowd flows will make it possible to improve safety in stadiums and other public places. With software developed by Siemens and the Technical University of Munich, dangerous crowd congestion can be predicted, visualised and simulated, and ways to prevent them can be tested in advance before situations become critical. (p. 101)

− Researchers at Siemens use computers to develop materials in the virtual world, addressing everything from atomic structures to questions regarding material behavior in a component. Using models to recreate a material behavior, they can test new ideas before investing time and money in producing the material in the lab. (p. 100)

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Molecular Detectives

They are invisible to the naked eye and therefore all the more dangerous. They are microorganisms that threaten our safety in hospitals, in foods and beverages; pollutants in industrial environments and in our air and water; molecules in patient exhalations that may be harbingers of diseases; and particles that may signal the presence of explosives. What can be done to combat these threats? Our armamentarium ranges from electronic sniffers that can detect threatening substances in drinking water, food, and power plant flue gases to systems that can spot the presence of antibiotic-resistant bacteria or identify markers for cancers and other diseases.

Visions of Greener Cities

Cities account for 75 percent of global energy consumption and are responsible for 80 percent of all greenhouse gas emissions. In light of climate change, city governments, scientists, and companies are therefore discussing new concepts for achieving sustainable urban development. These range from new mobility solutions and innovative systems for storing heat and cold to visionary ideas that include vertical agriculture and surfaces that bind carbon dioxide. Pioneering projects can be found around the world in Asia, the Americas and Europe. The European Green City Index, a study conducted on behalf of Siemens, has examined which European cities have made the most progress on the long road to environmental sustainability.